PART 2A – Nationwide Review of Best Management Practices for Stormwater Management (Post-Construction Phase)

Florida Board of Professional Engineers

Approved Course No. 0010329

4 PDH Hours

A test is provided to assess your comprehension of the course material – 24 questions have been chosen from each of the above sections. You will need to answer at least 17 out of 24 questions correctly (>70%) in order to pass the overall course. You can review the course material and re-take the test if needed.

You are required to review each section of the course in its entirety. Because this course information is part of your Professional Licensure requirements it is important that your knowledge of the course contents and your ability to pass the test is based on your individual efforts.

Course Description:

Uncontrolled stormwater runoff from construction sites can significantly impact rivers, lakes, and estuaries. Sediment in waterbodies from construction sites can reduce the amount of sunlight reaching aquatic plants, clog fish gills, smother aquatic habitat and spawning areas, and impede navigation.

This course is part of a 4 course, 2-PART Series of a compilation of nationwide Best Management Practices (BMPs) published by the U.S. Environmental Protection Agency (EPA). The course includes BMP fact sheets describing practices that engineers involved with stormwater management may want to consider and the fact sheets generally provide applicability, implementation, and effectiveness information. Overall this series offers a total of 16 PDH credit hours (Parts 1A, 1B, and 2A, 2B)

Part 1 is further separated into 2 courses (Part 1A and 1B) and covers **Stormwater BMPs related to the Construction Phase** of projects and will cover areas of interest including:

- Construction Site Planning and Management
- Erosion Control
- Runoff Control
- Sediment Control
- Good Housekeeping/Materials Management

Part 2 is further separated into 2 courses (Part 2A and 2B)Part 2 is covers **Stormwater BMPs related to the Post-Construction Phase** of projects and will cover areas of interest including:

- Innovative BMPs for Site Plans
- Infiltration
- Filtration
- Retention/Detention

How to reach Us …

If you have any questions regarding this course or any of the content contained herein you are encouraged to contact us at Easy-PDH.com. Our normal business hours are Monday through Friday, 10:00 AM to 4:00 PM; any inquiries will be answered within 2 days or less. Contact us by:

EMAIL: bajohnstonpe@aol.com
Phone: 813-398-9380

Refer to Course No. 0010329

PART 2A – Nationwide Review of Best Management Practices for Stormwater Management (Construction Phase)

How the Course Works…

What do you want To do?	LOOK For This!
Search for Test Questions and the relevant review section	Q1 Search the PDF for: Q1 for Question 1, Q2 for Question 2, Q3 for Question 3, Etc… (Look for the icon on the left to keep you ON Target!)

Easy-PDH.com (FBPE Approved Provider 442)
Britian Arthur Johnston PE (50603)
Johnston Service Corp
CA No. 30074
11909 Riverhills Drive, Tampa FL 33617
Email: bajohnstonpe@aol.com
Phone: 813-398-9380

24 QUESTIONS

Q1:	**Alternative turnarounds provide space in the road for vehicles to efficiently drive in the opposite direction. All of the following practices complement alternative turnarounds EXCEPT:**

(A)	Permeable pavements
(B)	Bioretention
(C)	Installation of curbs and gutters
(D)	Green parking

Q2:	**Reduction in the amount of impervious surface or stormwater discharge reduction provides the comparison for effectiveness of alternative turnarounds. How much impervious area is reduced with a 30 foot radius vs 40 foot radius turnaround:**

(A)	5024 square feet
(B)	2827 square feet
(C)	2512 square feet
(D)	2197 square feet

Q3:	**Conservation easements typically focus on which specific land uses:**

(A)	Agriculture
(B)	Forest
(C)	Historic Properties
(D)	All of the Above

Q4:	**Which state has received national recognition for its programs that provide funding for state and local parks and conservation areas:**

(A)	Maryland
(B)	Florida
(C)	Georgia
(D)	Virginia

Q5:	**Development districts are special zoning districts created for the purpose of permitting property development and are typically greater than what size:**

(A)	2 acres
(B)	3 acres
(C)	4 acres
(D)	5 acres

Q6:	**Municipalities are more likely to establish rural development districts on what area:**

(A)	Undeveloped land
(B)	Brownfields
(C)	Sparsely Developed land
(D)	A and C

Q7:	**What is the primary drawback to installation of curbs and gutters for stormwater management:**

(A)	Little or no stormwater pollutants are removed
(B)	They are part of standard elements of road sections
(C)	They require extra space for construction
(D)	Local codes requires the use of curbs

Q8:	**Several techniques are employed together to create Green Parking where stormwater discharge is reduced from parking lots. All of the following are appropriate techniques EXCEPT:**

(A)	Right sizing parking dimensions
(B)	Establishing a minimum number of parking spaces
(C)	Use alternative surfaces rather than asphalt
(D)	Encourage shared parking

Q9:	**Conventional minimum parking ratios vary dependent on the land use. Actual parking demand for a restaurant can be as HIGH as:**

(A)	10.45 spaces per 1000 sq foot Gross floor area
(B)	12.88 spaces per 1000 sq foot Gross floor area
(C)	14.75 spaces per 1000 sq foot Gross floor area
(D)	15.35 spaces per 1000 sq foot Gross floor area

Q10:	**Green roofs apply in all parts of the country, based on the local climate designers should carefully consider:**

(A)	Vegetation type
(B)	Media thickness
(C)	Soil Porosity
(D)	A and B

Q11:	**Green roofs are constructed of multiple layers. What is the layer typically installed just below the plants themselves:**

(A)	Growing medium
(B)	Filter fabric
(C)	Drainage layer
(D)	Waterproof membrane

Q12:	**Green roofs generally cost more to install than conventional roofs but an extensive green roof can last around how many years:**

(A)	15
(B)	20
(C)	25
(D)	30

Q13:	**Infrastructure planning can be a useful stormwater management tool to reduce sprawl development. It has been estimated that the United States loses about HOW MANY acres of farmland per hour to suburban and exurb development:**

(A)	75
(B)	125
(C)	175
(D)	225

Q14:	**The greatest stormwater discharge and pollutant reduction benefits typically occur when applying open space design to:**

(A)	Residential zones that have larger lots
(B)	Residential zones that have smaller lots
(C)	High-density residential zones
(D)	Infill developments

Q15:	**Open space design techniques can yield significant savings compared to traditional development due to:**

(A)	Reduced construction costs due to clearing and grading
(B)	Reduced costs for installation of landscaping
(C)	Reduced paving costs
(D)	All of the Above

Q16:	**A mixed-use community called Abacoa in Jupiter, Florida, puts many smart growth principles into action including reserving how green space:**

(A)	2055 acres
(B)	393 acres
(C)	260 acres
(D)	127 acres

Q17:	**Cost comparisons for preserving natural areas versus traditional development are difficult to determine but per RSMeans the cost of clearing and grading alone can easily exceed how much per acre:**

(A)	8,000 dollars
(B)	10,000 dollars
(C)	12,000 dollars
(D)	14,000 dollars

Q18:	**BMP fact sheets that contain additional information on stormwater practices related to REDEVELOPMENT include all of the following EXCEPT:**

(A)	Riparian and Forested Buffers
(B)	Green Parking
(C)	Infrastructure Planning
(D)	Open Space Design

Q19:	**Roadway planning has to balance meeting the needs of the community while also ensuring that roads are right-sized to provide the right amount of paved surface. In many residential settings, street widths can be as narrow as:**

(A)	18 to 22 feet
(B)	22 to 26 feet
(C)	26 to 30 feet
(D)	32 to 36 feet

Q20:	**Per RSMeans, in 2019 Asphalt material costs ranged between:**

(A)	4 to 5 dollars per square foot
(B)	3 to 4 dollars per square foot
(C)	2 to 3 dollars per square foot
(D)	1 to 2 dollars per square foot

Q21:	**Municipalities can set specific criteria for riparian buffers to achieve stormwater management or other community goals through local ordinances. Which of the following cities enacted such:**

(A)	Tampa
(B)	Kansas City
(C)	Tulsa
(D)	Atlanta

Q22:	**A green infrastructure practice of collecting and storing rainwater from roof tops uses what:**

(A)	Cisterns
(B)	Green Roofs
(C)	Rain Barrels
(D)	A and C

Q23:	**Urban Forests absorb water and can help provide stormwater management to an urban setting. Urban forests also provide what benefit:**

(A)	Create essential green spaces
(B)	Link walkways and trails
(C)	Improve air quality
(D)	All of the Above

Q24:	**Street present both a barrier to natural hydrology and an opportunity for municipalities to improve stormwater management. Streets makeup about what percentage of the impervious surface in many cities:**

(A)	25 percent
(B)	33 percent
(C)	50 percent
(D)	66 percent

End of Test Questions

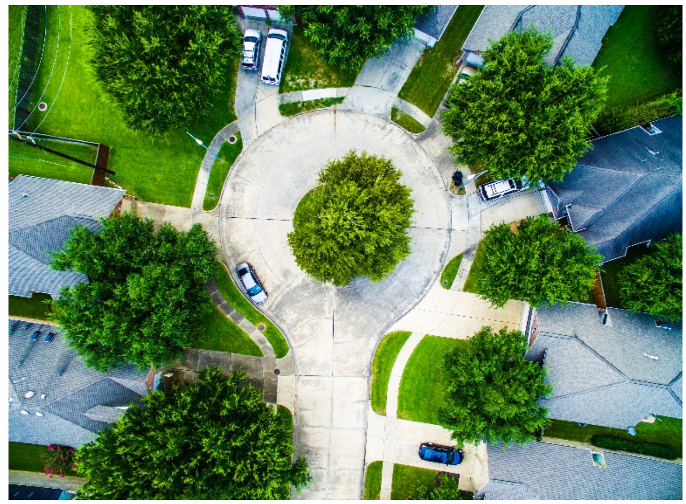
Stormwater Best Management Practice
Alternative Turnarounds

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative Practices for Site Plans

Description

Alternative turnarounds provide space in the road for vehicles to efficiently drive in the opposite direction. Roadway designers can reduce the hardened surfaces in neighborhoods by replacing or reducing the sizes of cul-de-sacs, which are local streets with closed circular ends that allow vehicles to turn around. Many cul-de-sacs span more than 40 feet. From a stormwater perspective, this represents a significant area of impervious surface that has the potential to generate large amounts of stormwater discharge. Reducing the sizes of cul-de-sacs, either through the use of alternative turnarounds or by eliminating them altogether, can reduce impervious cover and be part of a larger Green Streets program.

Numerous types of alternative turnarounds exist, all of which reduce impervious cover. Some common types include smaller turnarounds (e.g., with a radius of 30 feet), hammerheads,[1] and pervious islands in cul-de-sac centers.



An alternative turnaround with a vegetated island in the center reduces impervious area and is aesthetically pleasing.

Q1

Applicability

Designers can use alternative turnarounds in residential, commercial and mixed-use developments. Communities can also combine alternative turnarounds with other Green Street stormwater controls to complement their effectiveness. For instance, communities can place a rain garden in a pervious island with curb cuts to enhance infiltration and evapotranspiration of stormwater. By using properly designed and implemented turnaround alternatives in combination with other Green Street practices on a project scale, communities can dramatically reduce impervious cover and allow for on-site treatment of most stormwater.

The following practices complement alternative turnarounds:

- Permeable pavements
- Green parking
- Elimination of curbs and gutters
- Right-sized residential streets
- Alternative street design and patterns
- Bioretention
- Site design and planning strategies

Implementation

Sufficient turnaround area is an important design factor to consider. In particular, design engineers should consider the types of vehicles entering the cul-de-sac. Fire trucks, service vehicles and school buses are common examples of vehicles that need extra space to turn around. However, research shows that designers have been able to modify some fire trucks to allow for

[1] Hammerheads are T-shaped road ends, allowing for easier three-point turnarounds.

smaller turning radii. In addition, many new larger service vehicles have triaxles to help them turn in small spaces, and school buses usually do not enter individual cul-de-sacs.

Implementing alternative turnarounds can make community streets safer and more appealing for drivers, pedestrians, bicyclists and transit drivers. EPA specifically worked with firefighters to highlight how connected street networks can improve safety and health. Research indicates that a connected neighborhood network of narrower streets encourages people to walk more. Also, compared to areas with many cul-de-sacs, highly connected street networks shorten the distance emergency responders have to travel (U.S. EPA, 2019).

Limitations

Communities may need to update local regulations and address public perception issues when implementing alternative turnarounds. Local regulations often have specific design criteria for cul-de-sacs, such as turnaround dimensions, and local codes may not allow some types of alternatives. Communities can consider initiating a local site-planning round table to change some of these local regulations, starting with a collective effort to review local codes to promote better site design. The following resources may be helpful in addressing and overcoming barriers to implementation:

Q2

- *Tackling Barriers to Green Infrastructure: An Audit of Local Codes and Ordinances*
- *Green Infrastructure Opportunities and Barriers in the Greater Los Angeles Region*
- *Barriers and Gateways to Green Infrastructure*

In addition, the public may perceive smaller turning radii as limiting its ability to easily drive down roads. This public perception may dictate designs, particularly in residential areas. Although real estate sources often feature cul-de-sacs as highly marketable, actual research on market preference is not widely available.

Maintenance Considerations

Communities maintain any islands that are part of a turnaround whether hardscaped or otherwise. Keeping an island in a naturally vegetated condition may reduce maintenance costs related to hardscapes. Other fact sheets discuss maintenance requirements for stormwater controls that communities can implement in conjunction with alternative turnarounds, including bioretention practices and permeable pavements. Any option that requires less pavement entails less pavement-related maintenance, such as street sweeping and replacement costs.

Effectiveness

The comparative effectiveness of alternative turnarounds directly corresponds with the amount of impervious surface or stormwater discharge reduction that their designs achieve. For direct reductions in impervious surface, simple comparisons of the geometries of several types of turnarounds show that hammerheads create the least amount of impervious cover (Table 1).

Table 1. Impervious area for various turnaround options.

Turnaround Option	Impervious Area (Square Feet)[a]
40-foot radius	5,024
40-foot radius with 20-foot radius island	3,768
30-foot radius	2,827
30-foot radius with 10-foot radius island	2,512
Hammerhead (60-foot length, 20-foot width)	1,200

[a] Cost data source is RSMeans, 2019.

Costs

Alternative turnarounds reduce impervious cover. Consequently, they also reduce pavement-related construction costs as well as stormwater management costs given that they likely generate less stormwater discharge. Asphalt material costs $1 to $2 per square foot, depending on the thickness and type (RSMeans, 2019), while typical road construction can cost more than $15 per square foot when accounting for full construction costs (ARTBA, 2019; FDOT, 2019). If constructing a 30-foot turnaround with an island can save 2,500 square feet compared to a typical 40-foot turnaround (Table 1), the developer could save $2,500 to $40,000 in construction costs for an individual cul-de-sac. Assuming a small rain garden costs $4.60 per square foot of impervious surface that it treats (see Bioretention (Rain Gardens), installing a rain garden within the island to treat the remaining 2,500 square feet of impervious surface may cost around $12,000. From this perspective, the total cost (paving plus stormwater treatment) for a 30-foot turnaround with an island would likely be less than the cost of paving alone for 40-foot turnaround.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

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Florida Department of Transportation (FDOT). (2019). *Cost per mile models for long range estimating*. Florida Department of Transportation.

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Stormwater Best Management Practice

Conservation Easements

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative Practices for Site Plans

Description

Q3

Conservation easements are voluntary agreements that allow individuals or groups to limit the type or amount of development on their property to achieve certain conservation purposes. A conservation easement can cover all or just part of a property and can be either permanent or temporary. Easements typically focus on specific land uses, such as agriculture, forest, historic properties and open space.

Easements can relieve property owners of the burden of managing these areas. They shift responsibility to a private organization (land trust) or government agency that may be in a better position to take responsibility for management and compliance issues associated with the property. In some cases, property owners might realize tax benefits by placing conservation easements on some or all of their property.

Conservation easements may indirectly help protect water quality. Land that property owners set aside in a permanent conservation easement has a prescribed set of uses or activities that generally restrict future development. Often, this limits impervious surface development and preserves an area's natural hydrology.

Owners can evaluate the location of their land held in a conservation easement to determine its relative ability to provide water quality benefits. Property along stream corridors and shorelines can act as a vegetated buffer that filters out pollutants from stormwater discharge. The ability of a conservation easement to function as a stream buffer depends on the width of the easement and type and condition of the vegetation within the easement (see the "Riparian Forested Buffer" fact sheet).

Conservation easements allow property owners to conserve natural areas that may otherwise be developed.

Applicability

Conservation easements typically aim to preserve agricultural lands and natural areas that development threatens. For rapidly urbanizing areas, conservation easements may provide a way to preserve open space before land prices make it impractical for government agencies with limited budgets to buy land with important cultural and natural features. Urban areas typically have fewer conservation easements than other areas due to the lack of available open space for purchase and the high cost of undeveloped land. In addition, private land trusts may limit the size and type of land that they are willing to manage as conservation easements.

Implementation

Conservation easements ensure that land remains in its current state long after the original owners no longer control it. By agreeing to restrict the development rights for a parcel of land, landowners guarantee that it will remain in a prescribed state for a fixed period of time (e.g., 30 years, permanent) while receiving tax benefits. Often, state agencies and private land trusts have specific qualifications for a property before they enter into an easement agreement with landowners. Table 1 contains examples of criteria that private land trusts use to determine if a property is worth managing in a conservation easement.

