Post Construction Storm Water Management - Non Structural BMP's

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Credit: 6 PDH

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This course was adapted from the Environmental Protection Agency EPA's "Non-Structural BMP" section of the "Post Construction Storm Water Management in New Development and Redevelopment", which is in the public domain.

Post-Construction Storm Water Management in New Development and Redevelopment

Regulatory Text

- You must develop, implement, and enforce a program to address storm water runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale, that discharge into your small MS4. Your program must ensure that controls are in place that would prevent or minimize water quality impacts.
- You must:
  - Develop and implement strategies which include a combination of structural and/or non-structural best management practices (BMPs) appropriate for your community;
  - Use an ordinance or other regulatory mechanism to address post-construction runoff from new development and redevelopment projects to the extent allowable under State, Tribal or local law;
  - Ensure adequate long-term operation and maintenance of BMPs.

Guidance

If water quality impacts are considered from the beginning stages of a project, new development and potentially redevelopment provide more opportunities for water quality protection. EPA recommends that the BMPs chosen: be appropriate for the local community; minimize water quality impacts; and attempt to maintain pre-development runoff conditions. In choosing appropriate BMPs, EPA encourages you to participate in locally-based watershed planning efforts which attempt to involve a diverse group of stakeholders including interested citizens. When developing a program that is consistent with this measure's intent, EPA recommends that you adopt a planning process that identifies the municipality's program goals (e.g., minimize water quality impacts resulting from post-construction runoff from new development and redevelopment), implementation strategies (e.g., adopt a combination of structural and/or non-structural BMPs), operation and maintenance policies and procedures, and enforcement procedures. In developing your program, you should consider assessing existing ordinances, policies, programs and studies that address storm water runoff quality. In addition to assessing these existing documents and programs, you should provide opportunities to the public to participate in the development of the program. Non-structural BMPs are preventative actions that involve management and source controls such as: policies and ordinances that provide requirements and standards to direct growth to identified areas, protect sensitive areas such as wetlands and riparian areas, maintain and/or increase open space (including a dedicated funding source for open space acquisition), provide buffers along sensitive water bodies, minimize impervious surfaces, and minimize disturbance of soils and vegetation; policies or ordinances that encourage infill development in higher density urban areas, and areas with existing infrastructure; education programs for developers and the public about project designs that minimize water quality impacts; and measures such as minimization of percent impervious area after development and minimization of directly connected impervious areas. Structural BMPs include: storage practices such as wet ponds and extended-detention outlet structures; filtration practices such as grassed swales, sand filters and filter strips; and infiltration practices such as infiltration basins and infiltration trenches. EPA recommends that you ensure the appropriate implementation of the structural BMPs by considering some or all of the following: pre-construction review of BMP designs; inspections during construction to verify BMPs are built as designed; post-construction inspection and maintenance of BMPs; and penalty provisions for the noncompliance with design, construction or operation and maintenance. Storm water technologies are constantly being improved, and EPA recommends that your requirements be responsive to these changes, developments or improvements in control technologies.

BMP Fact Sheets

Structural BMPs

Ponds

Dry extended detention ponds

Wet ponds

Infiltration practices

Infiltration basin

Infiltration trench

Porous pavement

Filtration practices

Bioretention

Sand and organic filters

Vegetative practices

Storm water wetland

Grassed swales

Grassed filter strip

Runoff pretreatment practices

Catch basin

In-line storage

Manufactured products for storm water inlets

Nonstructural BMPs

Additional Fact Sheets

Nonstructural BMPs

Experimental practices

Alum Injection

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Alum injection is the addition of alum (an aluminum sulfate salt) solution to storm water, causing fine particles to flocculate (i.e., gather together to form larger particles) and settle out. Other pollutants also can be scavenged. Alum injection can help meet downstream pollutant concentration loads by reducing the concentrations of fine particles and soluble phosphorus. Alum treatment systems generally consist of a flow-weighted dosing system designed to fit inside a storm sewer manhole, remotely located storage tanks to provide the doser with alum, and a downstream pond which allows the alum, pollutants, and sediments to settle out (Kurz, 1998). When alum is injected into storm water it forms harmless precipitates, aluminum phosphate and aluminum hydroxide. These precipitates combine with heavy metals and phosphorus, causing them to be deposited into the sediments in a stable, inactive state (WEF, 1992). The collected mass of alum precipitates, pollutants, and sediments is commonly referred to as floc.

Applicability

The injection of liquid alum into storm sewers has been used to reduce the water quality impacts of storm water runoff to lakes and receiving waterbodies, particularly to reduce high phosphorus levels. Because of high installation and operation costs, alum injection is best applied in situations where a large volume of water is stored in one area, as in the case of combined sewer overflow (CSO) storage areas at wastewater treatment plants. Alum treatment can also be implemented as a pretreatment step to further reduce turbidity and total suspended solids (TSS) (Kurz, 1998).

Siting and Design Considerations

Alum injection systems need to incorporate several design features to properly apply alum and dispose of the floc formed during the process. Dosage rates, which range from 5 to 10 mg of Al per liter, are determined on a flow-weighted basis during storm events (Harper, 1996). Other chemicals, such as lime, may also be added during the process to enhance the pollutant settling. (Often, the pH is raised to between 8 and 11). The design needs to incorporate a doser system, as well as sufficient chemical storage in tanks to minimize the frequency with which they need to be refilled.

Disposal of the floc that settles in the downstream basin is critical, because of the concentration of dissolved chemicals, and also because bacteria and viruses remain viable in the floc layer (Kurz, 1998). In addition to the settling pond, a separate floc collection pump-out facility should be installed to further reduce the chance of resuspension and transport of floc to receiving waterbodies. The pump disposes the floc into the sanitary sewer system or onto nearby upland areas or sludge drying beds. A permit will be required to pump to the sanitary sewer, however. The quantity of sludge produced at a site can be as much as 0.5 percent of the volume of water treated (Gibb et al., 1991).

Limitations

While alum shows some potential as a storm water treatment practice, it has several limitations, including:

- Alum injection is an experimental practice, and little is known about its long-term performance.
- In addition to maintenance, alum injection requires ongoing operation, unlike most other post-construction storm water treatment practices.
- While alum injection can reduce pollutant loads, it cannot control flows or protect downstream channels from erosion.
- Chemicals added during the alum injection process may have negative impacts on downstream waters.
- The precipitates from the alum increase the solids that must be disposed of from the treatment.

Maintenance Considerations

Operation and maintenance for alum treatment is critical. Some typical items include:

- There must be routine inspection and repair of equipment, including the doser and pump-out facility.
- A trained operator should be on-site to adjust the dosage of alum and other chemicals, and possibly to regulate flows through the basin.
- If floc is stored on-site in drying beds, it will need to be disposed of on a regular basis.
- The settling basin will need to be dredged periodically to dispose of accumulated floc.

Effectiveness

Limited performance data of alum injection is available in Table 1. One study (Harper and Herr, 1996) found high removal rates for TSS and fecal coliform bacteria. This study and another (Carr, 1998) showed mixed results on total phosphorus and ortho-phosphorus.

Table 1. Alum injection removal rates

Study	TSS	TP	Ortho-phosphorus	TN	Fecal Coliform Bacteria	Heavy Metals	Zinc	Ammonia
Harper and Herr, 1996	95–99	85–95	90–95	60–70	]99	50–90	-	-
Carr, 1998	-	37	42	52.2	-	-	41	24.5

Cost Considerations

Alum injection is a relatively expensive practice. Construction costs for alum treatment systems range from $135,000 to $400,000; the cost depends on the watershed size and the number of outfall locations treated. Generally, alum treatment is applied to large drainage areas. In one study (Kurz, 1998), an alum treatment system was a successful storm water retrofit for a 460-acre urbanized watershed in downtown Tampa. Operation and maintenance costs, which include routine and chemical inspections, range from $6,500 to $25,000 per year (Harper and Herr, 1996).

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On-lot Treatment

On-Lot Treatment

Postconstruction Storm Water Management in New Development and Redevelopment

Description

A rain barrel is used to collect rooftop runoff using a gutter/downspout system

The term "on-lot treatment" refers to a series of practices that are designed to treat runoff from individual residential lots. The primary purpose of most on-lot practices is to manage rooftop runoff and, to a lesser extent, driveway and sidewalk runoff. Rooftop runoff, and particularly residential rooftop runoff, generally has low pollutant concentrations compared with other urban sources (Schueler, 1994b). The primary advantage of managing runoff from rooftops is to disconnect these impervious surfaces, reducing the effective impervious cover in a watershed. Many of the impacts of urbanization on the habitat and water quality of streams are related to the fundamental change in the hydrologic cycle caused by the increase of impervious cover in the landscape (Schueler, 1994a).

Although there are a wide variety of on-lot treatment options, they can all be classified into one of three categories: 1) practices that infiltrate rooftop runoff; 2) practices that divert runoff or soil moisture to a pervious area; and 3) practices that store runoff for later use. The best option depends on the goals of a community, the feasibility at a specific site, and the preferences of the homeowner.

The practice most often used to infiltrate rooftop runoff is the dry well. In this design, the storm drain is directed to an underground rock-filled trench that is similar in design to an infiltration trench (see Infiltration Trench fact sheet). French drains or Dutch drains can also be used for this purpose. In these designs, the relatively deep dry well is replaced with a long trench with a perforated pipe within the gravel bed to distribute flow throughout the length of the trench.

Runoff can be diverted to a pervious area or to a treatment area using site grading, or channels and berms. Treatment options can include grassed swales, bioretention, or filter strips. The bioretention design can be simplified for an on-lot application by limiting the pre-treatment filter and in some cases eliminating the underdrain (see Bioretention fact sheet). Alternatively, rooftop runoff can simply be diverted to pervious lawn areas, as opposed to flowing directly to the street and thus to the storm drain system.

Practices that store rooftop runoff, such as cisterns and rain barrels, are the simplest in design of all of the on-lot treatment systems. Some of these practices are available commercially and can be applied in a wide variety of site conditions. Cisterns and rain barrels are particularly valuable in the arid southwest, where water is at a premium, rainfall is infrequent, and reuse for irrigation can save homeowners money.

Application

Some sort of on-lot treatment can be applied to almost all sites, with very few exceptions (e.g., very small lots or lots with no landscaping). Traditionally, on-site treatment of residential storm water runoff has been encouraged, but has not generally been an option to meet storm water requirements. There are currently at least two jurisdictions, however, who offer "credits" in exchange for the application of on-site storm water management practices. In Denver, Colorado, sites designed with methods to reduce "directly connected impervious cover," including disconnection of downspout runoff from the storm system, are permitted to use a lower site impervious area when computing the required storage of storm water facilities (DUDFCD, 1992). Similarly, new regulations for Maryland allow designers to subtract each rooftop that is disconnected from the total site impervious cover when calculating required storage in storm water management practices (MDE, 2000).

Siting and Design Considerations

Although most residential lots can incorporate on-lot treatment, the best option for a site depends on site design constraints and the preferences of the homeowner. On-lot infiltration practices have the same restrictions regarding soils as other infiltration practices (see Infiltration Basin and Infiltration Trench fact sheets). If other design practices are used, such as bioretention or grassed swales, they need to meet the siting requirements of those practices (see Bioretention and Grassed Swale fact sheets). Of all of the practices, cisterns and rain barrels have the fewest site constraints. In order for the practice to be effective, however, homeowners need to have a use for the water stored in the practice, and the design must accommodate overflow and winter freezing conditions. These practices are best suited to an individual who has some active interest in gardening or landscaping.

Although these practices are simple compared with many other post construction storm water practices, the design needs to incorporate the same basic elements of any storm water practice. Pretreatment is important for all of these practices to ensure that they do not become clogged with leaf debris. Infiltration practices may be preceded by a settling tank or, at a minimum, a grate or filter in the downspout to trap leaves and other debris. Rain barrels and cisterns also often incorporate some sort of pretreatment, such as a mesh filter at the top of the barrel or cistern.

Both infiltration practices and storage practices typically incorporate some type of bypass so that larger storms flow away from the house. In rain barrels or cisterns, this bypass may be a hose set at a high level of the practice and directed away from the practice and building foundation. These practices also include a hose set at the elevation of the bottom of the practice. The homeowner can use the practice to irrigate landscaping or for other uses by attaching this hose to a standard garden hose, and controlling flow with an adjustable valve. In infiltration practices the bypass may be an aboveground opening of the downspout. As on-lot practices, grassed swales and bioretention can be designed on-line. The design directs all flows to the management practice, but larger flows generally flow over the practice and are not treated.

One important design feature of infiltration practices is that the infiltration area must be located sufficiently far from the house's foundation to prevent undermining of the foundation or seepage into basements. The infiltration area should be separated from the house by at least 10 feet to prevent these problems.

Limitations

There are some limitations to the use of on-lot practices, including the following:

- These practices require some maintenance and require some effort on the part of the homeowner.
- For homeowners who do not enjoy landscaping, it may be difficult for them to find a use for water stored in a rain barrel or cistern, since the water is not potable.
- On small lots, some of these practices may be impractical.
- Even if applied to every home in a watershed, these practices would only treat a relatively small portion of the watershed imperviousness, which is largely composed of roads and parking areas (see Narrower Residential Streets and Green Parking fact sheets).

Maintenance Considerations

Bioretention areas, filter strips, and grassed swales require regular maintenance to ensure that the vegetation remains in good condition (see Bioretention; Grassed Filter Strip; and Grassed Swale fact sheets). Infiltration practices require regular removal of sediment and debris settled in the pretreatment area, and the media might need to be replaced if it becomes clogged (see Infiltration Trench fact sheet). Rain barrels and cisterns require minimal maintenance, but the homeowner needs to ensure that the hose remains elevated during the winter to prevent freezing and cracking. In addition, the tank needs to be cleaned out approximately once per year.

Effectiveness

Although the practices used for on-lot applications can have relatively high pollutant removals (see Infiltration Trench; Bioretention; Grassed Filter Strip; and Grassed Swale fact sheets), it is not clear that these pollutant removal rates can be realized with the relatively low pollutant concentrations entering the practices. Some data suggest that, at least for storm water ponds, there may be an "irreducible concentration" below which no further pollutant removal can be achieved (Schueler, 1996). Another benefit of many on-lot practices is that they generally promote ground water recharge, either directly through infiltration or indirectly by applying or directing runoff to pervious areas.

Cost Considerations

On a cost per unit area treated, on-lot practices are relatively expensive compared with other storm water treatment options. It is difficult to make this comparison, however, because the cost burden of on-lot practices is born directly by homeowners. Typical costs are $100 for a rain barrel and $200 for a dry well or French drain. For many of these practices, homeowners can reduce costs by making their own on-lot practice rather than purchasing a commercial product.

Some treatment practices, such as rain barrels and on-lot bioretention, offer additional benefits to the homeowner that may offset the cost of applying the practice. Similarly, maintenance costs are essentially free, with the exception of replacement of a dry well system, which may require outside help.

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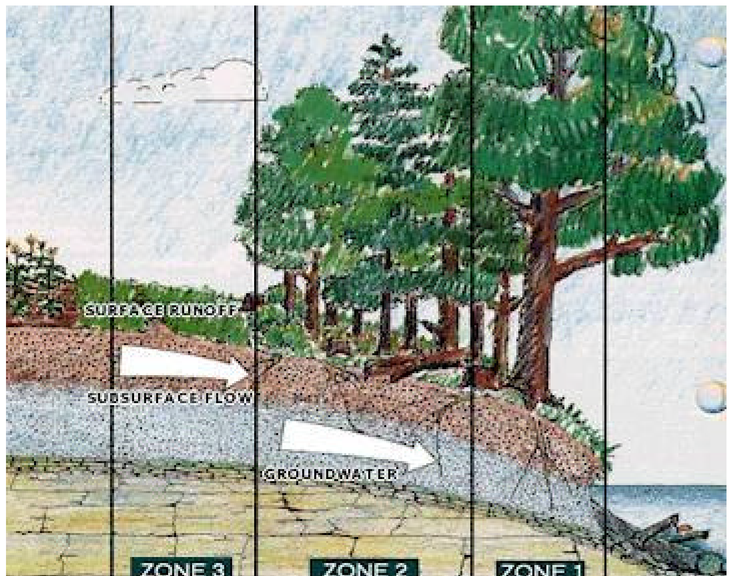
Better site design

Buffer Zones

Postconstruction Storm Water Management in New Development and Redevelopment

Description

An aquatic buffer is an area along a shoreline, wetland, or stream where development is restricted or prohibited. The primary function of aquatic buffers is to physically protect and separate a stream, lake, or wetland from future disturbance or encroachment. If properly designed, a buffer can provide storm water management and act as a right-of-way during floods, sustaining the integrity of stream ecosystems and habitats. Technically, aquatic buffers are one type of conservation area that function as an integral part of the aquatic ecosystem and can also function as part of an urban forest.



Sketch of a typical riparian forest buffer (Source: Chesapeake Bay Program, 2000)

The three types of buffers are water pollution hazard setbacks, vegetated buffers, and engineered buffers. Water pollution hazard setbacks are areas that separate a potential pollution hazard from a waterway. By providing setbacks from these areas in the form of a buffer, the potential for pollution can be reduced. Vegetated buffers are any number of natural areas that exist to divide land uses or provide landscape relief. Engineered buffers are areas specifically designed to treat storm water before it enters into a stream, lake, or wetland.

Applicability

Buffers can be applied to new development by establishing specific preservation areas and sustaining management through easements or community associations. For existing developed areas, an easement may be needed from adjoining landowners. A local ordinance can help set specific criteria for buffers to achieve storm water management goals.

In many regions of the country, the benefits of buffers are amplified if they are managed in a forested condition. In some settings, buffers can remove pollutants traveling in storm water or ground water. Shoreline and stream buffers situated in flat soils have been found to be effective in removing sediment, nutrients, and bacteria from storm water runoff and septic system effluent in a wide variety of rural and agricultural settings along the East Coast and with some limited capability in urban settings. Buffers can also provide wildlife habitat and recreation, and can be reestablished in urban areas as part of an urban forest.

Siting and Design Considerations

There are ten key criteria to consider when establishing a stream buffer:

- Minimum total buffer width
- Three-zone buffer system
- Mature forest as a vegetative target
- Conditions for buffer expansion or contraction
- Physical delineation requirements
- Conditions where buffer can be crossed
- Integrating storm water and storm water management within the buffer
- Buffer limit review
- Buffer education, inspection, and enforcement
- Buffer flexibility.

In general, a minimum base width of at least 100 feet is recommended to provide adequate stream protection. The three-zone buffer system, consisting of inner, middle, and outer zones, is an effective technique for establishing a buffer. The zones are distinguished by function, width, vegetative target, and allowable uses. The inner zone protects physical and ecological integrity and is a minimum of 25 feet plus wetland and critical habitats. The vegetative target consists of mature forest, and allowable uses are very restricted (flood controls, utility right-of-ways, footpaths, etc.).

The middle zone provides distance between upland development and the inner zone and is typically 50 to 100 feet, depending on stream order, slope, and 100-year floodplain. The vegetative target for this zone is managed forest, and usage is restricted to some recreational uses, some storm water BMPs, and bike paths. The outer zone functions to prevent encroachment and filter backyard runoff. The width is at least 25 feet and, while forest is encouraged, turfgrass can be a vegetative target. Uses for the outer zone are unrestricted and can include lawn, garden, compost, yard wastes, and most storm water BMPs.

For optimal storm water treatment, the following buffer designs are recommended. The buffer should be composed of three lateral zones: a storm water depression area that leads to a grass filter strip that in turn leads to a forested buffer. The storm water depression is designed to capture and store storm water during smaller storm events and bypass larger stormflows directly into a channel. The captured runoff within the storm water depression can then be spread across a grass filter designed for sheetflow conditions for the water quality storm. The grass filter then discharges into a wider forest buffer designed to have zero discharge of surface runoff to the stream (i.e., full infiltration of sheetflow).

Stream buffers must be highly engineered in order to satisfy these demanding hydrologic and hydraulic conditions. In particular, simple structures are needed to store, split, and spread surface runoff within the storm water depression area. Although past efforts to engineer urban stream buffers were plagued by hydraulic failures and maintenance problems, recent experience with similar bioretention areas has been much more positive (Claytor and Schueler, 1996). Consequently, it may be useful to consider elements of bioretention design for the first zone of an urban stream buffer (shallow ponding depths, partial underdrains, drop inlet bypass, etc).