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Table 1. Typical criteria that land trusts use to determine feasibility of entering into conservation easement agreements.

Criteria	Details
Natural resource value	Does the property provide a critical habitat or important environmental aspects worth preserving?
Uniqueness of the property	Does the property have unique traits worth preserving?
Size of land	Is the land large enough to have a natural resource or conservation value?
Financial considerations	Are funds available to meet all financial obligations?
Perpetuity	Is the conservation agreement a perpetual one?
Land trust's mission	Does the property align with the land trust's mission and the organization's specific criteria?

Conservation easements are applicable in all parts of the country; many private groups, both national and local, exist to preserve natural lands and manage conservation easements. States also use conservation easements and land purchase programs to protect significant environmental features and open space. The U.S. Land and Water Conservation Fund, a federally funded program, provides 50/50 matching grants to state and local governments to acquire land for public outdoor recreational use.

Q4

Maryland has received national recognition for its programs that provide funding for state and local parks and conservation areas. The state is one of the first to use real estate transfer taxes to pay for land conservation programs. Funding for several programs comes from this tax of one-half of one percent ($5 per thousand) of the purchase price of a home or land, or other state funding programs (MDNR, 2019). To date, Maryland has preserved more than 1.75 million acres of land, tracked through its interactive Protected Lands Dashboard. Maryland's conservation programs include:

- *Program Open Space.* This program, which has both a state and a local version, has acquired nearly 400,000 acres of open space for state parks, local parks and natural resource areas. Every five years, state, federal and local organizations develop a Land Preservation and Recreation Plan that outlines acquisition and development goals in order to maintain eligibility to receive Land and Water Conservation Fund grants and guide the long term vision of Program Open Space.
- *Maryland Environmental Trust.* This state-funded agency helps local citizen groups form and operate local land trusts. It offers the land trusts technical assistance, training, grants for land protection projects and administrative expenses, and participation in the Maryland Land Trust Alliance.
- *Rural Legacy Program.* This smart growth initiative redirects existing state funds into a focused, dedicated land preservation program that specifically aims to limit the adverse effects of sprawl on agricultural lands and natural resources. The program purchases conservation easements for large contiguous tracts of agricultural, forest and natural areas subject to development pressure, and it purchases fee interests in open space where public access and use are necessary.

Other examples where communities have strategically used conservation easements for water quality purposes can be found on EPA's Green Infrastructure Web site.

The holder of a conservation easement—whether a government agency or a private land trust—has certain management responsibilities. Some examples:

- Ensure that the easement's language is clear and enforceable.
- Develop maps, descriptions and baseline documentation of the property's characteristics.
- Regularly monitor the use of the land.
- Provide information on the easement to new or prospective property owners.
- Establish a review and approval process for land activities that the easement stipulates.
- Enforce the easement's restrictions through the legal system, if necessary.
- Keep property/easement-related records.

Limitations

Conservation easements have limits as a stormwater management tool. For example, there are significant impediments to using these measures in heavily urbanized areas, where the size, quality and cost of land limits the viability and feasibility of such easements. Depending on the specific type of easement, another limiting factor can be its duration—if the easement does not hold the land in perpetuity, long term water quality protection may not be possible. In addition, easements may not be able to address concentrated stormwater impacts from developed areas, because property owners use them more frequently outside of developed areas.

Maintenance Considerations

The responsibility for maintenance of property held in a conservation easement depends on the terms of the individual agreement. While many organizations assume the responsibility for managing the easement property and for meeting the terms of the easement, some land trusts leave maintenance responsibilities to the landowner.

Effectiveness

A conservation area's effectiveness in protecting water quality depends on how much land the property owner conserves, conservation techniques, the land's location in relation to a waterbody, and the specific nature of the easement. Generally, maximum effectiveness occurs when those responsible for the site keep it relatively undisturbed and ensure the retention of a site's natural hydrology. Any alteration of natural conditions, such as partial development or limited agricultural use by landowners, may reduce water quality benefits. The downstream effects of these management actions—whether positive or negative—tend to be enhanced the closer the easement property is to the downstream waterbody.

These benefits are difficult to measure directly, as the purpose of conservation easements is to prevent environmental impacts, not to remediate existing impacts. Still, studies have explored the benefit of conserving natural lands (or the impact of developing natural lands), showing direct links between the level of development and the health of benthic organisms in local streams, which is an indicator of water quality (May and Horner, 2002; Schueler et al., 2009; Walsh, 2004). Over time, these observations have caused stormwater practitioners to revise the broad goals of stormwater management, adding a focus on restoration or conservation of natural hydrologic processes to the traditional focus on flood control and pollution mitigation (Clark et al., 2010; Walsh et al., 2016).

Cost Considerations

The costs associated with conservation easements include administrative costs and land management costs. Generally, tax or fee programs fund these costs, though specific arrangements depend on local circumstances. For example, Virginia Beach's Open Space Special Revenue Fund receives partial funding through a $0.44 dedication of restaurant meal taxes (City of Virginia Beach, 2018), while organizations like Alachua Conservation Trust rely on donations and various grants to support the conservation of more than 53,000 acres of Florida land.

Additional Resources

Additional resources detailing design, implementation and funding of conservation easement programs include:

- The Land Trust Alliance—a national leader in policy, standards, education and training.
- *The Conservation Easement Handbook*—a resource for land conservation professionals developing conservation easement programs, by the Land Trust Alliance and the Trust for Public Land.
- *Better Site Design: A Handbook for Changing Development Rules in Your Community (Part 1)*—a handbook by the Center for Watershed Protection.
- The Pennsylvania Land Trust Association's Conservation Tools Web page—a resource for model easements, tax rules and helpful articles from conservation professionals.
- *Managing Growth and Development in Virginia: A Review of the Tools Available to Localities*—a report by the Virginia Chapter of the American Planning Association.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

City of Virginia Beach. (2018). *Adopted operating budget: Resource management plan FY 2017–2018*.

Clark, S. E., Baker, K. H., Treese, D. P., Mikula, J. B., Siu, C. Y., & Burkardt, C. S. (2010). *Sustainable stormwater management: Infiltration vs. surface treatment strategies.* Water Environment Research Foundation.

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Stormwater Best Management Practice

Stormwater Management for Development Districts

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment

Subcategory: Innovative BMPs for Site Plans

Description

Q5

Development districts are special zoning districts created for the purpose of permitting property development. Development districts are larger site areas (typically 5 or more acres), and their construction requires complex and coordinated rezoning, transportation and planning efforts. Examples of special zoning districts include, but are not limited to:

- Transit-oriented development districts
- Business improvement districts
- Traditional neighborhood designs
- Brownfield redevelopment projects
- Main street revitalization districts

Communities typically assess a development district's stormwater management performance at the site, neighborhood and regional (or watershed) levels. Although development districts generally have high percentages of impervious surface, they can allow for greater conservation of surrounding natural areas if municipalities implement them properly and comprehensively. For example, clustered, compact development can accommodate the same level of development (e.g., number of homes, businesses, etc.) on a smaller footprint than conventional, low-density development. If municipalities implement development districts in conjunction with natural area preservation, the net effect can be a reduction in total impervious surface, all while allowing a similar level of economic development. In addition, a coordinated planning effort can help identify strategic opportunities to incorporate green infrastructure practices, such as those listed to the right, and development designs that decrease stormwater impacts.

A city, county or township's planning or zoning department usually develops plans for development districts. Stormwater managers may need to meet with planning counterparts to coordinate plans because common standalone elements found in stormwater management plans for individual sites (e.g., site coverage limitations, infiltration requirements and rules discouraging sidewalks) can run counter to the urban design elements of successful development districts.

Development districts allow for denser development and preservation of surrounding natural areas.

Municipalities should consider the following practices as part of any development district approach:

- Bioretention practices
- Conservation easements
- Elimination of curbs and gutters
- Green parking
- Green roofs
- Narrower residential streets
- Open space design
- On-lot treatment
- Permeable pavements
- Protection of natural features
- Stormwater wetlands
- Street design and patterns

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Applicability

Regional Applicability

Development districts can be found in all regions of the United States. They can include large redevelopment efforts, infill projects or new “greenfield” projects, and therefore, they depend more on the state of development than on regional location. Development districts also tend to handle more development intensity and mixed-use development on a smaller footprint, thus creating opportunities for watershed planning and source water protection of surrounding undeveloped areas.

Urban Applicability

Implementing development districts in urban areas can be difficult if most of the land is already developed. Nevertheless, redevelopment is common and can create an opportunity to improve aspects of an existing developed area including development ordinances, stormwater treatment requirements and the incorporation of new, more effective stormwater retrofits (further discussion below). Additionally, certain types of development district planning, such as transit-oriented development and business improvement districts, are common and well-suited to urban areas.

Stormwater Retrofits

Because urban projects often involve redevelopment, they can offer opportunities to include both stormwater retrofits of older “gray” infrastructure and urban “green” techniques. For retrofits, cities may consider offering flexible approaches to meet the variety of unexpected site constraints found in highly developed urban areas.

Design Considerations

The design of a development district determines its effectiveness in mitigating stormwater impacts. Implementing smart growth practices that promote high-density development—walkable and bikeable neighborhoods, preserved green spaces, mixed-use development and mass transit—can be an effective way to facilitate effective stormwater management within the development district. Specifically, development district designs should consider the following:

Compact project and community design: A powerful strategy for reducing a development’s footprint—and its stormwater impact—is to focus on compact development and effective infrastructure planning. Clustering is one approach that can concentrate impervious surfaces, leaving more area as undeveloped or green space. Reducing an individual building’s footprint can also be a strategy to lessen urban stormwater impacts, though some circumstances call for greater lot coverage in districts that need higher development intensity (e.g., near transit stations). Compact development also can create additional space for more environmentally friendly transportation options, such as walking and biking or shorter and less frequent automobile trips.

Street design and transportation options: Well-designed, compact communities contain highly connected street and trail systems that accommodate multiple modes of transportation. The pattern does not need to be a grid; in some areas, topography and environmentally sensitive areas influence where roads go. A compact district also provides for more efficient use (and reuse) of infrastructure.

Mixed-use development: A community’s transportation options increase when jobs, housing and commercial activities are close to one another. Efficiencies for providing infrastructure emerge. Fewer automobile trips reduces the need to accommodate standard parking requirements. Mixing daytime and nighttime uses increases opportunities for businesses to share parking spaces.

City and county planners can establish development districts almost anywhere; however, some design considerations are worth accounting for based on existing land uses. For urban areas, planners should reuse existing impervious surfaces and infrastructure wherever possible. In addition, they should manage stormwater on-site wherever feasible using green infrastructure such as rain gardens, permeable pavement, green roofs or other on-site practices.

Conservation subdivisions or designs should look closely at the connections among transportation, community services and jobs. If new housing becomes part of a development pattern that includes dispersed uses, demands for upgrades to urban-level services and transportation, and a lack of connections among infrastructure elements, then this can negate the water benefits of conservation clustering.

Limitations

During the site design process, there may be pressure to leave out elements of the development district's stormwater management features. For example, a successful development district shortens, combines or eliminates automobile trips. However, if pressure to increase parking or decrease connections among uses mounts, a city or county may be unable to reduce the amount of paved surfaces, diminishing transportation and water benefits. In this instance, planners can consider using permeable pavements and other stormwater management techniques.

If the stormwater regulations for redevelopment districts are more stringent than those for greenfields, then cities may find it difficult to attract developers. Rules for water protection and stormwater should be consistent watershed-wide.

Maintenance Considerations

Maintenance considerations for development districts depend on the types of practices that a district incorporates. For example, development districts may implement a mix of green infrastructure and good housekeeping practices to meet stormwater treatment requirements. Planners should account for the maintenance requirements of proposed practices so that the development district can meet design and water quality goals within available budgets. Other fact sheets on EPA's Menu of BMPs Web page provide additional information on the maintenance considerations of individual practices.

Effectiveness

A development district can be effective at the site, neighborhood and watershed levels. Redevelopment can significantly reduce the demand for new development elsewhere in the watershed. Designs that repair existing infrastructure and treat stormwater on-site are particularly beneficial. Where urban redevelopment occurs on open lots that serve a stormwater-handling function, the city and developer should assess the neighborhood-wide impacts and mitigate accordingly.

Clustering, open space design and other "green" designs offer stormwater and water quality benefits to communities considering new housing developments. However, a site's design should combine with watershed and regional planning designs that curb uncontrolled, large-scale growth. The following questions are examples of considerations that developers can consider when identifying desired neighborhood and watershed outcomes:

- Will new conservation development spur unplanned development?
- Does conservation development complement the community's overall conservation goals?
- How does the new development relate to jobs, schools and services?

Cost Considerations

The costs of developing and implementing coordinated development districts vary. The primary drivers of these costs include the consultant and staff time required to develop or align plans; repairs to or establishment of water, sewer, and transportation infrastructure; and any incentives a city, county, or township provides to developers or public/private partnerships.

For developers, costs can vary from a conventional site plan, depending on the combination of stormwater controls and the relative cost of a more complex site development plan. However, the market price due for these developments, related to their location or enhanced desirability, can offset these costs in many redevelopment projects.

Combinations of Policies and Best Management Practices (BMPs) to Support Development Districts

A combination of practices support a development district's environmental performance. These include traditional stormwater control measures, emerging stormwater practices and land development policies that one might not traditionally view as stormwater BMPs. The following section offers a non-exclusive summary of BMPs that design engineers may use within a development district. How engineers ultimately select practices also depends on pollutant control requirements, as well as other water quality and quantity imperatives such as total maximum daily loads or downstream flooding.

Urban Settings

Urban development and redevelopment projects are more likely to have heavier transit service (i.e., subways and established bus lines), follow a traditional street pattern, and be subject to a complex set of existing land development requirements.

Municipalities can combine policies to promote desired densities. Some of these policies include:

- Creating transfer-of-development-rights receiving zones—a system in which a landowner in a “preservation area” or “sending zone” gets credits for foregoing development rights, which they can then sell or have a bank consolidate. Developers can buy and use these credits to gain permission to build in higher-density receiving zones, which are areas municipalities have targeted for denser development.
- Allowing the creation of bonus densities, which enable developers who agree to complete projects or project additions meeting specific goals to increase density.
- Creating mixed-use zoning.
- Creating form-based zoning codes.
- Modifying parking policies that, for example, allow a maximum number of parking spaces and better manage on-street parking.
- Creating sidewalk improvement programs.
- Encouraging micro-detention stormwater-handling areas, such as rain gardens or stormwater control measures that serve multiple purposes (e.g., green roofs).
- Encouraging street tree canopy programs.
- Creating financial incentives (e.g., tax-increment financing, vacant property reform).
- Enacting or promoting programs that enhance transit use (e.g., customized information, employer assistance).
- Enacting rehabilitation codes for older buildings and proprietary devices (e.g., in-pipe filtration devices).

Suburban Settings

Suburban development districts are likely to take advantage of existing development and infrastructure, and they require connections among older developed areas. In addition to some of the policies and practices listed above for urban settings, planners and developers in suburban settings could consider stormwater control measures and policies that help protect water resources, such as:

- Promoting “grayfields” programs to redevelop underperforming malls and strip malls.
- Creating highway corridor redevelopment programs.
- Enhancing retail and housing districts around park-and-ride lots.
- Adopting smart growth street design standards at the local and state level.
- Establishing infill policies.
- Adopting traditional neighborhood design manuals that integrate transportation.

Q6

Rural Settings

Municipalities are likely to establish rural development districts on undeveloped or sparsely developed land. Successful rural development districts complement or spur rural employment opportunities in areas such as agriculture, manufacturing, or warehousing and distribution. To protect water resources on a regional scale, planners should encourage conservation of rural settings to offset increased impervious areas in urban and suburban settings.

Several policies that encourage economic development while retaining rural character include:

- Creating transfer-of-development-rights sending zones.
- Establishing water protection overlay zones.
- Connecting housing with rural job and transportation centers.
- Creating watershed-wide impervious surface trading programs.
- Creating design manuals for rural housing or housing in environmentally sensitive areas.

  Encouraging main street redevelopment programs in older downtowns.

Additional Resources

- The Center for Watershed Protection's updated code and ordinance worksheet for improving local development regulations.
- EPA's Green Infrastructure Policy Guides webpage.
- EPA's Smart Growth and Economic Success: Investing in Infill Development webpage.
- The University of Wisconsin Sea Grant's Tackling Barriers to Green Infrastructure: An Audit of Local Codes and Ordinances report.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

Stormwater Best Management Practice

Eliminating Curbs and Gutters

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative Practices for Site Plans

Q7

Description

Curbs and gutters quickly convey stormwater from the street to the storm drain and, ultimately, to a local receiving water. Consequently, they remove little to no stormwater pollutants. Instead, curbs often trap deposited pollutants in between storms that are washed away during the next storm.

Green infrastructure alternatives to curbs and gutters exist that—in addition to conveying stormwater—can address some of the problems associated with curbs and gutters. These alternatives include grassed swales, vegetated bioswales, bioretention systems or rain gardens, tree boxes and permeable pavement; all of these can provide a range of additional benefits, including stormwater discharge reduction, pollutant removal and enhanced curb appeal (Harris, 2013; Ruby & Gillespie, n.d.; U.S. EPA, 2007). Often, a community can best implement these practices as part of a larger Green Streets program.

Many communities require curbs and gutters as standard elements of road sections. Traditionally, the alternative to curbs and gutters has been grassed swales. In some cases, localities would need to revise current local road and drainage regulations to promote greater use of green infrastructure alternatives in lieu of curbs and gutters.