Limitations

Only a handful of studies have measured the ability of stream buffers to remove pollutants from storm water. One limitation is that urban runoff concentrates rapidly on paved and hard-packed turf surfaces and often crosses the buffer as channel flow, effectively shortcutting through the buffer. To achieve optimal pollutant removal, the engineered buffer should be carefully designed with a storm water depression area, grass filter, and forested strip.

Maintenance Considerations

An effective buffer management plan should include establishment, management, and distinctions of allowable and unallowable uses in the buffer zones. Buffer boundaries should be well defined and visible before, during, and after construction. Without clear signs or markers defining the buffer, boundaries become invisible to local governments, contractors, and residents. Buffers designed to capture storm water runoff from urban areas will require more maintenance if the first zone is designated as a bioretention or other engineered depression area.

Effectiveness

The pollutant removal effectiveness of buffers depends on the design of the buffer; while water pollution hazard setbacks are designed to prevent possible contamination from neighboring land uses, they are not designed for pollutant removal during a storm. With vegetated buffers, some pollutant removal studies have shown that they range widely in effectiveness (Table 1). Proper design of buffers can help increase the pollutant removal from storm water runoff (Table 2).

Table 1: Pollutant removal rates in buffer zones

Reference	Buffer Vegetation	Buffer Width (meters)	Total % TSS Removal	Total % Phosphorous Removal	Total % Nitrogen Removal
Dillaha et al., 1989	Grass	4.6–9.1	63–78	57–74	50–67
Magette et al., 1987	Grass	4.6–9.2	72–86	41–53	17–51
Schwer and Clausen, 1989	Grass	26	89	78	76
Lowrance et al., 1983	Native hardwood forest	20–40	–	23	–
Doyle et al., 1977	Grass	1.5	–	8	57
Barker and Young, 1984	Grass	79	–	–	99
Lowrance et al., 1984	Forested	–	–	30–42	85
Overman and Schanze, 1985	Grass	–	81	39	67

Table 2: Factors that enhance/reduce buffer pollutant removal performance

Factors that Enhance Performance	Factors that Reduce Performance
Slopes less than 5%	Slopes greater than 5%
Contributing flow lengths <150 feet.	Overland flow paths over 300 feet
Water table close to surface	Ground water far below surface
Check dams/level spreaders	Contact times less than 5 minutes
Permeable but not sandy soils	Compacted soils
Growing season	Nongrowing season
Long length of buffer or swale	Buffers less than 10 feet
Organic matter, humus, or mulch layer	Snowmelt conditions, ice cover
Small runoff events	Runoff events >2 year event.
Entry runoff velocity less than 1.5 feet/sec	Entry runoff velocity more than 5 feet/sec
Swales that are routinely mowed	Sediment buildup at top of swale
Poorly drained soils, deep roots	Trees with shallow root systems
Dense grass cover, 6 inches tall	Tall grass, sparse vegetative cover

Cost Considerations

Several studies have documented the increase of property values in areas adjacent to buffers. At the same time, the real costs of instituting a buffer program for local government involve the extra staff and training time to conduct plan reviews, and to provide technical assistance, field delineation, construction, and ongoing buffer education programs. To implement a stream buffer program, a community will need to adopt an ordinance, develop technical criteria, and invest in additional staff resources and training. The adoption of a buffer program also requires an investment in training for the plan reviewer and the consultant alike. Manuals, workshops, seminars, and direct technical assistance are needed to explain the new requirements to all the players in the land development business. Lastly, buffers need to be maintained, and resources should include systematic inspection of the buffer network before and after construction and work to increase resident awareness about buffers.

One way to relieve some of the significant financial hardships for developers is to provide flexibility through buffer averaging. Buffer averaging 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. Variances can also be granted if the developer or landowner can demonstrate severe economic hardship or unique circumstances that make compliance with the buffer ordinance difficult.

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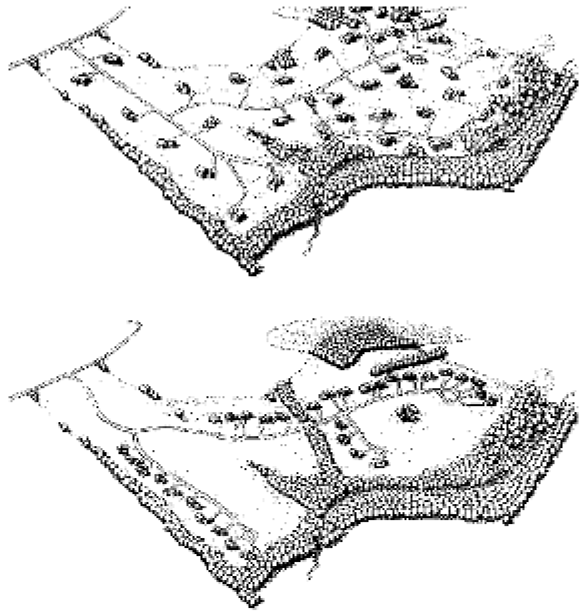
Open Space Design

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Open space design, also known as conservation development or cluster development, is a better site design technique that concentrates dwelling units in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. The minimum lot sizes, setbacks and frontage distances for the residential zone are relaxed in order to create the open space at the site. Open space designs have many benefits in comparison to the conventional subdivisions that they replace: they can reduce impervious cover, storm water pollutants, construction costs, grading, and the loss of natural areas. However, many communities lack zoning ordinances to permit open space development, and even those that have enacted ordinances might need to revise them to achieve greater water quality and environmental benefits.



A site developed using open space design principles (bottom) maintains more undeveloped common space than the conventional development plan (top) (Source: Arendt, 1996)

The benefits of open space design can be amplified when it is combined with other better site design techniques such as narrow streets, open channels, and alternative turnarounds (see Narrower Residential Streets, Eliminating Curbs and Gutters, and Alternative Turnarounds).

Applicability

The codes and ordinances that govern residential development in many communities do not allow developers to build anything other than conventional subdivisions. Consequently, it may be necessary to enact a new ordinance or revise current development regulations to enable developers to pursue this design option. Model ordinances and regulations for open space design can be found on http://www.cwp.org and in *Better Site Design: A Handbook for Changing Development Rules in Your Community* (CWP, 1998).

Open space design is widely applicable to most forms of residential development. The greatest storm water and pollutant reduction benefits typically occur when open space design is applied to residential zones that have larger lots (less than two dwelling units per acre). In these types of large lot zones, a great deal of natural or community open space can be created by shrinking lot sizes. However, open space design may not always be a viable option 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, open space design may need to be adapted, especially in communities where shared septic fields are not currently allowed by public health authorities.

Open space design can be employed in nearly all geographic regions of the country, with the result of different types of open space being conserved (forest, prairie, farmland, chaparral, or desert).

Siting and Design Conditions

Several site planning techniques have been proposed for designing effective open space developments (Arendt, 1996, and DE DNREC, 1997). Often, a necessary first step is adoption of a local ordinance that allows open space design within conventional residential zones. Such ordinances specify more flexible and smaller lot sizes, setbacks, and frontage distances for the residential zone, as well as minimum requirements for open space and natural area conservation. Other key elements of effective open space ordinances include requirements for the consolidation and use of open space, as well as enforceable provisions for managing the open space on a common basis.

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 more lengthy, costly, and potentially controversial than that required 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 maintain open space adequately. Finally, the general public is often 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, open space design policies and ordinances need to be carefully constructed and implemented so as not to lead to "leap-frogging," 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, many of these misconceptions can be directly addressed through a clear open space ordinance and by providing training and incentives to the development and engineering community. The Natural Resources Defense Council presents several examples of successful conservation-oriented developments in *Stormwater Strategies: Community Responses to Runoff Pollution* (1999).

Maintenance Considerations

Once established, common open space and natural conservation areas must be managed by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, the open space is protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements. In most communities, the authority for managing open space falls to a homeowner or community association or a land trust. Annual maintenance tasks for open space managed as natural areas are almost non-existent, and the annual maintenance cost for managing an acre of natural area is less than $75 (CWP, 1998). It may be useful to develop a habitat plan for natural areas that may require periodic management actions.

Effectiveness

Recent redesign research indicates that open space design can provide impressive 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 when two conventional subdivisions were redesigned as open space subdivisions. Other researchers have reported similar levels of pollutant reductions when conventional subdivisions were replaced by open space subdivisions (Maurer, 1996; DE DNREC, 1997; Dreher and Price, 1994; and SCCCL, 1995). In all cases, the reduction in pollutants was due primarily to the sharp drop in runoff caused by the lower impervious cover associated with open space subdivisions. In the redesign studies cited above, impervious cover declined by an average of 34 percent when open space designs were utilized.

Along with reduced imperviousness, open space designs provide a host of other environmental benefits lacking in most conventional designs. These developments reduce potential pressure to encroach on resource and buffer areas because enough open space is usually reserved to accommodate resource protection areas. As less land is cleared during the construction process, the potential for soil erosion is also greatly diminished. Perhaps most importantly, open space design reserves 25 to 50 percent of the development site in green space that would not otherwise be protected, preserving a greater range of landscapes and habitat "islands" that can support considerable diversity in mammals, songbirds, and other wildlife.

Cost Considerations

Open space developments can be significantly less expensive to build than conventional subdivisions. Most of the cost savings are due to savings in road building and storm water management conveyance costs. In fact, the use of open space design techniques at a residential development in Davis, California, provided an estimated infrastructure construction costs savings of $800 per home (Liptan and Brown, 1996). Other examples demonstrate infrastructure costs savings ranging from 11 to 66 percent. Table 1 lists some of the projected construction cost savings generated by the use of open space redesign at several residential sites.

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. Several regional studies estimate that residential properties in open space developments garner premiums that are 5 to 32 percent higher than conventional subdivisions and moreover, sell or lease at an increased rate. In Massachusetts, cluster developments were found to appreciate 12 percent faster than conventional subdivisions over a 20-year period (Lacey and Arendt, 1990). In Atlanta, Georgia, the presence of trees and natural areas measurably increased the residential property tax base (Anderson and Cordell, 1982).

Table 1. Projected construction cost savings for open space designs from redesign analyses

Residential Development	Construction Savings	Notes
Remlik Hall [1]	52%	Includes costs for engineering, road construction, and obtaining water and sewer permits
Duck Crossing [2]	12%	Includes roads, storm water management, and reforestation
Tharpe Knoll [3]	56%	Includes roads and storm water management
Chapel Run [3]	64%	Includes roads, storm water management, and reforestation
Pleasant Hill [3]	43%	Includes roads, storm water management, and reforestation
Rapahannock [2]	20%	Includes roads, storm water management, and reforestation
Buckingham Greene [3]	63%	Includes roads and storm water management
Canton, Ohio [4]	66%	Includes roads and storm water management

Sources: [1] Maurer, 1996; [2] CWP, 1998; [3] DE DNREC, 1997; [4] NAHB, 1986

In addition to being aesthetically pleasing, the reduced impervious cover and increased tree canopy associated with open space development reduce the size and cost of downstream storm water treatment facilities. The resulting cost savings can be considerable, as the cost to treat the quality and quantity of storm water from a single impervious acre can range from $2,000 to a staggering $50,000. The increased open space within a cluster development also provides a greater range of locations for more cost-effective storm water practices. Clearly, open space developments are valuable from an economic as well as an environmental standpoint.

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Urban Forestry

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Trees can be incorporated into urban landscapes for water quality benefits in addition to aesthetic and shade benefits (Source: Tree City USA, no date)

Urban forestry is the study of trees and forests in and around towns and cities. Since trees absorb water, patches of forest and the trees that line streets can help provide some of the storm water management required in an urban setting. Urban forests also help break up a landscape of impervious cover, provide small but essential green spaces, and link walkways and trails.

Successful urban forestry requires a conservation plan for individual trees as well as forest areas larger than 10,000 $feet^2$. A local forest or tree ordinance is one technique for achieving conservation, and when specific measures to protect and manage these areas are included, urban forests and trees can also help reduce storm water management needs in urban areas.

Applicability

From a stream preservation perspective, it is ideal to retain as much contiguous forest as possible. At the same time, this may not be an option in many urban areas. If forested areas are fragmented, it is ideal to retain the closest fragments together.

In rapidly urbanizing areas, where clearing and grading are important, tree preservation areas should be clearly marked. Delineating lines along a critical root zone (CRZ) rather than a straight line is essential to preserving trees and can help reduce homeowner complaints about tree root interference into sewer or septic lines.

Implementation

The concept of the CRZ is essential to a proper management plan. The CRZ is the area around a tree required for the tree's survival. Determined by the tree size and species, as well as soil conditions, for isolated specimen trees, the CRZ can be estimated as 1-1/2 feet of radial distance for every inch of tree diameter. In larger areas of trees, the CRZ of forests can be estimated at 1 foot of radial distance for every inch of tree diameter, or a minimum of 8 feet.

An urban forestry plan should include measures to establish, conserve, and/or reestablish preservation areas. A forest preservation ordinance is one way to set design standards outlining how a forest should be preserved and managed. The ordinance should outline some basic management techniques and should contain some essential elements. The following is a list of some typical elements of a forest conservation plan:

- A map and narrative description of the forest and the surrounding area that includes topography, soils, streams, current forested and unforested areas, tree lines, critical habitats, and 100-year flood plain.
- An assessment that establishes preservation, reforestation, and afforestation areas.
- A forest conservation map that outlines forest retention areas, reforestation, afforestation, 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 tree and forest protection measures.
- A reforestation and afforestation plan.

An ordinance can also be developed that addresses tree preservation at the site level both during construction and after construction is complete. This type of ordinance can be implemented on a smaller scale and can be integrated with a proposed development's erosion and sediment control and storm water pollution prevention plans, which many communities require of new developments.

American Forests, a non-profit organization dedicated to preserving and restoring forests in the United States, adopted an ecosystem restoration and maintenance agenda in 1999 to assist communities in planning and implementing tree and forest actions to restore and maintain healthy ecosystems and communities (American Forests, 2000). The agenda presents the organization's core values and policy goals as the basis for policy statements and as information to help community-based partners to prepare their own policy statements. Key policy goals include

- Increasing public and private sector investment in ecosystem restoration and maintenance activities
- Promoting an ecosystem workforce through training and apprenticeship programs and new job opportunities
- Building support for innovative monitoring systems to ensure collaborative learning and adaptive management
- Encouraging a "civic science" approach to ecosystem research that respects local knowledge, seeks community participation, and provides accessible information for communities.

Limitations

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

Forests may also harbor undesirable wildlife elements including insects and other pests. If forests border houses, this may be a concern for residents.

Maintenance Considerations

Maintenance considerations for urban forests may require fringe landscaping and trash pick-up. By using native vegetation and keeping the area as natural as possible, maintenance efforts can be minimized.

Effectiveness

There are numerous environmental and storm water benefits to urban forestry. These include the absorption of carbon dioxide by trees, reduction of temperature, and provision of habitat for urban wildlife. Urban forests can also act as natural storm water management areas by filtering particulate matter (pollutants, some nutrients, and sediment) and by absorption of water. Urban forestry also reduces noise levels, provides recreational benefits, and increases property values.

Urban forests and trees are known to have numerous environmental benefits, including pollutant removal. Trees can absorb water, pollutant gases, airborne particulates, sediment, nitrogen, phosphorous, and pesticides.

There are numerous economic benefits to urban forests, including proven increases in property values. In addition, by preserving trees and forests, clearing and grading as well as erosion and sediment costs are saved during construction. Maintenance costs are also minimized by keeping areas as natural as possible (Table 1).

Table 1: Annual maintenance costs of different types of green spaces (Adapted from Brown et al., 1998)

Land Use	Approximate Annual Maintenance Costs	Source
Natural Open Space: Only minimum maintenance, trash/debris cleanup	$75/acre/year	NPS, 1995
Lawns: Regular mowing	$270 to $240/acre/year	WHEC, 1992
Passive Recreation	$200/acre/year	NPS, 1995

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Conservation Easements

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Conservation easements are voluntary agreements that allow an individual or group to set aside private property to limit the type or amount of development on their property. The conservation easement can cover all or a portion of a property and can either be permanent or last for a specified time. The easement is typically described in terms of the resource it is designed to protect (e.g., agricultural, forest, historic, or open space easements) and explains and mandates the restrictions on the uses of the particular property. Easements relieve property owners of the burden of managing these areas by shifting responsibility to a private organization (land trust) or government agency better equipped to handle maintenance and monitoring issues.

Conservation easements are thought to make a contribution to protecting water quality, mostly in an indirect way. Land set aside in a permanent conservation easement is land that will have a prescribed set of uses or activities, generally restricting future development.

The location of the land held in a conservation easement may also determine if it will provide water quality benefits. Property along stream corridors and shorelines can act as a vegetated buffer that may filter out pollutants from storm water runoff. The ability of a conservation easement to function as a stream buffer is related to the width of the easement and in what vegetated state the easement is maintained (see Buffer Zones fact sheet).

Applicability

Conservation easements are typically done to preserve agricultural lands and natural areas that are facing development pressure on the suburban-rural fringe. For rapidly urbanizing areas, conservation easements may be a way to preserve open space before land prices make the purchase of land containing important cultural and natural features impractical for governmental agencies with limited budgets. Conservation easements are not often used in ultra-urban areas, due to both 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 the land that they are willing to manage as conservation easements.

Implementation

Conservation easements are designed to assure that the land is preserved in its current state long after the original owners no longer control the property. By agreeing to give up or restrict the development rights for a parcel of land, a landowner can guarantee that their property will remain in a prescribed state for perpetuity while receiving tax benefits. Often, state agencies and private land trusts have specific qualifications for a property before they will enter into an easement agreement with land owners. Table 1 contains examples of criteria that are used by private land trusts to determine if a property is worth managing in a conservation easement.

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

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 have been used in all parts of the country, and many private groups, both nationally and locally, exist to preserve natural lands and manage conservation easements. States also use conservation easements and land purchase programs to protect significant environmental features and tracts of open space. Maryland is one state that has been nationally recognized 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. Several programs are funded through this transfer tax of one-half of one percent ($5 per thousand) of the purchase price of a home or land, or other state funding programs. Conservation programs include:

- *Program Open Space*. This program is responsible for acquiring 150,000 acres of open space for state parks and natural resource areas and more than 25,000 acres of local park land. Every county must create a Land Preservation and Recreation Plan that outlines acquisition and development goals in order to receive a portion of the 50 percent that is granted to local governments (MDNR, no date).
- *Maryland Environmental Trust*. This trust is a state-funded agency that helps citizen groups form and operate local land trusts and offers the land trusts technical assistance, training, grants for land protection projects and administrative expenses, and participation in the Maryland Land Trust Alliance (MDNR, 2001a).
- *Rural Legacy Program*. This program is a Smart Growth Initiative that redirects existing state funds into a focused and dedicated land preservation program specifically designed to limit the adverse impacts 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 purchases fee interests in open space where public access and use is needed (MDNR, 2001b).

Regardless of whether a conservation easement is held by a government agency or a private land trust, certain management responsibilities must be addressed by the easement holder. The following is a list of some of these management duties:

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

Limitations

A number of limitations exist for using conservation easements as a storm water management tool. One is that there is no hard evidence that conservation easements actually do protect water quality. Another is that conservation easements are often not an option in more urbanized areas, where the size, quality, and cost of land can restrict the use of easements. Easements might also not be held in perpetuity, which means that land could still face development pressure in the future. Easements also may not provide for the filtering of pollutants from concentrated flows. More information on the filtering potential of stream buffers can be found in the Buffer Zones fact sheet.

Maintenance Considerations

The responsibility for maintenance of property in a conservation easement depends on the individual agreement with a land trust or agency. While many organizations assume the responsibility for managing and monitoring a property, some land trusts leave maintenance responsibilities to the landowner and act only to monitor that the terms of the easement are met.

Effectiveness

The pollutant removal efficiency of a conservation area will depend on how much is conserved, the techniques used to conserve it, and the specific nature of the easement. Conservation easements are assumed to contribute water quality benefits, but no national studies proving this have been released.

Cost Considerations

Table 2 summarizes the costs of maintaining green spaces with different types of uses.

Table 2: Annual maintenance costs of different types of green space uses (Adapted from CWP, 1998)

Land Use	Approximate Annual Maintenance Costs
Natural open space Only minimum maintenance, trash/debris cleanup	$75/acre/year
Lawns Regular mowing	$270 to $240/acre/year
Passive recreation	$200/acre/year

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Infrastructure Planning

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Developers can design streets and pedestrian paths to maximize convenience and safety while at the same time minimizing impervious surface area (Source: The Rouse Company, no date)

This practice requires changes in the regional growth planning process to contain sprawl development. Sprawl development is the expansion of low-density development into previously undeveloped land. The American Farmland Trust has estimated that the United States is losing about 50 acres an hour to suburban and exurban development (Longman, 1998). This 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. For example, in Prince William County, Virginia, officials have estimated that the costs of providing services to new residential homes exceeds what is brought in from taxes and other fees by $1,600 per home (Shear and Casey, 1996).