Applicability

Alternatives to curbs and gutters vary according to site or neighborhood conditions. Alternatives that need more space, such as grassed or vegetated swales, are more suitable in low- and medium-density residential zones where the soils, slope and housing density may accommodate them. Developers can overcome space limitations, to an extent, if they implement swales in conjunction with narrower streets or alternative street designs and patterns. For applications in higher-density residential, commercial or industrial areas that require curbs for parking purposes, developers can use regularly spaced curb cuts to direct small accumulations of

Curb cuts that drain to green infrastructure practices can be used as an alternative to traditional curbs and gutters.
Credit: Photo by Center for Neighborhood Technology on Flickr (Creative Commons license)

stormwater to compact practices such as bioretention practices or tree boxes. Examples of successful curb cut applications appear in the City of Mesa's *Low Impact Development Toolkit* as well as the California Water Boards' guidance for low impact development projects.

Siting and Design Considerations

Several factors—not just the space constraints mentioned above—determine whether eliminating curbs and gutters is appropriate and which green infrastructure alternative practices best suit a particular site.

The following fact sheets provide more detailed siting and design considerations for suitable green infrastructure alternatives to curbs and gutters:

- Grassed Swales
- Bioretention (Rain Gardens)
- Permeable Pavements
- Site Design and Planning Strategies
- Right-Sized Residential Streets

Development density. Practices such as grassed swales are often difficult to use when development density increases above four dwelling units per acre because the number of driveway culverts increases and the swale essentially becomes a broken-pipe system. In higher-density areas, other practices such as permeable pavement or tree boxes may be more appropriate.

Contributing drainage area. Most green infrastructure practices are for small or "micro" applications, not large drainage areas. For any individual green infrastructure practice serving as an alternative to curbs and gutters, where drainage areas are mostly—if not all—impervious, the drainage area should generally be smaller than 0.5 acres. In many cases, drainage areas less than 0.1 acres may be best.

Soils. Hydrologic soil groups A and B are most suitable for practices with an infiltration component. For hydrologic soil groups C and D, engineers may need to design practices with an underdrain to minimize the ponding of water.

Limitations

A number of real and perceived limitations hinder the use of green infrastructure alternatives to curbs and gutters:

- ***Snowplow operations can be more difficult without a defined road edge.*** However, roadside swales can offer more room for snow storage at the road edge; thus, smaller snowplows may be adequate. Communities may also mark the road edge using poles to help guide snowplow operators.
- A pavement edge along a swale or pervious area can experience more cracking and structural failure, increasing maintenance costs. Developers can alleviate the potential for pavement failure at the road/grass interface by "hardening" the interface with grass pavers, permeable concrete or geo-synthetics placed beneath the grass. Other options include placing a low-rising concrete strip along the pavement edge.
- ***Local code can require the use of curbs and gutters.*** Communities can consider initiating a local site-planning round table to change some of these regulations, starting with a collective effort to review local codes to promote better site design. The following resources may be helpful in addressing and overcoming barriers to implementation:
  - *Tackling Barriers to Green Infrastructure: An Audit of Local Codes and Ordinances*
  - *Green Infrastructure Opportunities and Barriers in the Greater Los Angeles Region*
  - *Barriers and Gateways to Green Infrastructure*
  - EPA's Water Quality Scorecard

Maintenance Considerations

Curbs and gutters generally require little maintenance aside from regular street cleaning and debris removal. Communities can remove accumulated pollutants in curbs and gutters using street sweepers. Maintenance requirements for vegetated roadside practices are different and can be more demanding depending on the type of practice. Practices with grass, such as swales or open pervious areas, require mowing during the growing season, while vegetated systems such as bioretention practices require periodic trimming and debris removal. In addition, it may be necessary to remove sediment deposits from the bottom of the roadside practice if clogging becomes a concern.

Effectiveness

Replacing curbs and gutters with green infrastructure practices can decrease peak flow rates and total discharge of stormwater and can provide enhanced pollutant removal in some cases. Developers can enhance the effectiveness of these approaches by implementing them within a comprehensive Green Streets design. EPA's Green Streets handbook provides guidance on how to design and implement an effective Green Streets program. A groundbreaking project in Seattle, Washington, dubbed the Street Edge Alternatives, incorporated vegetated swales, bioretention cells and narrower streets without curbs within a single neighborhood to reduce stormwater discharge and enhance infiltration. Compared to a conventional curb and gutter system, the project reduced the volume of stormwater discharge by 99 percent and reduced peak flows to pre-developed rates. There are additional examples of successful projects that eliminated curbs and gutters in the EPA report *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*.

Cost Considerations[1]

The cost of curbs and gutters ranges from about $20 to $40 per linear foot (RS Means, 2019). This standalone cost is often used to justify the cost-effectiveness of this traditional approach. However, this cost does not include drainage pipes or downstream stormwater controls necessary to treat stormwater discharge that is generated by this practice. Especially for new development projects, a comprehensive comparison of all relevant costs of traditional curbs and gutters and alternative practices is necessary to provide a more accurate evaluation of cost-effectiveness. In many cases, sound design using green infrastructure can offer cost savings compared to traditional curb and gutter approaches. In the case of Seattle's Street Edge Alternatives, which incorporated bioretention and other green infrastructure alongside curbless streets, the total cost was approximately $1 million, compared to an estimated cost of $1.3 million for a conventional curb and gutter approach. Moreover, at a total project length of 660 feet, curb and gutter costs would have only been around $40,000 (3 percent of the total conventional cost), illustrating how small their direct costs are relative to total system costs. In a review of the cost of 12 green infrastructure projects compared to conventional counterparts, U.S. EPA (2007) similarly found average cost savings of 35 percent in 11 of the 12 projects.

[1] Prices updated to 2019 dollars. Inflation data obtained from the Bureau of Labor Statistics CPI Inflation Calculator Web site: https://data.bls.gov/cgi-bin/cpicalc.pl. Reference dates for the calculation are January 2001 and January 2019.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Green Parking

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Q8

Description

"Green parking" refers to several techniques that, together, reduce stormwater discharge from parking lots. Green parking techniques include setting the maximum number of parking spaces, right-sizing the dimensions of parking spaces, substituting alternative surfaces for asphalt in overflow parking areas, using green infrastructure to treat stormwater, encouraging shared parking and providing economic incentives for structured parking.

Applicability

All green parking practices in the above description are applicable to new developments, and some are applicable to redevelopment projects, depending on site characteristics. In urban areas, practices such as encouraging shared parking and providing economic incentives for structured parking are practical and often necessary. Commercial areas can have excessively high parking ratios (the number of spaces per building area), providing an opportunity to convert impervious surfaces with infrequent use to permeable surfaces.

Implementation

The most straightforward green parking strategy is to right-size the number of parking spaces, ensuring that there are enough spaces for the intended uses. Parking lots typically have far more spaces than necessary. By right-sizing parking, planners, developers and the community can ensure that there is enough parking without creating unnecessary impervious surface. The problem of too much parking results from designing parking ratios around the highest hourly parking needs during peak seasons—a common practice in parking lot design. Designing to average demand, as opposed to the peak demand, results in fewer spaces and less

A parking lot designed with green infrastructure, vegetated buffers, and alternative surfaces can improve the quality of stormwater from the parking lot.

impervious space. For existing developments, design engineers can reduce the number of parking spaces and convert unused spaces to landscaped islands that provide aesthetic benefits and reduce impervious area. Table 1 provides examples of conventional parking requirements and compares them to average parking demand.

Resources

- *Parking Spaces/Community Places: Finding the Balance through Smart Growth Solutions* is a guidebook about parking policies and includes examples of how they can save money, improve the environment and meet broader community goals.
- EPA's *Mixed-Use Trip Generation Model* can help local governments better estimate parking demand.

Q9

Table 1. Conventional minimum parking ratios.

Land Use	Unit	ULI Standard Parking Value[a]	ITE Standard Parking Value[b]	Actual Parking Demand[c]
Apartment/ condominium	Spaces per dwelling unit	1.50–1.70	1.20–1.38	0.41–2.82
Retail	Spaces per 1,000 ft^2 GFA	3.60	2.65	0.36–3.0
Hotel	Spaces per room	1.00	0.64	0.31–15.35
Lounge	Spaces per 1,000 ft^2 GFA	10.00	13.30	3.93–8.38
Office	Spaces per 1,000 ft^2 GFA	3.8	2.84	0.56–2.88
Restaurant	Spaces per 1,000 ft^2 GFA	10.50	10.10	2.05–14.75

Source: Kimley-Horn, 2016

GFA = Gross floor area of a building without storage or utility spaces.

[a] Standard rate from Urban Land Institute (ULI) as cited in Kimley-Horn, 2016.

[b] Standard rate from Institute of Transportation Engineers (ITE) as cited in Kimley-Horn, 2016.

[c] Range of rates for 12 municipalities studied in Kimley-Horn, 2016.

Using permeable concrete instead of asphalt can reduce stormwater quantity and improve water quality.

Minimizing the length and width of individual parking spaces is another technique that can minimize impervious area. Planners often cite large sport utility vehicles as barriers to minimization techniques. One option to address this problem is to provide a mix of parking space sizes and designate smaller spaces for compact cars. New technologies also allow for the use of intelligent parking reservation systems that can assign a driver to a parking space according to their vehicle size (Caicedo et al., 2012).

Another effective green parking technique is the use of alternative surfaces. Alternative surfaces include permeable surfaces and reduce stormwater discharges by increasing infiltration. They can include gravel, cobbles, wood mulch, brick, grass pavers, turf blocks, natural stone and permeable pavements. Permeable pavements include permeable pavers, pervious concrete and porous asphalt and can be effective substitutes for conventional asphalt and concrete, given their durability. For more information on permeable pavements, refer to the Permeable Pavements fact sheet.

Green infrastructure practices such as bioretention practices and grassed swales are other green parking techniques that can effectively treat stormwater before it leaves a parking lot.

- Bioretention practices are shallow, landscaped areas that temporarily store stormwater. Stored water then filters down through the bed of the system, where it either infiltrates into the subsurface soils or is collected by an underdrain pipe for discharge into a storm sewer system or another stormwater facility. For redevelopment projects, design engineers can convert underutilized parking spaces to bioretention practices.
- Grassed swales are vegetated conveyances that slow stormwater flow, allowing solids to settle. Depending on site conditions and design type, grassed swales can also promote infiltration.

Design engineers can integrate both bioretention and grassed swale stormwater controls into parking lot landscaped areas and maintain them along with other landscaped areas.

In mixed-use areas, shared and structured parking can reduce the conversion of land to impervious cover.

- A shared parking arrangement involves two parties that share one lot. For example, an office that experiences peak demand during weekdays can share its parking lot with an adjacent church that experiences peak demand during weekends and evenings.
- Structured parking, such as above- or below-ground parking garages, can greatly reduce the amount of stormwater-generating area for a given parking demand.

Limitations

Limitations to green parking techniques include applicability, cost and maintenance. For example, shared parking is practical only in mixed-use areas, and the cost of land versus the cost of construction may limit structured parking.

The cost of individual green infrastructure practices may also be prohibitive in some cases. Permeable pavements, bioretention practices and grassed swales can be more costly than traditional development—though it is important to take into account the cost savings that can be achieved by reduced stormwater management requirements.

The pressure to provide an excessive number of parking spaces can result from the fear of customer complaints about limited parking. These factors can pressure developers into constructing more parking than is necessary. Together, these barriers inhibit the construction of parking lots using the maximum number of green parking techniques.

Effectiveness

In most cases, design engineers can use multiple practices together, increasing overall effectiveness. Depending on the combination of strategies designers implement, green parking can reduce the amount of impervious surface, reduce stormwater flow rates and volumes, reduce stormwater pollutant concentrations, and provide a range of other environmental benefits.

Heifer International's parking lot is an example of the benefits of rethinking parking lot design (Industrial Economics, Inc., 2007). This nonprofit sustainable community development organization in Little Rock, Arkansas, designed an environmentally friendly parking lot for its new headquarters. The lot features green parking techniques including permeable pavement for parking spaces and five bioswales to convey water to a detention pond and treatment wetland next to the site. The company also provided on-site bike racks and dedicated parking spaces for carpooling and hybrid vehicles. Water quality benefits include significant reductions in stormwater volume and pollutants, including nitrogen, phosphorus, suspended solids and several heavy metals.

Cost Considerations

While some green parking materials have higher construction costs than conventional development materials, implementing green parking techniques can lead to lower maintenance and stormwater management costs. For example, in Bellingham, Washington, Bloedel Donovan Park retrofitted part of its parking lot to add a 550-square-foot bioretention practice. In addition to offering an aesthetic benefit by adding native plants to the parking area, the bioretention practice reduced impervious cover in the parking lot and saved 75 to 80 percent over conventional stormwater management costs (LaCroix et al., 2004). Limiting the number of parking spaces, minimizing parking space dimensions and encouraging shared parking can also reduce construction costs.

Specific costs associated with individual stormwater controls can be found in the following fact sheets:

- Permeable Pavements
- Bioretention Practices
- Grassed Swales

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Green Roofs

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Description

Green roofs are a green infrastructure alternative to conventional roofs that reduce stormwater discharge and provide a wide range of additional environmental and aesthetic benefits. Through integrative design approaches, they offer opportunities to maximize the beneficial use of spaces traditionally unused for stormwater management. In contrast to traditional asphalt shingles or metal roofing, green roofs absorb, store, infiltrate, and evapotranspire stormwater. They also serve as thermal buffers for the building's underneath, cooling the buildings during warm weather and insulating them during cold weather. As greenspaces that are often within highly developed landscapes, green roofs can provide habitat for wildlife such as birds and insects and offer aesthetic amenities to building occupants.

If communities implement green roofs widely, the localized benefits of green roofs can add up in important and measurable ways. By reducing stormwater discharges, green roofs also reduce impacts to local waterways by reducing stream scouring, lowering water temperatures and improving water quality. Widespread implementation can also reduce combined sewer overflows (CSOs) in areas with combined sewer systems, potentially preventing the discharge of millions of gallons of sewage into local waterways. Through better thermal regulation, green roofs may not only reduce urban heat island effects, they may also increase the energy efficiency of buildings. This reduces heating and cooling energy use, thus helping to reduce greenhouse gas (GHG) emissions.

Applicability

Design engineers can apply green roofs to new construction or retrofit them onto existing residential, commercial and industrial buildings. Many cities, such as Chicago and the District of Columbia, actively encourage green roof construction to reduce stormwater discharges and CSOs. Other municipalities encourage green roof development with tax credits, density credits or grants. In

Green roofs provide an opportunity to utilize traditionally unused spaces for stormwater management

addition, green roofs can often provide several points toward a Leadership in Energy and Environmental Design (LEED) certification.

Regional Applicability Q10

Green roofs apply in all parts of the country, though designers should carefully consider vegetation type and media thickness based on local climate. In climates with extreme temperatures, the thermal benefits of green roofs can make them more financially justifiable for many facility operators. In drought-prone regions, drought-tolerant vegetation is crucial, and greater media thickness can often improve vegetation resilience.

The multi-agency report *Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West* contains additional information regarding implementation of green roofs in arid environments.

Urban Areas

Green roofs are ideal for urban areas because they provide stormwater benefits and other valuable ecological services without consuming additional land. To help offset costs and increase adoption of the

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practice, many highly urban municipalities have incentive programs such as grants or reduced stormwater fees. For example, the District of Columbia's green roof rebate program offers a rebate of $10 to $15 per square foot for voluntary installations. The Water Environment Federation's Stormwater Report contains descriptions of the types of incentives available and links to examples.

Stormwater Retrofit

A stormwater retrofit is a practice that design engineers put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding or meet other specific objectives. Green roofs are a useful tool for retrofitting existing impervious areas associated with building footprints. An important consideration for retrofit applications is the load-bearing capacity of the existing roof. Most existing flat-roofed buildings can accommodate the weight of a green roof without structural modifications, but qualified structural engineers should make this determination.

Siting and Design Considerations

Siting Considerations

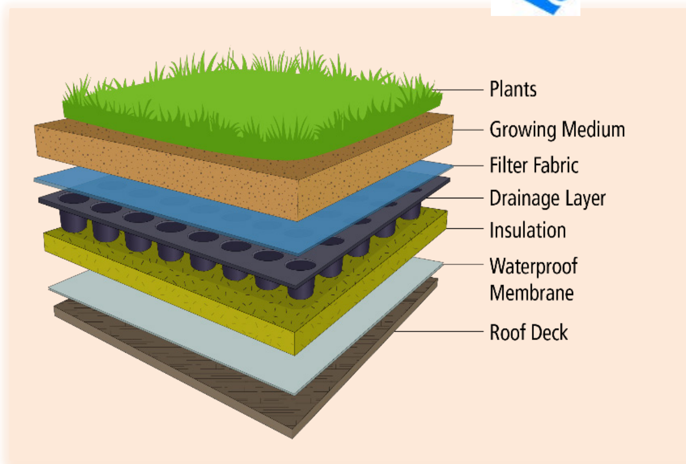
Construction staff can install green roofs during initial construction or place them on buildings as part of a retrofit. The following factors determine the amount of stormwater a green roof retains: the surface area of the green roof, the depth and type of growing medium, the slope, and the type of plants. Green roofs are appropriate for industrial and commercial facilities and multi-family residential buildings such as condominiums or apartment complexes. Green roofs can also prove useful for small residential buildings. In all cases, green roofs should be easily accessible and property owners should understand the maintenance requirements necessary to keep the roof functional.