Infrastructure planning makes wise decisions to locate public services—water, sewer, roads, schools, and emergency services—in the suburban fringe and direct new growth into previously developed areas, discouraging low-density development. Generally, this is done by drawing a boundary or envelope around a community, beyond which major public infrastructure investments are discouraged or not subsidized. Meanwhile, economic and other incentives are provided within the boundary to encourage growth in existing neighborhoods. By encouraging housing growth in areas that are already provided with public services—water, sewer, roads, schools, and emergency services—communities not only save infrastructure development costs, but reduce the impacts of sprawl development on urban streams and water quality.

Sprawl development negatively impacts water quality in several ways. The most significant impact comes from the increase in impervious cover that is associated with sprawl growth. In addition to rooftop impervious area from new development, extension of road systems and additions of paved surface from driveways create an overall increase in imperviousness. This increase in the impervious cover level of an area directly influences local streams and water quality by increasing the volume of storm water runoff. These elevated runoff levels impact urban streams in several ways, including enlarging stream channels, increasing sediment and pollutant loads, degrading stream habitat, and reducing aquatic diversity (Schueler, 1995). Sprawl has been reported to generate 43 percent more runoff that contains three times greater sediment loads than traditional development (SCCCL, 1995).

Sprawl development influences water quality in other ways. This type of development typically occurs in areas not served by centralized sewer or water services. For example, over 80 percent of the land developed in the state of Maryland in the last decade has been outside the sewer and water "envelope." This requires new housing developments to use septic systems or another form of on-site wastewater disposal to treat household sewage. These on-site treatment systems can represent a significant source of nutrients and bacteria that affect both surface waters and groundwater. More information about septic systems is contained in the fact sheets in both the Illicit Discharge Detection and Elimination Category and the Pollution Prevention Category.

Applicability

Sprawl development occurs in all regions of the country and has recently become the subject of many new programs to counteract its impacts. These programs seldom focus on the water quality implications of sprawl growth, instead concentrating on economic and transportation issues. Even so, methods such as infrastructure planning can reduce the impact of new development. Promoting the infill and redevelopment of existing urban areas in combination with other better site design techniques (see the other fact sheets in this category) will decrease impervious cover levels and lessen the amount of pollution discharged to urban streams.

Siting and Design Conditions

Various techniques have been used to manage urban growth while conserving resources. Although none of these techniques specifically concentrates on infrastructure planning, each of the techniques recognizes that directing growth to areas that have been previously developed or promoting higher density development in areas where services exist prevents sprawl development and helps communities to mitigate the water quality impacts of economic growth. Among the techniques that have been used are:

- *Urban Growth Boundaries*. This planning tool establishes a dividing line that defines where a growth limit is to occur and where agricultural or rural land is to be preserved. Often, an urban services area is included in this boundary that creates a zone where public services will not be extended.

- *Infill/Community Redevelopment*. This practice encourages new development in unused or underutilized land in existing urban areas. Communities may offer tax breaks or other economic incentives to developers to promote the redevelopment of properties that are vacant or damaged.

The State of Maryland has been one of the states that has recently passed legislation to control growth. This "Smart Growth" legislation allows the State to direct its programs and funding to support locally-designated growth areas and protect rural and natural areas. The central component of this legislative package is the "Priority Funding Areas" legislation that limits most state infrastructure funding and economic development program monies to areas that local governments designate for growth and that meet guidelines for intended use, availability of plans for sewer and water systems, and permitted residential density (MOP, no date).

The other bills in the legislative package also support development of existing areas and preservation of undeveloped land. A brownfields program encourages revitalization of existing neighborhoods and industrial areas and establishes a brownfield revitalization incentive program that provides grants and low-interest loans to fund brownfield redevelopment. A new "Live Near Your Work" pilot program supports this effort by providing cash contributions to workers buying homes in certain older neighborhoods. The "Rural Legacy Program" spurs preservation of undeveloped land by providing financial resources for the protection of farm and forest lands from development and for the conservation of these essential rural resources from development.

Limitations

Intense development of existing areas can create a new set of challenges for storm water program managers. Storm water management solutions are often more difficult and complex in ultra-urban areas than in suburban areas. The lack of space for structural storm water controls and the high cost of available land where structural controls could be installed are just two problems that program managers will face in managing storm water in intensely developed areas.

Infrastructure planning is often done on a regional scale and requires a cooperative effort between all the communities within a given region in order to be successful. Phase II program managers will need to develop lines of communication with other state and local agencies and community leaders to ensure that infrastructure plans direct growth to those areas that will have the least impacts on watersheds and water quality.

Effectiveness

The effectiveness of infrastructure planning at protecting water quality is currently unknown. Although studies exist detailing the economic benefits of infrastructure planning, how this translates to storm water pollutant reductions is difficult if not impossible to calculate. However, a relationship does exist between impervious cover levels and urban stream characteristics, and one can assume that tools such as infrastructure planning that help control imperviousness have a positive impact on water quality.

Compact development benefits program managers in numerous ways. One benefit is that compact development can preserve prime agricultural land and sensitive areas while reducing costly construction of new infrastructure (Pelley, 1997). Less new land developed translates into less need for new infrastructure and public services.

Cost Considerations

The economic benefits of reducing costly construction of new infrastructure and providing new services can be quite substantial. The following is a list of examples of the projected savings of limiting sprawl through managed growth (APA, no date):

- New Jersey's plan for managed growth will save the state $700 million in road costs, $562 million in sewer and water costs, $178 million in school costs, and up to $380 million in operating costs per year.
- Fifteen years of continued sprawl would cost Maryland $10 billion more than a more compact pattern of growth.
- A 1989 Florida study demonstrated that planned, concentrated growth would cost the taxpayer 50 percent to 75 percent less than continued sprawl.
- The Cities of Minneapolis-St. Paul will spend $3.1 billion by the year 2020 for new water and sewer services to accommodate sprawl.
- Since 1980 the City of Fresno, California, has added $56 million in yearly revenues but has added $123 million in service costs.

Other studies have found that planned development consumes about 45 percent less land and costs 25 percent less for roads, 15 percent less for utilities, 5 percent less for housing, and 2 percent less for other fiscal impacts (Burchell and Listokin, 1995, as cited in Pelley, 1997).

The control of sprawl development through legislation and "Smart Growth" programs is currently being implemented in a number of states and counties across the U.S. As these programs mature and begin to influence development patterns in urban areas, local governments should begin to see the positive impacts of condensed growth on the aquatic environment and water quality of local streams.

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Narrower Residential Streets

Postconstruction Storm Water Management in New Development and Redevelopment

Description

This better site design practice promotes the use of narrower streets to reduce the amount of impervious cover created by new residential development and, in turn, reduce the storm water runoff and associated pollutant loads. Currently, many communities require wide residential streets that are 32, 36, and even 40 feet wide. These wide streets provide two parking lanes and two moving lanes, but provide much more parking than is actually necessary. In many residential settings, streets can be as narrow as 22 to 26 feet wide without sacrificing emergency access, on-street parking or vehicular and pedestrian safety. Even narrower access streets or shared driveways can be used when only a handful of homes need to be served. However, developers often have little flexibility to design narrower streets, as most communities require wide residential streets as a standard element of their local road and zoning standards. Revisions to current local road standards are often needed to promote more widespread use of narrower residential streets.

Applicability

Narrower streets can be used in residential development settings that generate 500 or fewer average daily trips (ADT), which is generally about 50 single family homes, and may sometimes also be feasible for streets that are projected to have 500 to 1,000 ADT. However, narrower streets are not feasible for arterials, collectors, and other street types that carry greater traffic volumes or are not expected to have a constant traffic volume over time.

In most communities, existing local road standards will need to be modified to permit the use of narrower streets. Several communities have successfully implemented narrower streets, including Portland, OR; Bucks County, PA; Boulder, CO; and throughout New Jersey. In addition, there are numerous examples of communities where developers have successfully narrowed private streets within innovative subdivisions.

Siting and Design Conditions

Residential street design requires a careful balancing of many competing objectives: design, speed, traffic volume, emergency access, parking, and safety. 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. Several excellent references on narrow street design are provided at the end of this fact sheet.

Limitations

A number of real and perceived barriers hinder wider acceptance of narrower streets at the local level. Advocates for narrower streets will need to respond to the concerns of many local agencies and the general public. Some of the more frequent concerns about narrower streets are listed below.

- *Inadequate On-Street Parking*. Recent research and local experience have demonstrated that narrow streets can easily accommodate residential parking demand. A single family home typically requires 2 to 2.5 parking spaces. In most residential zones, this parking demand can be easily satisfied by one parking lane on the street and driveways.

- *Car and Pedestrian Safety.* Recent research indicates that narrow streets have lower accident rates than wide streets. Narrow streets tend to lower the speed of vehicles and act as traffic calming devices.

- *Emergency Access.* When designed properly, narrower streets can easily accommodate fire trucks, ambulances and other emergency vehicles.

- *Large Vehicles.* Field tests have shown that school buses, garbage trucks, moving vans, and other large vehicles can generally safely negotiate narrower streets, even when cars are parked on both sides of the street. In regions with high snowfall, streets may need to be slightly wider to accommodate snowplows and other equipment.

- *Utility Corridors*. It is often 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 the review of public roads is retained by state agencies. In these cases, street narrowing can be accomplished only on private streets (i.e., maintained by residents rather than a local or state agency).

Maintenance Considerations

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

Effectiveness

Since streets constitute the largest share of impervious cover in residential developments (about 40 to 50 percent), a shift to narrower streets can result in a 5-to 20-percent overall reduction in impervious area for a typical residential subdivision (Schueler, 1995). As nearly all the pollutants deposited on street surfaces or trapped along curbs are delivered to the storm drain system during storm events, this reduced imperviousness translates directly into less storm water runoff and pollutant loadings from the development. From the standpoint of storm water quality, residential streets rank as a major source area for many storm water pollutants, including sediment, bacteria, nutrients, hydrocarbons, and metals (Bannerman, 1994).