Design Considerations

A building should be able to support the loading of green roof materials under fully saturated conditions and snow loads, if applicable. This load typically ranges from 10 to 40 pounds per square foot but is design-specific (GSA, 2011; MAPC, 2010).

Green roof materials, or layers, vary according to specific types and applications but typically include (from top to bottom) a vegetation layer, an engineered planting medium, a filter mat, a drainage layer and a moisture barrier. Vegetation should be suited for local climatic conditions and can range from sedums, grasses and wildflowers on extensive roofs to shrubs and small trees on intensive roofs. Construction staff can build green roofs layer by layer or purchase them as a complete system. Some vendors offer modular trays containing the green roof components.

Q11



Green roof cross section showing typical material layers.
Based on USEPA's diagram of The Common Green Roof Layers

Design Variations

Green roofs include extensive, semi-intensive or intensive design variations (GSA, 2011; MDE, 2009; Tolderlund, 2010). The design selection depends on the loading capacity of the roof, the project budget, local climate and design goals such as the desired volume of stormwater retention. Generally, extensive green roofs have 6 inches or less of growing medium, whereas intensive green roofs have more than 6 inches of substrate. Semi-intensive green roofs are a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square footage is deeper than or shallower than the 6-inch threshold. Extensive green roofs provide many of the environmental benefits of intensive green roofs but are very low-maintenance and do not typically allow for public access. Engineers generally design semi-intensive and intensive green roofs for the public or building tenants to use as parks or relaxation areas. However, these green roofs require greater capital and maintenance investments than extensive green roofs. Intensive green roofs are particularly attractive for developers, property owners and municipalities in areas where land prices command a premium and property owners want to provide park-like amenities.

Limitations

In most climates, green roofs should include drought-tolerant plant species. In semiarid and arid climates, it can be a challenge to keep plants alive in a green roof shallower than 4 inches (Tolderlund, 2010). Therefore, developers typically prefer semi-intensive or intensive green roof systems in these climates. In arid regions, supplemental irrigation is sometimes a necessity.

Structurally, the roof slope and the load-bearing capacity of the building may limit green roof design. Roof slope should not be too steep, as steeper slopes can promote overland flow, uneven drainage or rapid drying of uphill portions. Although sources often cite 30 degrees as a maximum slope, design engineers should exercise caution when considering any slopes that are not flat. In new construction, engineers should design buildings to manage the increased weight associated with a saturated green roof. When designing green roofs for existing structures, engineers should take the load restrictions of the building into account.

Green roofs can also entail greater capital costs than conventional alternatives. In recognition of this possible barrier to adoption, a number of large cities have some type of incentive program to reduce upfront costs.

Maintenance Considerations

Immediately after construction, property owners need to regularly monitor green roofs to ensure that vegetation is healthy. During the first season, owners may need to water green roofs periodically if precipitation is insufficient. After the first season, property owners may only need to inspect and lightly fertilize extensive green roofs approximately once per year. Property owners need to maintain intensive green roofs like any other landscaped area. Maintenance may involve gardening and irrigation in addition to general roof maintenance.

Green roofs are less prone to leaking than conventional roofs. In most cases, detecting and fixing a leak under a green roof is no more difficult than doing the same for a conventional roof. Still, a qualified professional should use proper construction techniques and conduct leak testing before planting occurs. Many green roof guidance documents—including this General Services Administration report—provide helpful descriptions of leak detection methods, including flood tests and low-voltage leak detection.

Effectiveness

Green roofs can effectively reduce peak flows associated with storm events, reduce the total volume of stormwater discharge, and reduce the export of some pollutants often associated with traditional roofs. In a literature review of studies across climate and design types, Akther et al. (2018) found that green roofs had stormwater retention rates of at least 80 percent for small storm events but highly variable stormwater retention rates for larger storm events. In a review of green roof hydrology, Li and Babcock (2014) found that green roofs can reduce total stormwater volume and peak flow rates by around 30 to 90 percent and capture greater portions during smaller rain events prior to media saturation. Through exploratory modeling of the combined sewer system of New York City, Rosenzweig et al. (2006) also showed that a 50 percent adoption of green roofs across the sewershed would reduce total stormwater volume by up to 10 percent.

The ability of green roofs to address pollutant loading to downstream waters is mixed. As precipitation tends to be low in nutrients, green roofs often need fertilization to support healthy vegetation. When property owners fertilize green roofs excessively or outside of the growing season, green roofs may release nutrients, including nitrogen and phosphorus. Proper fertilization, combined with the ability of green roofs to reduce the total volume of stormwater, mitigates these effects. Still, in a study comparing the water quality of green roof and conventional roof discharges, EPA concluded that, if possible, property owners should direct green roof discharges to another green infrastructure practice for nutrient management and not discharge directly to a receiving water (U.S. EPA, 2009). However, green roofs have a clearer advantage over conventional roofs when it comes to toxic pollutants, as conventional roofs often produce discharges containing heavy metals and polycyclic aromatic hydrocarbons (Van Metre & Mahler, 2003).

Cost Considerations

Q12

Green roofs generally cost more to install than conventional roofs. However, they can be cost-competitive over their full life cycle when considering factors such as stormwater benefits, increased life span, increased energy efficiency and improved real estate value.

The life span of a green roof is generally similar to, if not better than, a conventional roof. For example, an extensive green roof can last around 25 years, which may be twice the life span of a conventional roof (Kosareo & Ries, 2007). This increased life span can often justify the high installation cost.

The size and type of a green roof influences its installation cost, with larger installations costing less per square foot than smaller installations, and extensive systems costing less than deeper, intensive systems. Compared to conventional roof installation costs of around $10 to $20 per square foot (Niu et al., 2010), green roof material costs are fairly low—with materials costing between $1 and $3 per square foot—but green roofs are labor-intensive to install and require a crane to lift materials to the roof, which can cost between $4,000 and $5,000 per day. Sources often cite the total cost of a green roof as $15 to $35 per square foot, with cost per square foot decreasing as size increases (GSA, 2011; RSMeans, 2019), though costs can be as high as $60 per square foot (Tolderlund, 2010). Maintenance costs for green roofs vary over time, and costs are initially higher to establish the vegetation. After the first 5 years, maintenance costs are typically between $0.10 to $1.00 per square foot per year (MPCA, 2020).

To capture the true cost of green roofs, including monetizable benefits, several studies have performed life cycle costing or net present value (NPV) assessments comparing the cost of traditional roof installations to green roof installations. Although the range of benefits varies between studies, most authors found net economic benefits for green roofs, especially for green roofs on larger buildings. A life cycle assessment by Blackhurst et al. (2010) found that green roofs may not be as cost-effective on individual small, residential single family homes, but multi-family and commercial building green roofs are competitive when considering social benefits like reductions in the urban heat island effect, GHG emissions and stormwater treatment. Using NPV and incorporating air quality, energy savings and stormwater reduction benefits, Niu et al. (2010) found the NPV of green roofs to be 30 to 40 percent less than conventional roofs over a 40-year lifetime. Additionally, GSA (2011) developed cost-benefit models for green roof implementation on commercial and institutional buildings ranging in size from 5,000 to 50,000 square feet. Using national averages as well as cost figures specific to the District of Columbia, GSA (2011) found that accounting for reductions in stormwater, energy use and GHG emissions was generally enough to balance out installation costs, and green roofs offer a significant cost advantage when considering real estate and community-based benefits.

Additional Resources

- What is Green Infrastructure?
- What is EPA Doing to Support Green Infrastructure?
- Green Infrastructure Modeling Tools
- Green Infrastructure Design and Implementation
- Green Infrastructure Funding Opportunities
- Tools, Strategies and Lessons Learned from EPA Green Infrastructure Technical Assistance Projects
- Managing Flood Risk with Green Infrastructure

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Infrastructure Planning

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Q13

Description

Infrastructure planning can be a useful stormwater management tool to reduce the deleterious effects of sprawl development. Sprawl development is the expansion of low-density development into previously undeveloped land. The American Farmland Trust (2018) estimated that the United States loses about 175 acres of farmland per hour to suburban and exurb development. Sprawl development requires local governments to extend public services to new residential communities whose tax payments often do not cover the cost of providing those services. It also diminishes the environmental services the previously undeveloped land provided, such as agricultural productivity, groundwater infiltration and maintenance of downstream waterbody health.

Community planners may consider using infrastructure planning as a stormwater management tool to direct new growth into previously developed areas and discourage low-density development. Generally, they do so by drawing an urban growth boundary around a community, beyond which they discourage or do not subsidize major public infrastructure investments. Meanwhile, communities provide economic and other incentives within the boundary to encourage growth in existing neighborhoods. By encouraging housing growth in areas that already receive public services—such as water, sewers, roads, schools and emergency services—communities save infrastructure development costs and reduce the impacts of sprawl development on urban streams and water quality.

Sprawl development negatively impacts water quality in several ways. One of the most significant impacts comes from the increase in impervious cover, including new rooftops, roads, driveways and compacted soils. This increase in impervious area directly increases the volume and peak flow rate of stormwater. Elevated stormwater flows erode stream channels, increase sediment and pollutant loads, degrade stream habitat, and reduce aquatic diversity (Paul & Meyer, 2001).

Sprawl development influences water quality in other ways. For example, sprawl often occurs at the edges of

Proper infrastructure planning can help limit sprawl development and improve stormwater quality.

urban areas outside of centralized water and sewer service areas. This requires new housing developments to use septic systems or other forms of on-site wastewater disposal to treat household sewage. Evidence has shown that on-site treatment systems with improper siting or poor design, installation, operation, or maintenance become significant sources of nutrients and bacteria that affect both surface waters and groundwater. The Preventing Stormwater Contamination from Septic System Failure fact sheet contains more information about septic systems. Additional information is also available on EPA's septic system webpage.

Applicability

Sprawl development occurs in all regions of the country and has motivated many efforts to counteract its impacts. However, these programs seldom focus on water quality considerations and instead concentrate on economic and transportation issues. Even so, effective infrastructure planning can reduce the impact of new development. Promoting infill and redevelopment of existing urban areas in combination with other site design techniques can decrease impervious area and

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the amount of pollution that sites discharge to urban waterbodies.

Site design techniques that can be part of smart infrastructure planning include:

- Zoning and development practices.
- Roadway practices.
- Green design and planning strategies.
- Promotion of green infrastructure.
- Protection of natural features.

Additional information on all of these topics can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater

Siting and Design Considerations

Various infrastructure planning techniques exist to manage urban growth while conserving resources. Each technique recognizes that directing growth to areas with previous development or promoting higher-density development in areas where services exist prevents sprawl development and helps communities reduce the water quality impacts of economic growth. These techniques include:

- ***Urban growth boundaries***. This method establishes a dividing line that defines where growth will occur and where preservation of agricultural or rural land will occur. Often, an urban service area exists within this boundary, creating a zone beyond which public services do not extend.
- ***Infill development/community redevelopment.*** This practice encourages new development on unused or underutilized land in existing urban areas. Communities may offer tax breaks or other economic incentives to developers to promote the redevelopment of vacant or damaged properties.
- ***Impact fees.*** When government entities assess higher impact fees on the development of natural spaces or farmland than on that of developed areas, impact fees can encourage redevelopment or infill development.
- ***Smart growth.*** This urban planning practice promotes high-density development characterized by walkable and bikeable neighborhoods, preserved green spaces, mixed-use development and mass transit.

Limitations

Intense development can create a new set of challenges for stormwater program managers. Stormwater management solutions can be more difficult and complex in dense urban areas than in suburban areas. The lack of space for structural stormwater controls and the high cost of available land where communities could install structural controls are just two problems that program managers likely face in managing stormwater in intensely developed areas.

Infrastructure planning often occurs on a regional scale and requires cooperation among all the communities within a given region to be successful. Stormwater managers should coordinate with other state and local agencies and community leaders to ensure that infrastructure plans direct growth to areas that will have the least impact on watersheds and water quality.

Effectiveness

Infrastructure planning can reduce the impervious cover and amount of compacted land of a community, which can be an effective means of reducing stormwater discharges. Although the ability to directly measure the water quality benefits of smart infrastructure planning is limited, given the lack of suitable control watersheds, modeling studies have shown that housing densities directly affect the generation of stormwater discharge within a watershed. Using a spreadsheet-based model, Jacob and Lopez (2009) showed that per capita pollutant loadings and stormwater discharge decreased significantly with higher density development. Similarly, researchers have shown that construction activities associated with residential development—mainly soil disturbances such as excavation and compaction—result in significantly lower infiltration rates and higher stormwater generation rates for non-impervious surfaces as well (Woltemade, 2010). Infrastructure planning techniques that reduce the total footprint of developed land through the use of higher densities can therefore help lessen total stormwater discharges.

Cost Considerations

Utilizing existing infrastructure and services rather than constructing new infrastructure can reduce costs while providing economic benefits. The following is a sampling of case studies from a Smart Growth America report summarizing the cost savings achieved by smart growth approaches (Fulton et al., 2013):

- An economic analysis for Champaign, Illinois, examined the costs and benefits of increasing the city's population by about 25 percent, from 75,000 people to 94,000 people. The analysis compared two scenarios: one in which all growth would occur inside the city's current service area and one in which a considerable portion of the growth would occur outside the service area. Over a 20-year period, the analysis projected that the smart growth scenario would provide the city with a net surplus of $33 million through savings in infrastructure and municipal service costs, compared to a $19-million deficit associated with the conventional suburban scenario.
- An analysis of infrastructure costs in Sarasota County, Florida, showed that smart growth development of the downtown area would generate enough tax revenue to pay off infrastructure costs in 3 years, compared to the 42 years that would be necessary for comparable suburban development.
- The State of Maryland conducted a study of a smart growth approach to statewide road construction projects and found that smart growth could save $1.5 billion per year for 20 years compared to conventional suburban development trends.
- The State of California commissioned a study of several different development scenarios to determine costs of development between 2010 and 2050. The study found that a smart growth development approach would save the state 20 percent compared to standard suburban development—with cost savings of $32 billion over the 40-year timespan considered.

Infill development potentially requires higher upfront costs than development on undeveloped land. Factors that may lead to higher upfront costs include demolition requirements, higher engineering and architectural costs, and higher construction costs associated with the taller buildings that are often necessary to accommodate larger populations on smaller footprints. However, residential and office infill development projects in urban environments retained their value better during the economic recession of the late 2000s. An analysis of home price changes between May 2012 and May 2013 found that price increases were greater in urban areas than suburban areas, providing further evidence that infill development provides better economic returns than new development (U.S. EPA, 2014).

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Open Space Design

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Description

Open space design, also known as conservation development or cluster development, is a site design technique that concentrates dwelling units in compact areas to provide for open space and natural areas elsewhere on the development site. Each different zoning district has a set of requirements for minimum lot sizes, setbacks and frontage distances. Communities implementing an open space design can update these requirements to preserve and create more open space. Open space designs have many benefits compared to the conventional subdivisions that they replace: they can reduce impervious cover, stormwater pollutants, construction costs, grading and the loss of natural areas. Some communities may lack zoning ordinances to permit open space development, and even those that have enacted ordinances may want to revisit them occasionally to achieve greater water quality and environmental benefits.

Communities can amplify the benefits of open space design by combining it with other better site design practices such as installing narrower streets, eliminating curbs and gutters, installing grassed swales, and utilizing alternative turnarounds.

Q14

Applicability

Open space design widely applies to most forms of development. The greatest stormwater discharge and pollutant reduction benefits typically occur when applying open space design to residential zones that have larger lots (less than two dwelling units per acre). In these types of large-lot zones, shrinking lot sizes can create a great deal of natural or community open space. However, open space design may not always be viable for high-density residential zones, redevelopment or infill development, where lots are small to begin with and clustering will yield little open space. In rural areas, it may be necessary to adapt open space design, especially in communities where public health authorities do not currently allow shared septic fields.

Open space design principals concentrate dwelling units together in neighborhoods while preserving open spaces, such as a lakes and forests, for common use.

Credit: Photo by La Citta Vitta on Flickr (Creative Commons license)

Nearly all geographic regions of the country can use open space design, which results in the conservation of different types of open space (forest, prairie, farmland, chaparral or desert).

Siting and Design Considerations

The codes and ordinances that govern residential development in some communities do not allow developers to build anything other than conventional subdivisions. These communities could consider enacting a new ordinance or revising current development regulations to enable developers to use this design option. The following resources provide helpful information for updating codes and ordinances to incorporate approaches like open space design:

- The Center for Watershed Protection's updated Code and Ordinance Worksheet for improving local development regulations.
- The University of Wisconsin Sea Grant's *Tackling Barriers to Green Infrastructure: An Audit of Local Codes and Ordinances* report.

- EPA's *Incorporating Low Impact Development into Municipal Stormwater Programs* fact sheet.

Often, a first step is adopting a local ordinance that allows open space design within conventional residential zones. The Land Use Department of New Castle County, Delaware, was one of the first local government agencies to promote a conservation design approach, requiring any new development project to incorporate 50 percent open space (Clar et al., 2009). Similar ordinances may specify smaller lot sizes, setbacks and frontage distances for the residential zone. Other key elements of effective open space ordinances include requirements for consolidating and using open space, as well as enforceable provisions for managing the open space.