Cost Considerations

Narrower streets cost less to build than wider streets. Considering that the cost of paving a road averages $15 per square yard, shaving even a mere four feet from existing street widths can yield cost savings of more than $35,000 per mile of residential street. In addition, since narrower streets produce less impervious cover and runoff, additional savings can be realized in the reduced size and cost of downstream storm water management facilities.

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Eliminating Curbs and Gutters

Postconstruction Storm Water Management in New Development and Redevelopment

Description


Developers can eliminate curbs and gutters to disconnect impervious surfaces and promote infiltration of storm water on vegetated areas (such as this grass-lined channel in a residential neighborhood)

This better site design practice involves promoting the use of grass swales as an alternative to curbs and gutters along residential streets. Curbs and gutters are designed to quickly convey runoff from the street to the storm drain and, ultimately, to the local receiving water. Consequently, curbs and gutters provide little or no removal of storm water pollutants. Indeed, curbs often act as a pollutant trap where deposited pollutants are stored until they are washed out in the next storm. Many communities require curb and gutters as a standard element of their road sections, and discourage the use of grass swales. Revisions to current local road and drainage regulations are needed to promote greater use of grass swales along residential streets, in the appropriate setting. The storm water management and pollutant removal benefits of grass swales are documented in detail in the Grassed Swales fact sheet.

Applicability

The use of engineered swales in place of curbs and gutters should be encouraged in low- and medium-density residential zones where soils, slope and housing density permit. However, eliminating curbs and gutters is generally not feasible for streets with high traffic volume or extensive on-street parking demand (i.e., commercial and industrial roads), nor is it a viable option in arid and semi-arid climates where grass cannot grow without irrigation. Moreover, the use of grass swales may not be permitted by current local or state street and drainage standards.

Siting and Design Conditions

A series of site factors must be evaluated to determine whether a grass swale is a viable replacement for curbs and gutters at a particular site.

Contributing drainage area. Most individual swales cannot accept runoff from more than 5 acres of contributing drainage area, and typically serve 1–2 acres each.

Slope. Swales generally require a minimum slope of 1 percent and a maximum slope of 5 percent.

Soils. The effectiveness of swales is greatest when the underlying soils are permeable (hydrologic soil groups A and B). The swale may need more engineering if soils are less permeable.

Water Table. Swales should be avoided if the seasonally high water table is within 2 feet of the proposed bottom of the swale.

Development Density. The use of swales is often difficult when development density becomes more intense than four dwelling units per acre, simply because the number of driveway culverts increases to the point where the swale essentially becomes a broken-pipe system. Typically, grass swales are designed with a capacity to handle the peak flow rate from a 10-year storm, and fall below erosive velocities for a 2-year storm.

Limitations

A number of real and perceived limitations hinder the use of grass swales as an alternative to curb and gutters:

- *Snowplow operation can be more difficult without a defined road edge*. However, on the plus side, roadside swales increase snow storage at the road edge, and smaller snowplows may be adequate.

- *The pavement edge along the swale can experience more cracking and structural failure, increasing maintenance costs*. The potential for pavement failure at the road/grass interface can be alleviated by "hardening" the interface with grass pavers or geo-synthetics placed beneath the grass. Other options include placing a low-rising concrete strip along the pavement edge.

- *The shoulder and open channel will require more maintenance*. In reality, maintenance requirements for grass channels are generally comparable to those of curb and gutter systems. The major requirements involve turf mowing, debris removal, and periodic inspections.

- *Some grass swales can have standing water, which make them difficult to mow, and can cause nuisance problems such as odors, discoloration, and mosquitoes*. In reality, grass channels are not designed to retain water for any appreciable period of time, and the potential for snakes and other vermin can be minimized by frequent mowing.

Other concerns involve fears about utility installation and worries that the grass edge along the pavement will be torn up by traffic and parking. While utilities will need to be installed below the paved road surface instead of the right of way, most other concerns can frequently be alleviated through the careful design and integration of the open channels along the residential street. (Consult the Grassed Swales fact sheet for details on design variations that can reduce these problems.)

Maintenance Considerations

The major maintenance requirement for grass swales involves mowing during the growing season, a task usually performed by homeowners. In addition, sediment deposits may need to be removed from the bottom of the swale every ten years or so, and the swale may need to be tilled and re-seeded periodically. Occasionally, erosion of swale side slopes may need to be stabilized. The overall maintenance burden of grass swales is low in relation to other storm water practices, and is usually within the competence of the individual homeowner. The only major maintenance problem that might arise pertains to "problem" swales that have standing water and are too wet to mow. This particular problem is often alleviated by the installation of an underground storm drain system.

Effectiveness

Under the proper design conditions, grass swales can be effective in removing pollutants from urban storm water (Schueler, 1996). More information on the pollutant removal capability of various grass swale designs can be found in the Grassed Swales fact sheet.

Cost Considerations

Engineered swales are a much less expensive option for storm water conveyance than the curb and gutter systems they replace. Curbs and gutters and the associated underground storm sewers frequently cost as much as $36 per linear foot, which is roughly twice the cost of a grass swale (Schueler, 1995, and CWP, 1998). Consequently, when curbs and gutters can be eliminated, the cost savings can be considerable.

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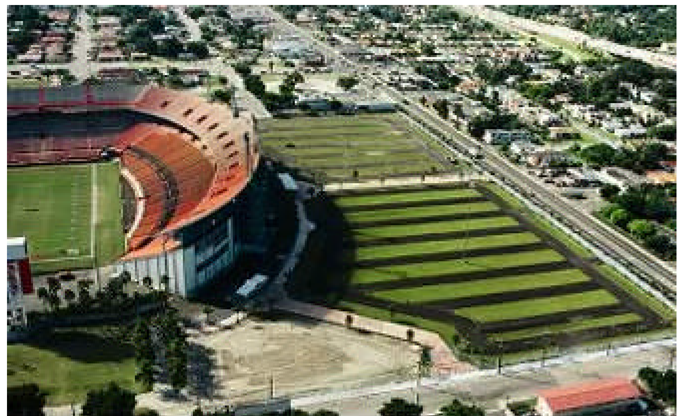
Green Parking

Postconstruction Storm Water Management in New Development and Redevelopment

Description


A green parking lot at the Orange Bowl in Miami, Florida (Source: Invisible Structures, no date)

Green parking refers to several techniques applied together to reduce the contribution of parking lots to the total impervious cover in a lot. From a storm water perspective, application of green parking techniques in the right combination can dramatically reduce impervious cover and, consequently, the amount of storm water runoff. Green parking lot techniques include setting maximums for the number of parking lots created, minimizing the dimensions of parking lot spaces, utilizing alternative pavers in overflow parking areas, using bioretention areas to treat storm water, encouraging shared parking, and providing economic incentives for structured parking.

Applicability

All of the green parking techniques can be applied in new developments and some can be applied in redevelopment projects, depending on the extent and parameters of the project. In urban areas, application of some techniques, like encouraging shared parking and providing economic incentives for structured parking, can be very practical and necessary. Commercial areas can have excessively high parking ratios, and application of green parking techniques in various combinations can dramatically reduce the impervious cover of a site.

Implementation

Many parking lot designs result in far more spaces than actually required. This problem is exacerbated by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand. Table 1 provides examples of conventional parking requirements and compares them to average parking demand.

Table 1: Conventional minimum parking ratios (Source: ITE, 1987; Smith, 1984; Wells, 1994)

Land Use	**Parking Requirement**		**Actual Average Parking Demand**
	Parking Ratio	**Typical Range**	
Single family homes	2 spaces per dwelling unit	1.5–2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0–6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0–10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5–2.0	1.48 per 1000 ft^2 GFA
Medical/ dental office	5.7 spaces per 1000 ft^2 GFA	4.5–10.0	4.11 per 1000 ft^2 GFA
GFA = Gross floor area of a building without storage or utility spaces.			

Another green parking lot technique is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall. Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier to implementing stall minimization technique, stall width requirements in most local parking codes are much larger than the widest SUVs (CWP, 1998).

Utilizing alternative pavers is also an effective green parking technique. They can replace conventional asphalt or concrete in both new developments and redevelopment projects. Alternative pavers can range from medium to relatively high effectiveness in meeting storm water quality goals. The different types of alternative pavers include gravel, cobbles, wood mulch, brick, grass pavers, turf blocks, natural stone, pervious concrete, and porous asphalt. In general, alternate pavers require proper installation and more maintenance than conventional asphalt or concrete. For more specific information on alternate pavers, refer to the Alternative Pavers fact sheet.

Bioretention areas can effectively treat storm water leaving a parking lot. Storm water is directed into a shallow, landscaped area and temporarily detained. The runoff then filters down through the bed of the facility and is infiltrated into the subsurface or collected into an underdrain pipe for discharge into a stream or another storm water facility. Bioretention facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of bioretention areas, refer to the Bioretention fact sheet.

Shared parking in mixed-use areas and structured parking also are green parking techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings. Costs may dictate the usage of structured parking, but building upward or downward can help minimize surface parking.

Limitations

Some limitations to applying green parking techniques include applicability, cost, and maintenance. For example, shared parking is only practical in mixed use areas, and structured parking may be limited by the cost of land versus construction. Alternative pavers are currently only recommended for overflow parking because of the considerable cost of maintenance. Bioretention areas increase construction costs.

The pressure to provide excessive parking spaces can come from fear of complaints as well as requirements of bank loans. These factors can pressure developers to construct more parking than necessary and present possible barriers to providing the greenest parking lot possible.

Effectiveness

Applied together, green parking techniques can effectively reduce the amount of impervious cover, help to protect local streams, result in storm water management cost savings, and visually enhance a site. Proper design of bioretention areas can help meet storm water management and landscaping requirements while keeping maintenance costs at a minimum.

Utilizing green parking lots can dramatically reduce the amount of impervious cover created. The level of the effectiveness depends on how much impervious cover is reduced as well as the combination of techniques utilized to provide the greenest parking lot. While the pollutant removal rates of bioretention areas have not been directly measured, their capability is considered comparable to a dry swale, which removes 91 percent of total suspended solids, 67 percent of total phosphorous, 92 percent of total nitrogen, and 80–90 percent of metals (Claytor and Schueler, 1996).

An excellent example of the multiple benefits of rethinking parking lot design is the Fort Bragg vehicle maintenance facility parking lot in North Carolina (NRDC, 1999). This redesign reduced impervious cover by 40 percent, increased parking by 20 percent, and saved $1.6 million (20 percent) on construction costs over the original, conventional design. Stormwater management features, such as detention basins located within grassed islands and an onsite drainage system that took advantage of existing sandy soils, were incorporated into the parking lot design as well.