Limitations

A number of real and perceived barriers hinder wider acceptance of open space designs by developers, local governments and the general public. For example, despite strong evidence to the contrary, some developers still feel that open space designs are less marketable than conventional residential subdivisions. In other cases, developers contend that the review process for open space design is longer, more costly and potentially more controversial than that for conventional subdivisions—and thus not worth the trouble.

Local governments may be concerned that homeowner associations lack the financial resources, liability insurance or technical competence to adequately maintain open space. Additionally, the general public can be suspicious of cluster or open space development proposals, feeling that they are a "Trojan Horse" for more intense development, traffic and other local concerns. At the regional level, government entities need to carefully construct and implement open space design policies and ordinances so as not to lead to "leapfrogging," which is the creation of additional development in already built-up areas. An open space development that requires new infrastructure—such as roads, water and sewer lines, and commercial areas—can actually create more imperviousness at the regional level than it saves at the site level.

In reality, government entities can directly address many of these misconceptions by adopting a clear open space ordinance and by providing training and incentives to the development and engineering communities.

Maintenance Considerations

Following establishment, a responsible party who can maintain common open space and natural conservation areas in a natural state and in perpetuity should manage them. Typically, legally enforceable deed restrictions, conservation easements or maintenance agreements protect the open space. In most communities, the authority for managing open space falls to a property owner, community association or land trust. Annual maintenance tasks for natural open space areas are almost nonexistent, as their purpose is to allow natural processes to take place without obstruction. It may be useful to develop a habitat plan for natural areas that requires periodic management actions such as invasive or exotic species control.

Effectiveness

The effectiveness of open space design depends on the degree to which the design reduces impervious surface and maintains a site's natural hydrology. In a review of nearly 4,000 conservation development projects that incorporated various types of open space design, Milder and Clark (2011) found that development approaches like conservation subdivisions and conservation-oriented, master-planned communities were able to conserve a total of 90 percent of the land area those projects encompassed.

Research indicates that open space design can provide significant stormwater discharge and pollutant reduction benefits compared to the conventional subdivisions they replace. For example, the Center for Watershed Protection (1998) reported that nutrient export declined by 45 percent to 60 percent after the redesign of two conventional subdivisions as open space subdivisions. Clar et al. (2009) modeled the hydrologic effects of implementing the conservation design strategies outlined in *Conservation Design for Stormwater Management* (DE DNREC & Brandywine Conservancy, 1997). They found that implementing conservation design strategies—including open space design—in conjunction with other low impact development practices could effectively maintain predesign hydrologic conditions across a 60-acre development site.

Along with reducing imperviousness, open space designs provide a host of other environmental benefits that most conventional designs lack. These developments reduce the potential pressure to encroach on resource and buffer areas because they usually reserve enough open space to accommodate resource protection areas. Moreover, because open space designs clear less land during the construction process, they also greatly diminish the potential for soil erosion. Perhaps most importantly, open space design generally reserves at least 50 percent of the development site as green space that would not otherwise receive protection, preserving a greater range of landscapes and habitat "islands" that can support considerable diversity in mammals, songbirds and other wildlife.

Q15

Cost Considerations

Open space developments can be significantly less expensive to build than conventional subdivisions—mostly due to savings in road-building and stormwater management conveyance costs. The Conservation Research Institute (2005) reviewed the costs associated with conservation development approaches, including open space design techniques, and found that they could achieve significant savings compared to traditional development due to:

- Reduced construction costs associated with clearing and grading, stormwater and transportation infrastructure, and utilities when using clustering to preserve open space.
- Reduced installation costs of natural landscaping compared to turf grass applications.
- Reduced maintenance costs of natural landscaping compared to turf grass applications.
- Reduced paving costs.
- Reduced long-term stormwater infrastructure costs.

While open space developments are frequently less expensive to build, developers find that these properties often command higher prices than homes in more conventional developments. Using hedonic price analysis, a large body of research has established that proximity to open space increases property value (Anderson & West, 2006; Heal, 2001; Lutzenhiser & Netusil, 2001; Irwin, 2002). Often, this benefit is more prominent in high-density areas where proximity to open space provides greater contrast than low-density areas (Anderson & West, 2006). A review of over 60 studies showed that proximity to open spaces mostly increases property values, sometimes on the order of thousands of dollars, but that the magnitude depends on the size of the open space area, proximity to the property and the type of open space (Shoup & Ewing, 2010).

In addition to being aesthetically pleasing, the reduced impervious cover and increased tree canopy associated with open space development reduces the size and cost of downstream stormwater treatment facilities. The resulting cost savings can be considerable, as the cost to treat stormwater discharge from a single impervious acre can range from $15,000 to more than $200,000 (King & Hagan, 2011). The increased open space within a cluster development also provides a greater range of locations for more cost-effective stormwater practices.

The Mill Creek subdivision in Kane County, Illinois, uses mixed-use and cluster development principles. The site includes 1,500 acres with the goal of protecting natural wildlife habitats and maintaining open spaces to increase flood resiliency. The redevelopment project focused on reducing impervious spaces and maintaining 45 percent of the neighborhood as open space through cluster development. The developers conducted an economic study and determined that by increasing the density of housing within the community, cluster development saved about $3,700 per lot over conventional development approaches (CRI, 2005). In addition to reducing building footprints, using natural, existing or established vegetation and green ifrastructure practices reduced the amount of stormwater discharge, which in turn provided further cost savings by reducing drainage infrastructure costs.

Additional Resources

- Pennsylvania Department of Transportation, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Department of Community and Economic Development, & Pennsylvania Land Trust Association. (2011). *The official map: A handbook for preserving and providing public lands and facilities* (PUB 703).
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Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Disclaimer

This fact sheet is intended to be used for informational purposes only. These examples and references are not intended to be comprehensive and do not preclude the use of other technically sound practices. State or local requirements may apply.

Stormwater Best Management Practice

Protection of Natural Features

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Description

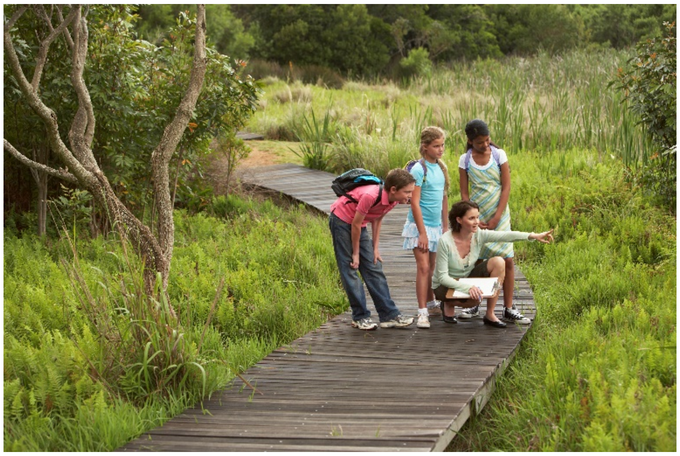
Undeveloped sites can have numerous natural features that provide environmental, aesthetic and recreational benefits if preserved and protected from the impacts of construction and development. These features include wetlands, riparian areas, aquifer recharge areas, mature trees, woodlands and other wildlife habitat. Site designs should also protect restricted areas such as floodplains and steep slopes.

Natural area protection can also be important on properties undergoing redevelopment. They might have attractive open space, well-drained soils or riparian areas that design engineers should identify and consider for preservation early in the planning process.

Design engineers, construction staff, and municipalities can protect natural features and open space—both during development and after a site is in use—through a combination of site planning techniques, construction site stormwater controls and post-construction stormwater controls.

Q16

A mixed-use community called Abacoa in Jupiter, Florida, puts many smart growth principles into action, including cluster design and land preservation. The community encompasses 2,055 acres, including 393 acres preserved for open space and another 260 acres reserved for green space. Local ordinances and mixed-use cluster development make this protection of open space possible. The community and surrounding landscape focus on protecting wildlife habitat and riparian buffers, including native pine woods, wetlands and habitat for the endangered gopher tortoise. Abacoa's natural features also provide stormwater management benefits by reducing stormwater discharge through natural infiltration and providing water quality treatment in streams, lakes and wetlands.



A teacher and students on an elevated path in a marshland.

Implementation

Site Planning Techniques

Developments can incorporate existing environmental features into a site's design and market them as amenities. This can be accomplished by delineating a "development envelope" for buildings and infrastructure that keeps them from affecting natural features. Current design manuals for cities like Portland, Seattle and Philadelphia (City of Portland, 2016; PWD, 2018; SPU, 2017) build on this concept through incorporation of other *smart growth* practices, which provide financial and planning incentives to combat urban sprawl, promote compact development and conserve natural lands.

The first step in urban conservation is to assemble background information by:

- Determining the local context (urban, agricultural, forested, etc.).
- Mapping significant features as candidate conservation areas, including floodplains, slopes, soils, wildlife habitats, woodlands, farmland, historical/cultural sites, views, aquifer recharge areas and others.

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- Ranking conservation areas based on how special, unique, irreplaceable, environmentally valuable, historic or scenic they are.
- Identifying areas to place buildings and infrastructure so as to minimally impact conservation areas.
- Establishing the layout of buildings and infrastructure, using techniques such as clustering buildings and designing smaller lots, shared driveways and narrower streets.

Site evaluation and design can enable the preservation of significant features while maintaining the desired overall site density (although density in localized parts of the development will be higher when open space is set aside). There can be some negative perceptions associated with high-density residential areas. Developers want to achieve a particular development density when building subdivisions or commercial sites. Also, for residential developments, lot size is an important factor in determining lot prices. Setting aside natural areas can take space away from yards, parking, transportation infrastructure and other built features. Developers can accommodate overall site density using clustering techniques, smaller lots, density increases and more efficient street layouts. To offset lost premiums from smaller individual lots, developers can market a lot's proximity to natural areas and attractive views as amenities.

Also, local zoning codes might restrict the use of clustering, reduced road widths and other techniques for natural area preservation. Developers should work with local regulatory agencies to determine whether they can obtain waivers to protect natural features.

Stormwater Controls During Construction

Design engineers and construction staff need to take extra care during site preparation to protect environmentally significant areas of the property (see Preservation of Natural or Existing Vegetation). They should indicate a limit of disturbance and the locations of protected areas in design drawings, stormwater pollution prevention plans and on-site maps. They should also post signs with prohibitions and educate workers about the importance of and special considerations for the protected areas. Without training and explicit signage, vehicle traffic, stored waste and materials, and other construction-related activities could damage areas slated for protection. Construction staff should check areas regularly to identify problems and determine if additional controls are needed (e.g., more training, explicit signage, obvious barriers). Operators should also look for signs of unintended consequences of construction activities on the natural areas (e.g., changes in hydrology, flooding, accidental spills) and take appropriate actions to mitigate the damage.

Developers and construction site operators can employ the following specific practices to protect each type of resource:

- **Mature trees or woodlands.** Surround the area to protect with bright orange fencing placed at or beyond the tree's dripline. Prohibit clearing and grubbing, limit heavy equipment traffic and prohibit material storage inside the barrier. Include signage with specific prohibitions and educate employees. Visually monitor vegetation to ensure that construction is not damaging it (e.g., soil compaction from heavy equipment traffic might cause localized flooding in nearby natural areas).
- **Steep slopes.** Protect steep slopes and vegetation. Avoid development and removal of vegetation on steep slopes. Fence off these areas and assess whether to add further erosion controls. Check erosion controls on upslope areas that will be cleared and graded; use either a pipe slope drain or a diversion (placed at the top of the slope) to divert stormwater away from or around the slope. Post signs prohibiting heavy vehicle traffic and educate crews about the sensitivity of steep slopes to erosion.
- **Well-drained soils and aquifer recharge areas.** Protect areas with well-drained soils and those that feed aquifers from compaction. Maintain vegetation if possible; for a cleared area, minimize heavy traffic by fencing the area and posting signs. Before planting permanent vegetation, aerate the soil to ensure that stormwater infiltrates. These areas may later be critical to the success of post-construction stormwater controls.
- **Wetlands and riparian areas.** Establish a buffer around marshes, swamps or other wetlands and along stream corridors in which no construction activity occurs. Avoid stream crossings wherever possible. When necessary, set up perimeter sediment controls (e.g., silt fence) and visually

monitor protected areas—especially after each storm—to check for damage from flooding and for signs of impacts from construction activities, including sedimentation, vegetation disruption, erosion, dumping, habitat destruction or fish kills. Set up stream crossings to minimize disturbance of streamside vegetation and instream habitat. Post signs and educate workers about the sensitive nature of the area; include prohibitions for storing or dumping materials. Make sure all development activities comply with Section 404 of the Clean Water Act.

The Mill Creek subdivision in Kane County, Illinois, uses mixed-use and cluster development principles. The site includes 1,500 acres with the goal of protecting natural wildlife habitats and maintaining open spaces to increase flood resiliency. The redevelopment project focused on reducing impervious spaces and maintaining 45 percent of the neighborhood as open space through cluster development. The developers conducted an economic study and determined that by increasing the housing density within the community, cluster development saved about $3,700 per lot over conventional development approaches (CRI, 2005). In addition to a reduced building footprint, using natural or existing vegetation and green infrastructure practices reduced the amount of stormwater discharge, which in turn provided further cost savings through reduced drainage infrastructure costs.

- **Wildlife habitat**. Contact a local wildlife authority if you find nests, dens or other animal dwellings on the property—if any are found, remove or relocate them before construction begins.
- The presence of threatened or endangered species or habitats critical to their survival on the site might require a consultation with the U.S. Fish and Wildlife Service or the National Oceanic and Atmospheric Administration’s (NOAA’s) National Marine Fisheries Service. Ensure compliance with all regulations and any state or local permit requirements.
- **Floodplains**. Municipal code typically restricts the placement of buildings in floodplains because of safety concerns and the risk of property damage, so these areas should remain outside the limit of disturbance (restrictions will vary from one municipality to the next, so check with local authorities about floodplain restrictions in the area). Establish perimeter controls, including fencing, and post signage that prohibits dumping and material storage in these areas. Inspect protected areas regularly to ensure that vegetation has not been disturbed and that no dumping has occurred.

After Site Development

After development, natural areas become amenities for the site’s occupants (e.g., property owners or commercial tenants). These natural areas also become the responsibility of the owner or occupant. Developers should inform the occupant about each natural area or protected feature’s importance and outline activities that the occupant should prohibit to adequately protect the resource.

Developers should also provide guidance to occupants on how to maintain these areas. For example, occupants should not mow a preserved prairie or riparian stream buffer or manicure it like turf. Property owners or maintenance crews should employ special procedures to preserve native species, such as integrated pest management practices like hand-weeding and limiting chemical use. They should use the same practices in areas where traditional landscape maintenance activities could threaten water quality, such as in or adjacent to wetlands and riparian areas or where endangered species are present. Property owners can post interpretive signage to educate occupants and visitors about the significance of the features, as well as to describe prohibited activities such as mowing, dumping and vehicle traffic. They can install barriers to protect natural areas from damage without detracting from their aesthetics and function. These barriers can include strategic placement of low fences, walls, bollards or large rocks that unobtrusively limit access to the areas.

Using Conservation Easements

Developers can use conservation easements to maintain open space over the long term. For example, the Minnesota Land Trust implements “subdivision conservation,” protecting thousands of acres and hundreds of shoreline miles along various lakes. This approach involves compacting development areas and preserving part of the development area as natural land. For example, the Fields of St. Croix residential development in Lake Elmo, Minnesota, permanently protected 60 percent of the development’s 226 acres through a conservation easement granted to the Minnesota Land Trust (Anderson, 2014).

Effectiveness

A Johns Hopkins University study showed that conserving natural areas can improve stormwater quality and reduce pollutant loading to receiving streams. Specifically, riparian forest buffers and riparian grass buffers achieved a 20 to 60 percent reduction in total nitrogen, total phosphorus and total suspended solids depending on buffer width, slope and hydrogeological conditions (Baish & Caliri, 2009). Similar data from the Chesapeake Bay region show forested buffers can achieve load reductions of 6–12 lbs total nitrogen, 0.4–1.5 lbs total phosphorus and 120–1,500 lbs total suspended solids per acre of forest buffer (CBP, 2018). Preserving natural spaces and maintaining natural stream buffers will help to remove pollutants from stormwater, thus improving aquatic life, habitat and water quality.

Cost Considerations[1]

Q17

Cost comparisons for preserving natural areas and open space versus traditional development are difficult to determine because the quantity and type of natural features vary from site to site. In general, preserving natural areas can add costs for planning and inspections to meet local regulatory requirements using innovative site designs. Also, the need for smaller construction equipment could increase costs if equipment operators need to maneuver around trees and other protected features. Offsetting these higher costs are the cost savings that come with disturbing less space—costs for clearing, grading, temporary erosion control, landscaping and stormwater management. These savings can be substantial; the cost of clearing and grading alone can easily exceed $10,000 per acre (RSMeans, 2019) while the cost of implementing a new post-construction stormwater control can entail capital costs of $50,000 to $100,000 per acre of impervious surface treated (King & Hagan, 2011).

Additionally, developments that use clustering can reduce infrastructure costs by shortening road lengths, eliminating curbs and gutters, and using vegetated areas and swales instead of structural stormwater controls. Preserving forested or other natural areas can save up to $12 per square foot (or $525,000 per acre) over conventional landscape solutions, thanks to a long-term reduction in maintenance requirements for mowing grass and purchasing fertilizer (SSI, 2009).