Cost Considerations

Setting maximums for parking spaces, minimizing stall dimensions, and encouraging shared parking can result in considerable construction cost savings. At the same time, implementing green parking techniques can also reduce storm water management costs.

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Alternative Turnarounds

Postconstruction Storm Water Management
in New Development and Redevelopment

Description

Rather than having a fully paved cul-de-sac bulb, site designers can incorporate pervious circles with vegetation that reduce the site's overall impervious area

Alternative turnarounds are designs for end-of-street vehicle turnaround that replace cul-de-sacs and reduce the amount of impervious cover created in residential neighborhoods. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a storm water perspective, cul-de-sacs create a huge bulb of impervious cover, increasing the amount of storm water runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac. These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerheads, loop roads, and pervious islands in the cul-de-sac center.

Applicability

Alternative turnarounds can be applied in the design of residential, commercial, and mixed-use developments. Combined with alternative pavers, green parking, curb elimination, and other techniques, the total reduction to site impervious cover can be dramatic, reducing the amount of storm water runoff from the site. With proper designs, much of the remaining storm water can be treated on site.

Implementation

Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. Fire trucks, service vehicles, and school buses are often cited as examples for increased turning radii. However, research shows that some fire trucks are designed for smaller turning radii. In addition, many new larger service vehicles are designed using a tri-axle, and school buses usually do not enter individual cul-de-sacs.

Implementation of alternative turnarounds will also have to address local regulations and marketing issues. Communities may have specific design criteria for cul-de-sacs and other alternative turnarounds. Also, although cul-de-sacs are often featured as highly marketable, actual research on market preference is not widely available.

Limitations

Local regulations often dictate requirements for turnaround radii, and some of the alternatives may not be allowed by local codes. In addition, marketing perceptions may also dictate designs, particularly in residential areas. While changing local codes is no small effort, by initiating a local site planning roundtable, communities can change some of these regulations through a cluster ordinance or through a collective effort to review local codes to promote better site design.

Maintenance Considerations

If islands are constructed as part of a turnaround, these areas will need to be maintained. Kept as a natural area, the costs could be minimal. Bioretention areas will also require maintenance. The other options create less asphalt to repave, and maintenance will remain the same and cost less.

Effectiveness

In comparisons of several different turnaround options, hammerheads were found to create the least amount of impervious cover, as shown in Table 1.

Table 1. Impervious cover created by each turnaround option (Schueler, 1995)

Turnaround Option	Impervious Area (square feet)
40-foot radius	5,024
40-foot radius with island	4,397
30-foot radius	2,826
30-foot radius with island	2,512
Hammerhead	1,250

Costs

Since alternative turnarounds reduce the amount of impervious cover created, construction savings can be an incentive (asphalt costs $0.50–$1.00 per square foot in materials alone). Bioretention is estimated at $6.40 per cubic foot, and while it costs more than providing naturally vegetated areas, it can help reduce overall storm water management costs.

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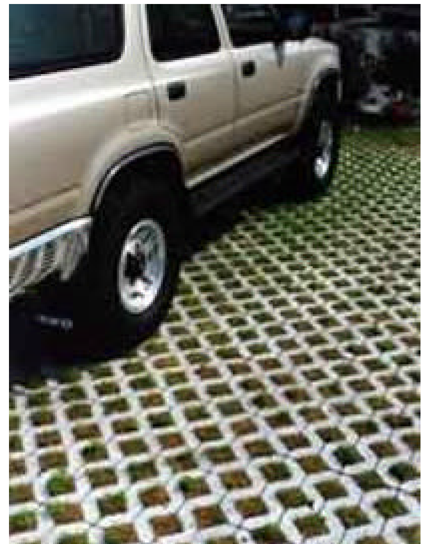
Alternative Pavers

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Alternative pavers are permeable surfaces that can replace asphalt and concrete and can be used for driveways, parking lots, and walkways. From a storm water perspective, this is important because alternative pavers can replace impervious surfaces, creating less storm water runoff. The two broad categories of alternative pavers are paving blocks and other surfaces, including gravel, cobbles, wood, mulch, brick, and natural stone. While porous pavement is an alternative paver, as an engineered storm water management practice it is discussed in detail in the Porous Pavement fact sheet.



One type of alternative paver consists of a concrete lattice structure for support with grass growing in the void spaces (Source: Lo Gioco Landscaping, Inc., no date)

Paving Blocks

Paving blocks are concrete or plastic grids with gaps between them. Paving blocks make the surface more rigid and gravel or grass planted inside the holes allows for infiltration. Depending on the use and soil types, a gravel layer can be added underneath to prevent settling and allow further infiltration.

Other Alternative Surfaces

Gravel, cobbles, wood, and mulch also allow varying degrees of infiltration. Brick and natural stone arranged in a loose configuration allow for some infiltration through the gaps. Gravel and cobbles can be used as driveway material, and wood and mulch can be used to provide walking trails.

Applicability

Alternative pavers can replace conventional asphalt or concrete in parking lots, driveways, and walkways. At the same time, traffic volume and type can limit application. For this reason, alternative pavers for parking are recommended only for overflow areas. In residential areas, alternative surfaces can be used for driveways and walkways, but are not ideal for areas that require handicap accessibility.

Siting and Design Criteria

Accessibility, climate, soil type, traffic volume, and long-term performance should be considered, along with costs and storm water quality controls, when choosing paving materials. Use of alternative pavers in cold climates will require special consideration, as snow shovels are not practical for many of these surfaces. Sand is particularly troublesome if used with paving blocks, as the sand that ends up between the blocks cannot effectively wash away or be removed.

In addition, salt used to de-ice can also infiltrate directly into the soil and cause potential ground water pollution.

Soil types will affect the infiltration rates and should be considered when using alternative pavers. Clayey soils (D soils) will limit the infiltration on a site. If ground water pollution is a concern, use of alternative pavers with porous soils should be carefully considered.

The durability and maintenance cost of alternative pavers also limits use to low-traffic-volume areas. At the same time, alternative pavers can abate storm water management costs. Used in combination with other better-site-design techniques, the cumulative effect on storm water can be dramatic.

Limitations

Alternative pavers are not recommended for high-traffic volumes for durability reasons. Access for wheelchairs is limited with alternative pavers. In addition, snow removal is difficult since plows cannot be used, sand can cause the system to clog, and salt can be a potential pollutant.

Maintenance Considerations

Alternative pavers require periodic maintenance, and costs increase when the permeable surface must be restored.

Effectiveness

The most obvious benefit of utilizing alternative pavers includes reduction or elimination of other storm water management techniques. Applied in combination with other techniques such as bioretention and green parking, pollutant removal and storm water management can be further improved. (see Bioretention and Green Parking fact sheets for more information.)

Alternative pavers all provide better water quality improvement than conventional asphalt or concrete, and the range of improvement depends on the type of paver used. Table 1 provides a list of pavers and the range of water quality improvement achievable by different types of alternative pavers.

Table 1. Water quality improvement of various pavers (Source: BASMAA, 1997)

Material	Water Quality Effectiveness
Conventional Asphalt/ Concrete	Low
Brick (in a loose configuration)	Medium
Natural Stone	Medium
Gravel	High
Wood Mulch	High
Cobbles	Medium

Cost Considerations

The range of installation and maintenance costs of various pavers is provided in Table 2. Depending on the material used, installation costs can be higher or lower for alternative pavers than for conventional asphalt or concrete, but maintenance costs are almost always higher.

Table 2. Installation and maintenance costs for various pavers (Source: BASMAA, 1997)

Material	Installation Cost	Maintenance Cost
Conventional Asphalt/Concrete	Medium	Low
Brick (in a loose configuration)	High	Medium
Natural Stone	High	Medium
Gravel	Low	Medium
Wood Mulch	Low	Medium
Cobbles	Low	Medium

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BMP Inspection and Maintenance

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Regular inspection and maintenance of storm water best management practices is important to ensure that the practices are functioning properly and to remove trash and organic debris

To maintain the effectiveness of postconstruction storm water control best management practices (BMPs), regular inspection of control measures is essential. Generally, inspection and maintenance of BMPs can be categorized into two groups—expected routine maintenance and nonroutine (repair) maintenance. Routine maintenance refers to checks performed on a regular basis to keep the BMP in good working order and aesthetically pleasing. In addition, routine inspection and maintenance is an efficient way to prevent potential nuisance situations (odors, mosquitoes, weeds, etc.), reduce the need for repair maintenance, and reduce the chance of polluting storm water runoff by finding and correcting problems before the next rain.

In addition to maintaining the effectiveness of storm water BMPs and reducing the incidence of pests, proper inspection and maintenance is essential to avoid the health and safety threats inherent in BMP neglect (Skupien, 1995). The failure of structural storm water BMPs can lead to downstream flooding, causing property damage, injury, and even death.

Applicability

Under the proposed Storm Water Phase II rule, owners and operators of small municipal separate storm sewer system (MS4) facilities would be responsible for implementing BMP inspection and maintenance programs and having penalties in place to deter infractions (USEPA, 1999). All storm water BMPs should be inspected for continued effectiveness and structural integrity on a regular basis. Generally, all BMPs should be checked after each storm event in addition to these regularly scheduled inspections. Scheduled inspections will vary among BMPs. Structural BMPs such as storm drain drop inlet protection may require more frequent inspection to ensure proper operation. During each inspection, the inspector should document whether the BMP is performing correctly, any damage to the BMP since the last inspection, and what should be done to repair the BMP if damage has occurred.

Siting and Design Considerations

In the case of vegetative or other infiltration BMPs, inspection of storm water management practices following a storm event should occur after the expected drawdown period for a given

BMP. This allows the inspector to see whether detention and infiltration devices are draining correctly.

Inspection checklists should be developed for use by BMP inspectors. Checklists might include each BMP's minimum performance expectations, design criteria, structural specifications, date of implementation, and expected life span. In addition, the maintenance requirements for each BMP should be listed on the inspection checklist. This will aid the inspector in determining whether a BMP's maintenance schedule is adequate or needs revision. Also, a checklist will help the inspector determine renovation or repair needs.

Limitations

Routine maintenance materials such as shovels, lawn mowers, and fertilizer may be easily obtained on short notice with little effort. Unfortunately, not all materials that may be needed for emergency structural repairs are obtained with such ease. Thought should be given to stockpiling essential materials in case immediate repairs must be made to safeguard against property loss and to protect human health.