Additional Resources

- Pennsylvania Department of Transportation, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Department of Community and Economic Development, & Pennsylvania Land Trust Association. (2011). *The official map: A handbook for preserving and providing public lands and facilities* (PUB 703).
- U.S. Environmental Protection Agency (U.S. EPA). (2011). *Smart growth illustrated.*

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

[1] Prices updated to 2019 dollars. Inflation rates obtained from the Bureau of Labor Statistics CPI Inflation Calculator website: https://data.bls.gov/cgi-bin/cpicalc.pl.

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Stormwater Best Management Practice

Redevelopment

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Q18

Description

Although there is no single, nationwide definition, stormwater professionals typically define redevelopment as development on previously developed land. In some states and localities, new development and redevelopment are subject to the same requirements. Redevelopment of existing impervious surfaces can be a key strategy for reducing net increases in impervious surfaces and associated degradation to receiving waters. The use of newer, more effective stormwater management practices can also help improve the treatment of existing stormwater discharges.

Municipalities and property owners can redevelop on a site-by-site basis, but redevelopment can also be part of a larger effort to spur coordinated investment and development across a larger geographic area. Common programs include business improvement districts, Main Street programs for older downtowns, brownfields programs, vacant property campaigns and efforts to revive older, underperforming shopping malls. The transfer of development rights can also help spur redevelopment by directing development demand to existing activity centers.

Related Fact Sheets

The following fact sheets contain additional information on stormwater practices related to redevelopment:

- Alternative Turnarounds
- Eliminating Curbs and Gutters
- Green Parking
- Green Roofs
- Open Space Design
- Infrastructure Planning
- Protection of Natural Features
- Right-Sized Residential Streets
- Site Design and Planning Strategies

A before and after redesign option for 6th Avenue in Des Moines, Iowa. The design features green infrastructure, local art and a bus shelter.
Credit: Vireo/BNIM

Applicability

Redevelopment involves existing developed land and is therefore most common in highly urbanized areas. Still, suburban and even rural areas commonly contain vacant or underperforming properties that may be suitable for redevelopment. Individual jurisdictions within economic development offices or in the local chamber of commerce typically run programs to address redevelopment. On a regional scale, municipal planners can use coordinated redevelopment as part of economic development or stormwater planning programs.

In districts with multiple redevelopment-ready properties, economic factors, such as location to amenities and proximity to transit, guide which properties are a priority

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for redevelopment. However, these properties may not be the ones that will deliver the greatest stormwater benefits. It is therefore important to have a clear redevelopment ordinance and plan review process to ensure redevelopment activities maximize stormwater improvement benefits.

Design Considerations

The stormwater controls chosen for redevelopment should consider the unique circumstances of the redevelopment project. Common land-related constraints include irregularly shaped properties with varying topography, small lots, legacy contamination and noncompliant building features/footprints. Water quality considerations can also influence stormwater control selection. In some cases, the main factor will be flow reduction; in others, the focus will be the treatment of specific pollutants.

For urban areas, micro-detention practices, urban forestry techniques and structured soils are often best. Green building techniques and green roofs may also be good choices. As noted above, cities and counties will want to coordinate infrastructure repair and upgrades with redevelopment efforts so that water and wastewater capacity are not barriers to redevelopment.

Some of the strategies for redevelopment include:

- **Green roofs.** Green roofs help reduce the urban "heat island" effect and reduce peak stormwater flows by absorbing stormwater on-site. The vegetated cover also helps protect and insulate the roof, extending its life and reducing heating and cooling costs.
- **Micro practices.** Micro practices are intended to treat small amounts of stormwater and occupy small amounts of space. They are therefore often appropriate for redevelopment when space is limited. A single practice rarely manages the entire volume of stormwater generated at a site—so a micro practice is typically only one of a series of stormwater controls. Micro practices include any feature that promotes stormwater infiltration, filtration or evapotranspiration: for example, small garden areas, tree grates, perimeter hedges and rain gardens.
- **Permeable pavements.** Alternative pavers, porous asphalt and permeable concrete help reduce stormwater flows by allowing water to infiltrate their porous surfaces and soak into the ground beneath. Alternative surfaces can often cost less than traditional storm drain systems and can replace existing impervious surfaces.
- **Infrastructure upgrades.** Redevelopment offers an opportunity to upgrade grey infrastructure like storm grates and pipes or reduce stormwater discharge by using green infrastructure.
- **Manufactured products.** A growing number of devices are coming on the market that provide a range of mitigation functions for stormwater management. These devices commonly work to separate large debris collected in stormwater, intercept sediments, promote infiltration or improve water quality. Examples include hydrodynamic separators and catch basin inserts. They range in size, cost and maintenance needs, but are often appropriate for areas where space is limited.

Limitations

Redevelopment has certain policy and technical limitations. As a stormwater strategy, it can require larger regional cooperation. In growing rural districts, residents may not view a redevelopment strategy for established commercial as advantageous. For multi-jurisdictional regions, it will be important to clearly identify parties responsible for implementation and maintenance of stormwater controls during redevelopment activities.

From a technical perspective, site conditions (e.g., infiltration rates, groundwater conditions, stormwater hotspots) can also impose constraints. Since many urban buildings come with basements and underground garages, infiltration may not be an option if there is not enough distance between the stormwater control and the building. Also important are site-specific pollutants of concern: some stormwater controls are only effective at removing specific pollutants.

Effectiveness

Redevelopment is intended to reduce the quantity and improve the quality of stormwater leaving a site. Where new impervious surfaces simply replace existing impervious surfaces, water quality may not improve. However, reducing impervious surface or installing new stormwater controls should decrease stormwater quantity and pollutants. The local construction plan review process should have a procedure in place for requiring and reviewing any redevelopment project's pre- and post-construction hydrology.

For examples of how five communities have used redevelopment to improve not only their stormwater management, but also their overall livability and economic viability, read these Community Stories.

Additional Resources

Additional resources that provide a wealth of knowledge regarding redevelopment approaches, specific practices and success stories include:

- The International Stormwater BMP Database
- EPA's green infrastructure site
- EPA's smart growth site

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

Stormwater Best Management Practice

Right-Sized Residential Streets

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Q19

Description

Roadway planning is a delicate balance between meeting the needs of the community while also ensuring that roads are right-sized to provide the right amount of paved surface. Reducing the width of residential streets is a practice that can provide a number of community benefits, including a reduction in impervious surface and stormwater discharge. Currently, many communities require residential street widths of 32, 36 or even 40 feet. Wide streets include two parking lanes and two moving lanes, but they often provide more parking than is necessary and enable higher traffic speeds, which negatively affect pedestrian safety (NHTSA, 1999; SGA, 2019). In many residential settings, street widths can be as narrow as 22 to 26 feet without sacrificing emergency access, on-street parking, or vehicular and pedestrian safety. Developers can install even narrower access streets or shared driveways when they only need to serve a small number of homes. However, developers need to balance many competing interests and often have little flexibility because most communities require wide residential streets as a standard element of their local road and zoning standards. Revisions to current local road standards, based on an inclusive review of street design needs, are often necessary to promote the narrowing of residential streets. Communities typically accomplish this by implementing a more comprehensive Green Streets program.

Applicability

Narrower streets are appropriate for local streets with limited traffic, not collectors (roadways that connect local roads or streets with arterials) or arterials (freeways and multi-lane highways that supplement the interstate system). Combining narrow streets with green infrastructure can also enhance their benefits. Through a comprehensive Green Streets design, communities can substantially reduce stormwater discharge and become more livable. EPA's Green Streets handbook provides guidance on how to implement a holistic green streets program.

Right sized residential streets can reduce the impervious area in a neighborhood.

Siting and Design Considerations

Residential street design requires balancing competing objectives: design, speed, traffic volume, emergency access, parking and safety. Solutions for accommodating these competing interests may include alternative street parking configurations, vehicle pullout space, connected street networks, prohibitions on parking near intersections and smaller block lengths (Lukes & Kloss, 2008).

Other practices that complement right-sized streets:

- Permeable pavements
- Green parking
- Elimination of curbs and gutters
- Alternative street design and patterns
- Bioretention (rain gardens)
- Site design and planning strategies

Communities that want to change their road standards to permit narrower streets need to involve all the stakeholders who influence street design in the revision process. A common concern with right-sizing streets is a lack of parking. One method to preserve parking is to use curb bump-outs at intersections. These slow traffic and allow pedestrians and vehicles to see each other, increasing safety. Several communities across the nation have adopted narrower street width standards. Table 1 provides examples of these new standards.

Table 1. Examples of adopted narrow street widths.

Jurisdiction	Street Width (in Feet)	Parking Condition
Phoenix, Arizona	28	Parking both sides
Santa[EH1] Rosa, California	30	Parking both sides, less than 1000 average daily traffic
	26–28	Parking one side
	20	No parking
	20	Neck-downs at intersection
Orlando, Florida	28	Parking both sides, residential lots greater than 55 ft wide
	22	Parking both sides, residential lots greater than 55 ft wide
Birmingham, Michigan	26	Parking both sides
	20	Parking one side
Howard County, Maryland	24	Parking unregulated
Kirkland, Washington	12	Alley
	20	Parking one side
	24	Parking both sides, low density only
	28	Parking both sides
Madison, Wisconsin	27	Parking both sides, less than 3 dwelling units per acre
	28	Parking both sides, 3–10 dwelling units per acre

Source: WERF, 2009

In any location, efficient access for emergency responders and their vehicles is often the main concern when implementing narrow street designs. EPA provides a number of resources to help communities confront these emergency response challenges on their Smart Growth Streets and Emergency Response webpage.

Limitations

Real and perceived barriers hinder wider acceptance of narrower streets at local levels. Advocates for narrower streets need to respond to the concerns of local agencies and the general public. Some of the more frequent concerns about narrower streets include:

- **Inadequate on-street parking.** Research and local experience have demonstrated that narrow streets can adequately accommodate residential parking demand. A single-family home typically requires 2 to 2.5 parking spaces. In most residential zones, one parking lane on the street and a driveway can satisfy this parking demand.
- **Car and pedestrian safety.** Research indicates that narrow streets have lower accident rates than wide streets (NHTSA, 1999; SGA, 2019). Narrow streets tend to lower vehicle speeds and calm traffic. Furthermore, adding sidewalks can improve pedestrian safety. Although this might create additional impervious area, greater reductions in street width and incorporation of additional green infrastructure and green design strategies can decrease the net impervious area.
- **Emergency access.** With proper designs, narrower streets can easily accommodate fire trucks, ambulances and other emergency vehicles. The Uniform Fire Code requires that streets have a minimum of 20 feet of unobstructed width, which narrow street designs easily accommodate. EPA provides additional resources for addressing emergency access.
- **Large vehicle access.** Field tests have shown that school buses, garbage trucks, moving vans and other large vehicles can generally safely negotiate narrower streets, even with cars parked on both

sides. In regions with high snowfall, streets may need to be slightly wider to accommodate snow plows and other equipment.

- **Utility corridors.** Often it is necessary to place utilities underneath the street rather than in the right-of-way.

In addition, local communities may lack the authority to change road standards when state agencies retain the review of public roads. In these cases, narrowing can only occur on private streets that residents rather than local or state agencies maintain.

Examples of how communities have overcome various barriers and successfully implemented narrow street designs as standalone programs or as part of wider Green Streets programs are below:

- *Neighborhood Street Design Guidelines: An Oregon Guide for Reducing Street Widths*
- *Implementing Living Streets: Ideas and Opportunities for the City and County of Denver*
- *Green Infrastructure Opportunities and Barriers in the Greater Los Angeles Region*
- *Flexible Design of New Jersey's Main Streets*

Maintenance Considerations

Narrower streets should slightly reduce road maintenance costs for local communities because they have a smaller surface area to maintain and repair.

Effectiveness

Urban roads, sidewalks and parking lots make up two-thirds of the total impervious cover in urban environments (Lukes & Kloss, 2008). A reduction in width from 36 feet to 26 feet represents a nearly 30 percent reduction in impervious surface, which translates directly to reductions in stormwater discharge. Moreover, if developers can use the space they save for additional stormwater controls, such as grassed swales or bioretention systems, they can dramatically reduce stormwater discharge and roadway pollutants.

Cost Considerations

Q20

Because narrower streets require less material, they cost less to build than wider streets. Asphalt alone costs around $1 to $2 per square foot depending on the thickness and type (RSMeans, 2019), while typical road construction can cost more than $15 per square foot when considering full construction costs (ARTBA, 2019; FDOT, 2019). Reducing road width by just 4 feet can yield savings in asphalt paving costs alone of more than $35,000 per mile of residential street. In addition, because narrower streets produce less impervious cover and stormwater discharge, developers can realize additional savings by reducing the size and cost of downstream stormwater management facilities.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Disclaimer

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Stormwater Best Management Practice

Riparian/Forested Buffer

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative Practices for Site Plans

Description

A riparian or forested buffer is an area along a shoreline, wetland or stream where localities restrict or prohibit development. Its primary function is to physically protect and separate a stream, lake or wetland from future development, disturbance or encroachment. With proper design, a buffer can provide stormwater management benefits, provide room to mitigate natural flooding, and assist in sustaining the integrity of stream ecosystems and habitats. As conservation areas, buffers are part aquatic ecosystem and part urban forest.

There are three types of buffers:

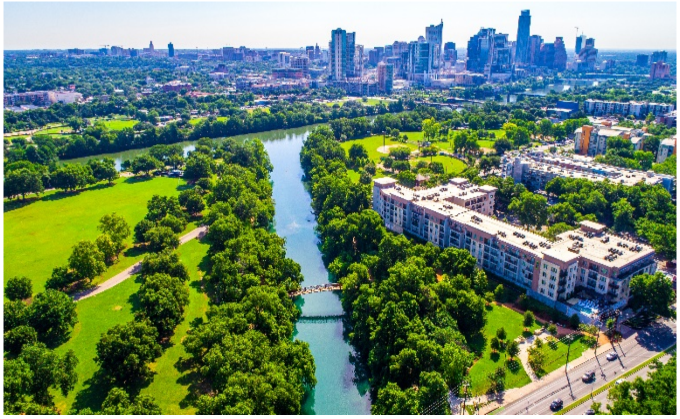
- *Water pollution hazard setbacks*—areas separating potential pollution hazards from waterways. Such buffer setbacks reduce the potential for pollution.
- *Vegetated buffers*—natural areas that divide land uses or provide landscape relief.
- *Engineered buffers*—areas with specific designs to treat stormwater before it enters streams, lakes or wetlands.

Buffers can be effective stormwater controls while also providing a range of other environmental and public benefits. In addition to reducing stormwater, improving water quality and helping to mitigate flooding risks, they can preserve habitat, provide recreational opportunities and increase surrounding property values.

Applicability

Q21

Buffers are applicable to new development and redevelopment areas. For new development areas, planners can incorporate buffers through the designation of specific preservation areas. These areas can be managed through long-term easements or by community associations. For existing developed areas, an easement to the property of adjoining landowners may be necessary. A local ordinance, such as Kansas City's stream setback ordinance (Brown et al., 2009), can help set specific criteria for buffers to achieve stormwater management or other community goals.



Riparian forested buffers can reduce pollution in stormwater from urban landscapes.

In many regions of the country, managing buffers in a forested condition can enhance their benefits. This is because buffers mimic the functioning of natural forested riparian zones. In most settings, buffers can remove surface and subsurface pollutants through interception and treatment of stormwater and shallow groundwater. Shoreline and stream buffers in flat or gently sloping areas are particularly effective at removing sediment, nutrients and bacteria, as they mimic natural floodplain processes.

Note that federal regulations (see 40 CFR 450.21[a][6]) also dictate that National Pollutant Discharge Elimination System permits for active construction sites disturbing 1 or more acres must require operators to provide and maintain "natural buffers" around any waters of the United States. The specific requirements for these buffers depend on the permitting authority.

Siting and Design Considerations

Buffer establishment considerations vary widely depending on restoration goals, local design standards and site conditions including soil type, land use and topography. Design engineers should consult local permitting authorities at the start of the project to ensure they follow local design standards and obtain any required permits. Depending on the site or the presence of jurisdictional wetlands or flood zone designations, the site may require several permits. Examples include:

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- State or municipal permits.
- U.S. Army Corps of Engineers Nationwide Permit 27, "Aquatic Habitat Restoration, Enhancement, and Establishment Activities."
- U.S. Army Corps of Engineers Section 404 Permit, "Dredge and Fill."

A common and effective approach to buffer design or preservation is the three-zone buffer system, consisting of inner, middle and outer zones (Brown et al., 2009; Hawes & Smith, 2005; Schultz et al., 2013). Function, width, vegetative target and allowable uses distinguish the zones, with the type and number of uses increasing with distance from the waterbody. The design of each zone should encourage sheet flow and avoid concentrated channel flow.

- The inner zone protects physical and ecological integrity by providing bank stabilization, and habitat and flood protection. It is generally the narrowest zone, often around 25 feet, and encompasses wetlands and other critical habitats. Its allowable uses are very restricted and may include minimal utility infrastructure and footpaths.
- The middle zone provides distance between upland development and the inner zone. It is typically 50 to 100 feet depending on stream order, slope, width of the 100-year floodplain or presence of jurisdictional wetlands. The vegetative target for this zone is mature riparian vegetation, which in most cases consists of riparian forest. Usage is restricted to limited recreational activities, stormwater controls and bike paths.
- The outer zone is the first zone to encounter stormwater discharge from upland development. It prevents encroachment while slowing and filtering stormwater discharge, similar to a vegetated filter strip. The outer zone's width is variable, though guidance manuals often recommend a minimum of around 25 feet. While a natural forest is preferable, turf-grass or ornamental vegetation is also appropriate. Any vegetation should not receive regular fertilization. The outer zone's uses are unrestricted; they can include lawn, garden, compost, yard wastes and most stormwater controls.

If design engineers expect the forested riparian buffer to receive a large amount of stormwater discharge from upland areas, they can incorporate a depression into the outer zone to provide temporary storage and limit overland flow through the buffer. They should design the depression to capture and store stormwater from smaller events and bypass stormwater from larger events. It may be useful to consider elements of bioretention design such as shallow ponding depths, underdrains and drop inlet bypasses. The design should also allow any discharge to sheet flow to downstream practices to limit erosion. Ultimately, the goal of any depression area or other stormwater control within the buffer should be to minimize overland flow to the downstream waterbody by promoting stormwater infiltration.

Limitations

In urban areas especially, paved and hard-packed turf surfaces concentrate stormwater discharge and generate high flow rates. If the stormwater discharges toward a riparian buffer, it can result in channel flow that reduces the buffer's effectiveness and potentially causes erosion of both the buffer and stream banks. Therefore, riparian forested buffers are not suitable "end of pipe" stormwater controls. Design engineers should implement buffers in highly urban areas in conjunction with upstream stormwater controls to reduce the amount and rate of stormwater discharge.

Maintenance Considerations

An effective buffer management plan includes activities associated with vegetation establishment and maintenance, as well as designation and monitoring of allowable and prohibited uses in the buffer zones. Planners should clearly define buffer boundaries and make them visible before, during and after construction so that local governments, contractors and residents can follow the management plan.

Vegetation management activities vary by location and project type. New buffers require establishing and monitoring vegetation to ensure survival. For conservation of existing buffers, removing invasive species or replanting areas with low vegetation survival may be necessary. Generally, engineers should design inner zones to be dynamic and regenerative, similar to natural riparian areas, which should reduce maintenance requirements over time. Outer zones, especially those with the designs and maintenance of lawns, gardens or stormwater controls, require maintenance typical of those uses.

The Green Book for the Buffer, a report for Maryland's Critical Area Commission, provides guidance on preparation and implementation of a buffer management plan.

Effectiveness

Forested riparian buffers are effective at reducing peak flows to downstream waterbodies, reducing stormwater pollutant concentrations through direct filtration, and enhancing in-stream and riparian nutrient processing through increased stream–floodplain connectivity. The effectiveness of each depends on the design of the buffer and the length of installation along the riparian zone. Although quantifying the effectiveness of stream-floodplain connectivity is still an evolving area of research, more data exists to quantify the effectiveness of buffers as direct filtration systems.

Unlike more traditional stormwater treatment practices, design engineers generally size buffers according to the space available and not around any specific treatment volume. Accordingly, buffers' abilities to reduce peak flows, infiltrate stormwater and filter pollutants are more variable, according to pollutant removal studies (see Table 1). Still, proper buffer design can increase pollutant removal from stormwater discharge. Factors that improve effectiveness include:

- Slopes less than 5 percent
- Upgradient overland flow paths less than 150 feet
- Groundwater close to the surface
- Contact times longer than 5 minutes
- Planting during the growing season
- Buffer widths greater than 25 feet
- Presence of organic matter, humus or mulch layer
- Entry stormwater velocity less than 1.5 feet per second
- Trees with deep root systems

Table 1. Pollutant removal rates in buffer zones.

Buffer Vegetation	Buffer Width (Meters)	Total Percent Mass Total Suspended Solids Removal	Total Percent Mass Phosphorus Removal	Total Percent Mass Nitrogen Removal	Total Percent Mass Nitrate as Nitrogen Removal	References
Grass	0–5	—	—	—	48	Jaynes and Isenhart, 2019
Grass	5–10	75–95	55–78	25–80	50–62	Schmitt et. al., 1999 Lee et al., 2000 Lee et al., 2003
Grass	10–20	88–93	72–83	40–52	25	Schmitt et al., 1999 Jaynes and Isenhart, 2019
Grass	20–30	—	—	—	39–84	Jaynes and Isenhart, 2019
Grass/woody	10–20	85–97	72–94	40–91	85	Schmitt et al., 1999 Lee et al., 2000 Lee et al., 2003
Forested	10–20	—	—	—	97	Schoonover et al., 2005

Cost Considerations

The upfront costs of forested riparian buffers include those typical of stormwater controls, including design, permitting, grading, planting and maintenance. However, buffers have some economic benefits that can offset these costs, including higher property values and mitigation of flood impact costs (Brown et al., 2009; Kenney et al., 2012).

For local governments, the costs of instituting a buffer program include extra staff, plan review training, technical assistance, field delineation, construction and ongoing buffer education programs. A community wanting to implement a stream buffer program would likely adopt an ordinance, develop technical criteria, and invest in additional staff resources and training. Buffer programs also often include a training component for plan reviewers and consultants. To explain the new requirements to stakeholders and land developers, communities can develop manuals, workshops, seminars and direct technical assistance. Lastly, buffers require maintenance. Activities should include systematic inspections of the buffer networks before and after construction, as well as increasing resident awareness about buffers.

One way to provide flexibility is to allow buffer averaging. This option allows developers to narrow the buffer width at some points if the average width of the buffer and the overall buffer area meet the minimum criteria. Municipalities can also grant variances for redevelopment projects if the landowner or property owner can demonstrate severe economic hardship or unique circumstances that make compliance with the buffer ordinance difficult.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Site Design and Planning Strategies

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Description

Urban development can significantly alter the natural features and hydrology of a landscape. Development and redevelopment usually create impervious surfaces like sidewalks, parking lots, roadways, buildings and compacted open spaces. Rainwater cannot soak into these hard surfaces and instead flows across them, collecting sediment, used motor oil, pesticides, fertilizers and other pollutants. In most urban areas, a complex pipe system conveys this contaminated stormwater into streams and coastal waters.

Historically, the goal of stormwater planning has been to prevent localized flooding by moving large amounts of water off-site as quickly as possible. This traditional approach can lead to downstream effects related to water quantity and quality. Stormwater that flows directly into storm drains cannot soak into soil and recharge aquifers. Larger storms have led to increased stormwater volumes and velocities that can cause flooding of pivotal streets, which leads to safety concerns, traffic nightmares, stream bank erosion and water quality impairments. Additionally, traditional stormwater management approaches can be costly and may strain municipal budgets as the need for expanding storm sewer systems and maintaining the existing systems increases.

Concerned by the environmental impacts and rising costs of traditional stormwater management approaches, many communities are implementing alternative site design strategies that aim to restore natural hydrologic processes. These strategies include approaches like green infrastructure, conservation development, better site design and smart growth. The goals of these various design approaches are to lessen the stormwater impacts while still providing opportunities for development.

Green Infrastructure

Green infrastructure is defined in the Clean Water Act as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." Implementing green infrastructure can include integrating green infrastructure practices throughout a site, such as green spaces, native landscaping, and a variety of micro-scale stormwater controls that capture and manage stormwater on-site, and other techniques described below. These features reduce peak stormwater flows by allowing rainwater to soak into the ground, evaporate into the air, or collect in storage receptacles for irrigation and other beneficial uses. As a result of using green infrastructure, developers can more closely maintain pre-development hydrology at a site. Evidence has also shown that green infrastructure practices are cost-effective and, in some cases, cheaper than traditional stormwater management techniques (U.S. EPA, 2007).

Examples of green infrastructure practices include the following:

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- *Bioretention practices* are relatively small-scale, landscaped depressions containing plants and a soil mixture that absorbs and filters stormwater. For more information, see the Bioretention fact sheet.
- *Cisterns and rain barrels* collect and store rainwater from rooftops. By storing and diverting stormwater, these devices help reduce the flooding and erosion that stormwater discharges cause. Because they contain no salts or sediment, they can supply water for garden or lawn irrigation, reducing water bills and conserving municipal water supplies. For more information, see the On-Lot Treatment fact sheet.
- *Green roofs* are rooftops with a vegetation cover. Having been in use for decades in Europe and parts of the U.S., green roofs help with temperature regulation both internal and external to the building, mitigate the urban heat island effect and reduce stormwater flows. The vegetated cover also protects and insulates the roof, extending its life and reducing energy costs. For more information, see the Green Roofs fact sheet.

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- *Permeable pavements* reduce stormwater discharge by allowing water to soak through the paved surface into the ground beneath. Permeable pavement encompasses a variety of media, from porous concrete and asphalt to plastic grid systems and interlocking paving bricks suitable for driveways and pedestrian malls. For more information, see the Permeable Pavements fact sheet.
- *Grassed swales* are open channels on which erosion-resistant, flood-tolerant grasses grow. In applications alongside roadways as stormwater conveyances, grassed swales can slow and filter stormwater flows and promote infiltration. Grassed swales and other biofiltration devices like grass filter strips improve water quality and reduce in-stream erosion by slowing the velocity of stormwater before it enters a stream. For more information, see the Grassed Swales fact sheet.
- Using infrastructure planning to increase development density and maximize green space.
- Protecting natural features such as forests and green spaces.
- Protecting or creating stream buffers.
- Reducing the footprint of necessary impervious surfaces (e.g., right-sizing road and sidewalk widths, right-sized parking lots, minimizing or removing cul-de-sacs, replacing paving materials with pervious alternatives).
- Incorporating green infrastructure practices (e.g., bioretention practices, permeable pavements, green roofs) into development plans.

Conservation Development

Conservation development is an approach to design that mitigates the effects of urbanization. It prioritizes the conservation of existing natural resources, including aquatic habitat, forested areas and green spaces. For example, conservation development often uses compact, clustered lots surrounding a common open space. The goal of conservation development is to disturb as little land area as possible while allowing for the maximum number of residences that zoning laws permit (Pejchar et al., 2007).

Before new construction, conservation developers evaluate natural topography, natural drainage patterns, soils and vegetation. Developers maintain areas that are important for the site's natural hydrology, such as forested areas, streams and wetlands, while they integrate other stormwater controls into developed areas. By maintaining natural hydrological processes, conservation development creates conditions that slow, absorb and filter stormwater on-site.

To ensure that future development does not threaten these natural features, municipalities should consider providing for long-term resource protection. For example, conservation easements, transfer of development rights and other "in perpetuity" mechanisms ensure that protective measures remain in place long after site development. For more information, see the National Association of Conservation Districts and Land Trust Alliance web sites.

Better Site Design

Better site design aims to reduce impervious cover, preserve natural lands and capture stormwater on-site. Better site design techniques focus on modifying municipal codes and ordinances that are inflexible and require large uniform lots, wide roads and a large number of parking spaces. Better site design techniques that reduce impervious cover include protecting natural features, right-sizing streets and sidewalks, minimizing cul-de-sacs, incorporating green parking techniques, and reducing the size of driveways and housing lots.

Better site design techniques that reduce stormwater discharge include preserving natural lands; preserving native vegetation and clusters of trees; employing landscaping techniques that flatten slopes; and using riparian or forested buffers along streams, wetlands and steep slopes. Designers can also use green infrastructure practices such as bioretention practices, grassed swales and filter strips to manage stormwater and protect downstream water resources.

Development Districts

Development districts are areas zoned by communities specifically for property development. Development districts are concentrated areas of mixed-use development, typically 5 acres or larger. They may have a high concentration of impervious area, but also a smaller footprint than areas that follow traditional development patterns. A development district with a good design can contribute to many water quality benefits. For example, redevelopment (i.e., development of an existing urban area) reduces the need to disturb natural areas for new construction. In addition, many development districts incorporate practices to manage stormwater on-site, such as tree-lined streets, rain gardens and green roofs. Compact development districts also lend themselves to more environmentally friendly transportation options, like biking or walking, and shorter and less frequent automobile trips, which can also reduce stormwater pollutants. For more information, see the Zoning fact sheet.

Smart Growth

Smart growth is a set of development strategies that seek to balance economic growth, urban renewal and conservation. In newly developing areas, smart growth promotes compact, town-centered communities that consist of open green space, businesses and affordable housing, interconnected by pedestrian walkways and bicycle lanes. Smart growth emphasizes walkable communities and alternative forms of transportation, which can help alleviate the environmental consequences of automobile use. Smart growth also advocates the revitalization of inner cities and older suburbs. Reusing existing infrastructure often costs less than new construction and helps slow the spread of impervious surfaces.

The Smart Growth Network developed 10 core principles that guide smart growth:

- Mix land uses.
- Take advantage of compact building design.
- Create a range of housing opportunities and choices.
- Create walkable neighborhoods.
- Foster distinctive, attractive communities with a strong sense of place.
- Preserve open space, farmland, natural beauty and critical environmental areas.
- Strengthen and direct development toward existing communities.
- Provide a variety of transportation choices.
- Make development decisions predictable, fair and cost-effective.
- Encourage community and stakeholder collaboration in development decisions.

While not explicitly a guiding principle, stormwater management can benefit from smart growth. Combining compact, high-density development with an emphasis on preserving open spaces reduces the spread of impervious surfaces within a watershed, helping to reduce stormwater discharge. Infill and redevelopment that reuse existing infrastructure can be more cost-effective than new development, which requires expensive new infrastructure. The "fix it first" management philosophy advocates repairing and upgrading existing infrastructure before spending money on new infrastructure.

For more information on programs and funding opportunities, visit EPA's Smart Growth website.

Integrated Stormwater Planning/Long-Term Stormwater Planning

The above design strategies can benefit stormwater management and other municipal services subject to Clean Water Act (CWA) regulations, such as wastewater treatment programs. For example, in areas with combined sewer systems, practices that reduce stormwater discharge can also reduce the burden on local wastewater treatment plants and reduce the frequency and magnitude of combined sewer overflows (CSOs). Furthermore, with adequate planning, municipalities may be able to achieve desired results at lower costs. For example, municipalities can often reduce the nutrient load to downstream waterbodies by improving stormwater management or wastewater treatment—one option is often more cost-effective than the other. However, stormwater and wastewater departments often operate separately, leading to missed opportunities for more effective and lower-cost comprehensive management solutions. EPA's CSO Control Plans and Remedies web page provides resources to help incorporate green infrastructure planning as part of a larger CSO control program.

EPA's integrated planning approach offers an opportunity for municipalities to propose to meet multiple CWA requirements simultaneously by identifying efficiencies from wastewater and stormwater programs and sequencing investments so that the highest-priority projects come first. This approach can also lead to more sustainable, comprehensive solutions that improve water quality and provide multiple benefits that enhance community vitality. The integrated planning approach does not change existing regulatory or permitting standards or delay necessary improvements; rather, it is an option to help municipalities meet their CWA obligations while optimizing infrastructure investments through an appropriate sequencing of work.

As the name suggests, EPA's voluntary long-term stormwater planning approach specifically focuses on stormwater management in the long-term. As communities continue to grow and develop their local economies, they look for sustainable and effective approaches to reduce these existing and emerging sources of pollution. Communities can consider developing a comprehensive long-term community stormwater plan that integrates stormwater management with communities' broader plans for economic development, infrastructure investment and environmental compliance. Through this approach, communities can prioritize actions related to stormwater management as part of capital improvement plans, integrated plans, master plans or other planning efforts.

Additional Resources

- What is Green Infrastructure?
- What is EPA Doing to Support Green Infrastructure?
- Green Infrastructure Modeling Tools
- Green Infrastructure Design and Implementation
- Green Infrastructure Funding Opportunities
- Tools, Strategies and Lessons Learned from EPA Green Infrastructure Technical Assistance Projects
- Green Streets Program
- Manage Flood Risk with Green Infrastructure
- Build Resiliency to Drought
- Green Infrastructure Webcast Series

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Urban Forestry

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Description

Urban forestry is the study of trees and forests in and around towns and cities. Since trees absorb water, patches of forest can help provide stormwater management to an urban setting. Urban forests also help break up a landscape of impervious cover, provide small but essential green spaces, link walkways and trails, improve overall air and water quality, attract wildlife, and provide opportunities for community recreation.

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Applicability

Municipalities can apply urban forestry practices by preserving existing trees or planting new trees. In addition to providing stormwater management benefits, urban forests also provide aesthetic amenities in public spaces. For stormwater management, urban forestry is especially useful along roadways, around retention basins, along the banks of waterbodies and in sloping areas to catch excess stormwater and prevent soil erosion. Generally, it is ideal to preserve as much contiguous forest as possible; however, this may not be an option in many urban areas. If municipalities fragment forested areas, it is ideal for them to retain the closest fragments together.

Implementation

Critical Root Zone (CRZ)

The concept of a Critical Root Zone (CRZ) is essential to a proper management plan. The CRZ is the root area around a tree necessary for the tree's survival. Tree size, tree species and soil conditions determine the CRZ. Typically, the CRZ is the area around the tree's base that extends approximately 1 to 1.5 feet radially for every inch of the tree's diameter. The tree's diameter is measured at "breast height," which is 4.5 feet above grade. The CRZ can also be defined as the tree's drip line, which is the area under the tree's canopy. Whichever measurement is larger should define the CRZ, or an arborist or State Urban Forestry Coordinator—who can assess the importance of other environmental factors, such as tree age, soil conditions and others—should decide the CRZ. Municipalities should not disturb the CRZ for the sake of the tree's stability (North Carolina Urban Forest Council, n.d.).

Trees installed on both sides of a roadway.
Photo Credit: Mateus Campos Felipe/Unsplash

Urban Forestry Plans and Ordinances

Urban forestry plans and ordinances are tools municipalities can use to ensure the preservation and promotion of urban trees. An urban forestry plan should include measures to establish, conserve or reestablish preservation areas. The following are some typical elements of a forest conservation plan (MNCPP, 2011):

- A map and a narrative description of the forest and surrounding area that include topography, soils, streams, current forested and unforested areas, tree lines, critical habitats, and 100-year floodplain.
- An assessment that establishes preservation and reforestation areas, including any calculations, local requirements and tables summarizing forest areas.

> Organizations like American Forests dedicate themselves to helping municipalities focus on forest preservation and establishment. They provide updated research, tools, collaboration atmospheres, funding and organization partnerships to create policies and programs for local, state and federal organizations to empower the forestry field. Another program, the Urban and Community Forestry Program, provides information, tools, funding and even job opportunities in forestry.

- A forest conservation map that outlines forest retention areas, reforestation, protective devices, limits of disturbance and stockpile areas.
- A schedule of any additional construction in and around the forest area.
- A specific management plan, including permanent tree and forest protection measures.

The Urban and Community Forestry Program of the North Carolina Forest Service and the North Carolina Wildlife Resources Commission provides a guide to creating a tree protection ordinance. According to the guidance, goals for a tree protection ordinance should include (Nicholas Institute, 2017):

- Reducing stormwater discharge.
- Moderating temperature and promoting energy conservation.
- Improving air quality.
- Improving surface drainage and aquifer recharge.
- Preventing soil erosion while promoting soil stabilization and enrichment.
- Improving water quality.
- Conserving natural resources and maintaining tree canopy.
- Providing wildlife habitat.
- Encouraging the protection and planting of native trees.
- Protecting, facilitating and enhancing the aesthetic qualities of the community to ensure that tree removal does not reduce property values.

A forest preservation ordinance is another way for a municipality to set design standards outlining how to preserve and manage a forest. Ordinances can apply to a site both during and after construction. Ordinances can stand on their own, or municipalities can require developers to integrate them into a proposed development's erosion and sediment control and stormwater pollution prevention plans, which many communities require of new developments. Resources like the Center for Watershed Protection's *Better Site Design Code and Ordinance Worksheet* (CWP, 2018) can help communities develop and evaluate codes and ordinances, especially those with the purposes of minimizing impervious cover, conserving natural areas and promoting practices that reduce stormwater discharge.

Trees as Urban Stormwater Management Systems

The prevalence of hard surfaces such as concrete in urban areas provides location limitations for new trees. However, municipalities can utilize structural cell systems on sidewalks and other paved areas to provide space for trees and underground stormwater management that would otherwise not exist. A typical structural cell system should incorporate suspended pavement with support from a network of pillars to allow for a large volume of soil, load-bearing capacity, drainage and root growth beneath the pavement. The cell should allow for stormwater capture and drainage during flooding. To further manage stormwater, green infrastructure such as permeable pavement, bioretention and green roofs can supplement the streetscape plots. For further structural information, see EPA's *Stormwater to Street Trees* report (U.S. EPA, 2013).

Limitations

One of the biggest limitations to urban forestry is development pressure. Incorporating ordinances, conservation easements and other techniques into management programs can help alleviate future development pressures. The size of the land may also limit the ability to protect individual trees. In such areas, a tree ordinance may be a more practical approach.

Forests may also harbor undesirable wildlife elements such as insects and other pests. If forests border houses, this may be a concern for residents. Additionally, the species and age of the tree affect its effectiveness as a stormwater management practice. Finally, as droughts, wildfires and higher-intensity storms become more frequent, trees may struggle to survive.

Maintenance Considerations

Maintenance considerations for urban forests may include fringe landscaping, trash pickup, watering and even removal. Municipalities can minimize maintenance efforts by using native vegetation and keeping the area as natural as possible.

Effectiveness

There are numerous environmental and stormwater benefits to urban forestry. Urban forests can:

- Act as natural stormwater management areas by filtering particulate matter, nutrients, sediments and pesticides. An acre of urban forest can reduce the annual load of nitrogen in stormwater by 21 to 82 pounds, phosphorus by 0.31 to 1.3 pounds, and total suspended solids by 520 to 1500 pounds (CBP, 2018).

- Reduce stormwater discharges by intercepting water in their canopies and root zones. The stormwater then evaporates and transpires instead of converting to discharge. Through transpiration, tree roots also reduce soil moisture levels, which further increases the soil's infiltration and storage capacity.
- Reduce soil erosion by intercepting rainfall in their canopies, therefore reducing the volume and velocity of the rainfall hitting the soil.
- Absorb carbon dioxide and airborne pollutants, resulting in improved air quality.
- Absorb, transform or store trace amounts of pollutants from the soil and stormwater. These include metals, organic compounds, fuels and solvents.
- Provide habitat for urban wildlife.
- Provide recreational benefits and engage the community. Trees can provide attractive meeting places for the community, reduce the area's noise level and provide opportunities for education through organized planting events.

Cost Considerations[1]

Costs associated with implementing urban forestry practices can vary widely, especially when comparing the cost of conservation versus reforestation. Costs can be minimal when simply conserving existing trees and may only be due to planning and maintenance activities.

The costs associated with new urban forest areas can also vary depending on whether construction staff need to remove existing pavement or infrastructure, whether they need to purchase land, and what type of trees they are planting. As an average, the Maryland Department of the Environment estimates that the planting of urban trees or forest buffers costs roughly $13,000 per acre, not including the cost of impervious surface removal (King & Hagan, 2011). This cost is likely to be less if the area already has native trees. Moreover, urban forests can be a much cheaper option for cities than traditional landscaping. According to a 2008 forum that the American Society of Landscape Architects and the Urban Land Institute co-sponsored, preserving existing forested areas can save $530,000 per acre in development costs compared to conventional landscape solutions (SSI, 2009).

Urban forests require routine maintenance that, depending on the type of trees, can include watering, pruning, mulching and crown thinning. The Maryland Department of the Environment estimates the annual cost of maintaining an urban forest to be $470 per acre (King & Hagan, 2011). If municipalities do not maintain trees, the cost of removing dead trees from their plots and the property damage from fallen branches or whole trees can be larger than the annual maintenance cost (Vogt et al., 2015).

> In a study by the U.S. Department of Agriculture (USDA) Forest Service, a tree can hold up to 0.008 inches of rainwater per unit area of canopy cover in a given rainfall event. For a typical tree with a canopy area of 3000 square feet, this translates to about 13 gallons of water (USDA Forest Service, 2020).

In addition to typical economic considerations, trees have natural properties that lead to indirect economic benefits for residential and municipal properties (Coder, 2017; U.S. EPA, 2007; Peper et al., 2007). Studies have shown forests to increase property value due to their aesthetic appeal (U.S. EPA, 2007). In a study of New York City trees, Peper et al. (2007) found trees to increase property values by $24 to $155 per tree in an urban setting, depending on the species. The authors also found that each tree provided, on average, a $78 benefit in terms of its stormwater management services through canopy interception and transpiration. In total, by estimating a suite of monetizable benefits that trees provide in an urban setting—which include reducing the energy demand of buildings through shading and passive cooling, carbon capture, improved air quality, stormwater management, and aesthetic benefits—Peper et al. (2007) found that for every $1 spent on tree installation and management, $5.6 were returned to the community.

[1] Prices updated to 2020 dollars. Inflation rates obtained from the Bureau of Labor Statistics CPI Inflation Calculator Web site https://data.bls.gov/cgi-bin/cpicalc.pl.

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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Stormwater Best Management Practice

Street Design and Patterns

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

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Description

Streets make up a third or more of all land and half of impervious surface in many cities (NACTO, 2017). Traditionally, they collect and convey stormwater directly into storm sewer systems that lead to nearby waterways. As such, they present both a barrier to natural hydrology and an opportunity for municipalities to improve stormwater management. Streets that capture and infiltrate stormwater back into the urban ecosystem can generate ecological, economic and public health benefits.

The design of an individual street (e.g., cross-sectional layout, length, intended use) and the layout of a network of streets in a community both impact stormwater because they affect the total amount of impervious surface, neighborhood connectivity and overall development patterns in a region. Streets that follow a "smart growth" approach are well connected, support multiple transportation modes and provide a range of community benefits—from stormwater management to greenhouse gas reduction and enhanced livability.

Alternative street design resources:

- Institute of Transportation Engineers' list of Complete Streets Resources
- Federal Highway Administration's Eco-Logical Annual Reports
- Strategic Highway Research Program 2
- EPA's Smart Growth and Transportation Web site

Artistic rendering of a street redesign to include narrower lanes, bike lanes, and planters.
Credit: Photo by Spackman Mossop Michaels on USEPA's Flickr

Applicability

Conventional street layouts tend to follow a hierarchy. Many smaller roads, serving residential areas, feed into larger roads and arterials; these in turn funnel traffic onto regional roads and highways. This funneling of traffic creates congested chokepoints, with few (if any) alternative routes from place to place. This system was a result of a highly separated and dispersed land use system (e.g., sprawling suburban residential areas surrounding concentrated urban economic and cultural centers).

A connected street system does not need to be a formal grid of streets. Often, links among activity centers (e.g., schools, jobs) define the connections as much as the street layout. Many local governments and states are realizing the need for better-connected, multimodal street networks. As municipalities develop regional master plans or capital improvement plans, municipal leaders should identify all available opportunities to redesign streets following smart growth practices, including addressing stormwater management at the forefront. States should enact policies that support a connected streets approach so that new residential or mixed-use development projects have more than one connection to neighboring retail, commercial or transportation centers. Urban areas can add streets around transportation hubs to enhance circulation and multimodal connections. Examples of policies include New Jersey's Future in Transportation program and Virginia's Secondary Street Acceptance Requirements.

Smart growth street designs support more intense development on a smaller footprint. These designs can help make streets safer and more inviting for pedestrians, bicyclists, transit users and drivers while also incorporating stormwater management. A smart growth street layout can result in less impervious coverage and reduce sprawl. In addition, concentrating growth and development in certain parts of the watershed can help protect more sensitive areas, such as headwaters. To the extent that street designs can reduce vehicular traffic, running vehicles will sit for shorter periods, releasing less pollutants onto the road surface for stormwater to pick up.

Siting and Design Considerations

Standard road design practice has been to design post-construction stormwater controls after already designing the roadway. This not only limits options, but often focuses attention on end-of-pipe treatment controls rather than in-line measures or preventive measures, which are generally less expensive to build and maintain and more effective at protecting water quality. For new development or redevelopment of any part of a transportation system, stormwater management features should be an integral part of the design, not add-on features. EPA's Green Streets handbook and Green Streets resources provide guidance on how to implement such a holistic approach. The complete Green Streets concept is to make streets functional and safe for all users (i.e., pedestrians, bicyclists, vehicles and users of public transportation).

Another approach, context sensitive solutions and design, uses a collaborative, interdisciplinary decision-making and design approach involving all stakeholders. Designing streets to meet or exceed transportation, environmental and stakeholder needs will create lasting value to the community. (The Federal Highway Administration, which created this approach, offers several case studies at the site linked above.)

Street Design in New Projects

For new projects, smart growth street designs are typically part of an overall site design that seeks to meet transportation, economic and multimodal objectives. Though one set standard does not exist, street designs should meet the following objectives:

- Support mixed uses.
- Develop green parking plans to optimize the number of spaces and layout for multimodal connections.
- Incorporate features such as boulevard islands, rotary islands, parking lot islands, alternative turnarounds, right-sized streets, grassed swales, sidewalk trees and groundcover planters that capture, filter and infiltrate stormwater. Planners often already incorporate these features as aesthetic amenities and for traffic-calming purposes; they can also manage stormwater.
- Integrate sidewalks, crosswalks and traffic-calming approaches to support bicycling, walking and automobile traffic.
- Design streets with shorter block lengths.
- Engineer right-sized streets to facilitate pedestrian crossings and moderate automobile speed while meeting the needs of emergency responders.
- Provide access lanes, on-street parking and turning lanes to complement the land development design, sidewalks and building setbacks.

Additionally, EPA provides guidance for communities in two *Essential Smart Growth Fixes* documents, covering rural and urban planning, zoning and development codes. These guides cover topics such as right-sizing streets, density planning, parking and fostering walkability.

Modification of Existing Streets

Where possible, a street retrofit should take advantage of opportunities to improve the drainage system or add structural and non-structural stormwater controls to reduce the flow of stormwater or filter pollutants. This will require a new approach to street repair and retrofits. Departments of public works and stormwater engineers should consult with land use planners and site designers to find ways to reduce volume and treat stormwater before entering the public conveyance system. Organizations like the *Clean Water America Alliance* and the University of Wisconsin's *Sea Grant Program* provide guidance on how to reinvent design code to include green infrastructure.

Local governments can use several methods to incorporate smart growth features and stormwater benefits into existing streets. Some of these strategies include:

- Connecting disconnected streets, lanes and cul-de-sacs.
- Adding paths to link housing and other uses in areas where a new street is impossible.
- Converting unused streetscapes into green parking or using them to introduce bike lanes.
- Replacing traditional curbs and gutters with site stormwater design features like tree planters and vegetated bulb-outs.

Limitations

At the regional level, many different agencies control street and road designs. State departments of transportation typically control the design and operations of highways and larger arterial streets, while local governments control smaller streets. Interagency coordination and cooperation is necessary for successful implementation of smart street designs.

Limitations to innovative street designs might also occur within stormwater regulations themselves. Blanket regulations that require land set-asides, mandatory infiltration or swales can create barriers to better site design. For example, sizing requirements for swales might consume land needed for connections to a higher-intensity transit district. To address this limitation, regulators can create incentives for alternative street designs by modifying stormwater management requirements in targeted areas. And, even in densely developed, highly impervious areas, communities can achieve very low stormwater generation rates through reasonable, low-maintenance measures. The following documents provide examples of how various communities have overcome implementation barriers:

- *Implementing Living Streets: Ideas and Opportunities for the City and County of Denver*
- *Green Infrastructure Opportunities and Barriers in the Greater Los Angeles Region*
- *Flexible Design of New Jersey's Main Streets*

Finally, the street system alone will not bring about stormwater benefits. Integration among the street layout, the development plan and existing activity centers is crucial for obtaining stormwater benefits.

Maintenance Considerations

Separate stormwater sewers typically discharge water into receiving bodies with little or no treatment. Thus, maintenance considerations for curb and gutter designs include street sweeping, cleaning catch basins, clearing blocked sewer lines, repairing and replacing failed pipes, and conducting other aspects of buried/hard infrastructure maintenance. Maintenance of aboveground bioretention and bio-infiltration features—such as swales and infiltration trenches—largely entails maintaining established vegetation. Depending on locations and designs, removal of accumulated sediment and debris is also typically necessary. Porous or pervious surface materials generally need little maintenance aside from periodic cleaning with a vacuum truck. In-line and end-of-pipe commercial swirl separators or filter devices need regular clean-out.

In northern climates, storing plowed snow from streets is a major consideration. Narrower streets translate into less on-street snow, though multi-use streets (e.g., with parking on each side and frequent intersections) need advanced planning for snow storage. Like stormwater, snowmelt can carry pollutants and water volume, so techniques to filter pollutants and reduce the velocity of melting snow are also important. Some communities plan storage by designating park areas or infiltration strips to handle and eventually release collected snow from streets.

Communities should inspect all system types regularly to ensure they are functioning properly.

Effectiveness

Smart growth street design can be effective at the street, neighborhood and watershed levels. In addition, smart growth street designs benefit both redevelopment and new development by absorbing development demand on a smaller footprint. Furthermore, less land disturbance during initial construction results in less exposure and risk of sedimentation.

The Atlantic Station redevelopment project in midtown Atlanta, Georgia, is a good example of a project that considered streets, the development plan and stormwater control in an integrated fashion. The 138-acre former steel mill site holds a mix of residential, office and retail space, all designed around better mobility and reduced environmental impact. The site designers used high-density development concepts, separated the combined sewer system serving the site and installed pretreatment controls for stormwater within the site. To assess the regional environmental benefits of the site, the designers considered an alternative "greenfield" (or previously undeveloped land) development scenario that reflected the prevailing development and street patterns of the outlying area. Owing to its smaller footprint than the greenfield scenario, Atlantic Station resulted in fewer vehicle miles traveled, fewer greenhouse gas emissions and substantial reductions in the amount of stormwater discharge generated annually.

Cost Considerations

Cost considerations for implementing alternative street designs and patterns depend on factors that differ for individual projects. The most basic costs to consider are for street construction itself. Alternative street designs and patterns may cost more to build, per unit, than traditional design because they incorporate multiple infrastructure components (e.g., streets, utilities, drainage infrastructure, stormwater controls, green spaces, bike lanes) in a smaller footprint. However, they create benefits for the community by coordinating transportation and environmental planning, which is not possible with traditional design. Planners should take these benefits—including reduced stormwater discharge generation, improved mobility and increased property values—into account when considering the cost-effectiveness of alternative street designs and patterns. The following reports provide resources and a range of case studies to outline those costs and benefits:

- EPA's *Managing Wet Weather with Green Infrastructure*
- Naturally Resilient Communities' Green Streets Web page
- EPA's *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

References

National Association of City Transportation Officials (NACTO). (2017). *Urban street stormwater guide*. Island Press.

Disclaimer

This fact sheet is intended to be used for informational purposes only. These examples and references are not intended to be comprehensive and do not preclude the use of other technically sound practices. State or local requirements may apply.