Maintenance Considerations

It is important that routine maintenance and nonroutine repair of storm water BMPs be done according to schedule or as soon as a problem is discovered. Because many BMPs are rendered ineffective for runoff control if not installed and maintained properly, it is essential that maintenance schedules are maintained and repairs are made promptly. In fact, some cases of BMP neglect can have detrimental effects on the landscape and increase the potential for erosion. However, "routine" maintenance, such as mowing grasses, should be flexible enough to accommodate the fluctuations in need based on relative weather conditions. For example, more harm than good may be caused by mowing during an extremely dry period or immediately following a storm event.

Effectiveness

The effectiveness of BMP inspection will be a function of the familiarity of the inspector with each particular BMP's location, design specifications, maintenance procedures, and performance expectations. Documentation should be kept regarding the dates of inspection, findings, and maintenance and repairs that result from the findings of an inspector. Such records are helpful in maintaining an efficient inspection and maintenance schedule and providing evidence of ongoing inspection and maintenance.

Because maintenance work for storm water BMPs is usually not technically complicated (mowing, removal of sediment, etc.), workers can be drawn from a large labor pool. As structural BMPs increase in their sophistication, however, more specialized maintenance training might be needed to sustain BMP effectiveness.

Cost Considerations

Mowing of vegetated and grassed areas may be the costliest routine maintenance consideration (WEF, 1998). Management practices using relatively weak materials (such as filter fabric and wooden posts) may mean more frequent replacement and therefore increased costs. The use of more sturdy materials (such as metal posts) where applicable may increase the life of certain BMPs and reduce replacement cost. However, the disposal requirements of all materials should be investigated before BMP implementation to ensure proper handling after the BMP has become ineffective or when it needs to be disposed of after the site has reached final stabilization. Table 1 shows maintenance costs, specific activities, and schedules for several postconstruction runoff BMPs.

Table 1. Maintenance costs, activities, and schedules for urban management practices (Adapted from CWP, 1998)

Type of Practice	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Detention/ Retention Practices	Ponds/ wetlands	3%–6%	$3,000 to $6,000	• Cleaning and removal of debris after major storm events; (>f rainfall) • Harvest vegetation when a 50% reduction in the original open water surface area occurs • Repair of embankment and side slopes • Repair of control structure	Annual or as needed
				• Removal of accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost	5-year cycle
				• Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	20-year cycle
	Dry Ponds	~1%	$1,200	See above	
	Wetlands	~2%	$3,800	See above	
Infiltration Facilities	Infiltration Trench	5%–20%	$2,300 to $9,000	• Cleaning and removal of debris after major storm events; (>2" rainfall) • Mowing and maintenance of upland vegetated areas • Sediment cleanout • Repair or replacing of stone aggregate • Maintenance of inlets and outlets	Annual or as needed
				• Removal of accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been lost	4-year cycle
	Infiltration Basin	1%–10%	$150–$1,500	• Cleaning and removal of debris after major storm events; (>2" rainfall) • Mowing and maintenance of upland vegetated areas • Sediment cleanout	Annual or as needed
				• Removal of accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been lost	3- to 5-year cycle

Table 1. (continued)

Type of Practice	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
Filtration Practices	Sand Filters	11%–13%	$2,200	• Removal of trash and debris from control openings • Repair of leaks from the sedimentation chamber or deterioration of structural components • Removal of the top few inches of sand, and cultivation of the surface, when filter bed is clogged	Annual or as needed
				• Clean out of accumulated sediment from filter bed chamber once depth exceeds approximately ½ inch, or when the filter layer will no longer draw down within 24 hours • Clean out of accumulated sediment from sedimentation chamber once depth exceeds 12 inches	3- to 5-year cycle
	Dry Swales, Grassed Channels, Biofilters	5%–7%	$200 to $2,000	• Mowing and litter/debris removal • Stabilization of eroded side slopes and bottom • Nurtient and pesticide use management • Dethatching swale bottom and removal of thatching • Discing or aeration of swale bottom	Annual or as needed
				• Scraping swale bottom and removal of sediment to restore original cross section and infiltration rate • Seeding or sodding to restore ground cover (use proper erosion and sediment control)	5-year cycle
	Filter Strips	$320/acre (maintained)	$1,000	• Mowing and litter/debris removal • Nutrient and pesticide use management • Aeration of soil on the filter strip • Repair of eroded or sparse grass areas	Annual or as needed
	Bioretention	5%–7%	$3,000 to $4,000	• Repair of erosion areas • Mulching of void areas • Removal and replacement of all dead and diseased vegetation • Watering of plant material	Biannual or as needed
				• Removal of mulch and application of a new layer	Annual

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Ordinances for Postconstruction Runoff

Postconstruction Storm Water Management in New Development and Redevelopment

Description

The management of storm water runoff from sites after the construction phase is vital to controlling the impacts of development on urban water quality. The increase in impervious surfaces such as rooftops, roads, parking lots, and sidewalks due to land development can have a detrimental effect on aquatic systems. Heightened levels of impervious cover have been associated with stream warming and loss of aquatic biodiversity in urban areas. Runoff from impervious areas can also contain a variety of pollutants that are detrimental to water quality, including sediment, nutrients, road salts, heavy metals, pathogenic bacteria, and petroleum hydrocarbons.

An ordinance promotes the public welfare by guiding, regulating, and controlling the design, construction, use, and maintenance of any development or other activity that disturbs or breaks the topsoil or results in the movement of earth on land. The goal of a storm water management ordinance for postconstruction runoff is to limit surface runoff volumes and reduce water runoff pollutant loadings.

Applicability

These ordinances are applicable to all major subdivisions in a municipality. The size of the development to which postconstruction storm water management runoff control applies varies, but many communities opt for a size limit of 5,000 square feet or more. Applicability should be addressed in more detail in the ordinance itself. It is important to note that all plans must be reviewed by local environmental protection officials to ensure that established water quality standards will be maintained during and after development of the site and that postconstruction runoff levels are consistent with any local and regional watershed plans.

Several resources are available to assist in developing an ordinance. EPA's (2000) postconstruction model ordinance web site (*http://www.epa.gov/nps/ordinance/postcons.htm*) provides a model ordinance and examples of programs currently being implemented. In addition, the Stormwater Managers Resource Center (*http://www.stormwatercenter.net*), which was created by the Center for Watershed Protection (no date) and sponsored by the U.S. Environmental Protection Agency, provides information to storm water management program managers in Phase II communities to assist in meeting the requirements of the National Pollutant Discharge Elimination System Phase II regulations.

Siting and Design Considerations

The purpose of the postconstruction ordinance is to establish storm water management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within a jurisdiction. The following paragraphs provide the general language and concepts that can be included in your ordinance.

General Provisions

This section should identify the purpose, objectives, and applicability of the ordinance. The size of the development to which postconstruction runoff controls apply varies, but many communities opt for a size limit of 5,000 square feet or more. This section can also contain a discussion of the development of a storm water design manual. This manual can include a list of acceptable storm water treatment practices and may include the specific design criteria for each storm water practice. In addition, local communities should select the minimum water quality performance standards they will require for storm water treatment practices, and place them in the design manual.

Definitions

It is important to define the terms that will be used throughout the ordinance to assist the reader and prevent misinterpretation.

Permit Procedures and Requirements

This section should identify the permit required; the application requirements, procedures, and fees; and the permit duration. The intent of the permit should be to ensure that no activities that disturb the land are issued permits prior to review and approval. Communities may elect to issue a storm water management permit separate from any other land development permits required, or, as in this ordinance, to tie the issuing of construction permits to the approval of a final storm water management plan.

Waivers to Storm Water Management Requirements

This section should discuss the process for requesting a waiver and to whom this waiver would be applicable. Alternatives such as fees or other provisions for those requesting a waiver should be addressed as well.

General Performance Criteria for Storm Water Management

The performance criteria that must be met should be discussed in this section. The performance criteria can include the following:

- All sites must establish storm water practices to control the peak flow rates of storm water discharge associated with specified design storms and reduce the generation of storm water.

- New development may not discharge untreated storm water directly into a jurisdictional wetland or local waterbody without adequate treatment.

- Annual groundwater recharge rates must be maintained by promoting infiltration through the use of structural and non-structural methods.

- For new development, structural sewage treatment plants must be designed to remove a certain percentage of the average annual postdevelopment total suspended solids (TSS) load.

Basic Storm Water Management Design Criteria

Rather than place specific storm water design criteria into an ordinance, it is often preferable to fully detail these requirements in a storm water design manual. This approach allows specific design information to be changed over time as new information or techniques become available without requiring the formal process needed to change ordinance language. The ordinance can then require those submitting any development application to consult the current storm water design manual for the exact design criteria for the storm water management practices appropriate for their site. Topics in the manual can include minimum control requirements, site design feasibility, conveyance issues, pretreatment requirements, and maintenance agreements.

Requirements for Storm Water Management Plan Approval

The requirements for a storm water management plan to be approved should be addressed in this section. This can be accomplished by including a submittal checklist in the storm water design manual. A checklist is particularly beneficial because changes in submittal requirements can be made as needed without needing to revisit and later revise the original ordinance.

Construction Inspection

This section should include information on the notice of construction commencement, as-built plans, and landscaping and stabilization requirements.

Maintenance and Repair of Storm Water Facilities

Maintenance agreements, failure to maintain practices, maintenance covenants, right-of-entry for inspection, and records of installation and maintenance activities should be addressed in this section.

Enforcement and Penalties

This section should include information regarding violations, notices of violation, stop work orders, and civil and criminal penalties.

Limitations

Site inspections are required for a postconstruction storm water ordinance to be effective. In addition, an adequate staff must be available to review permit applications and proposed plans.

Maintenance Considerations

The operation and maintenance language in a storm water ordinance can ensure that designs facilitate easy maintenance and that regular maintenance activities are completed. In the "Maintenance and Repair of Storm Water Facilities" section of your ordinance, it is important to include language regarding a maintenance agreement, failure to maintain practices, maintenance covenants, right-of-entry for inspection, and records of installation and maintenance activities.

Effectiveness

If a storm water management ordinance for existing development is properly implemented and enforced, the community can effectively achieve the following:

- Minimize increases in storm water runoff from any development to reduce flooding, siltation, and streambank erosion and to maintain the integrity of stream channels.

- Minimize increases in nonpoint source pollution caused by storm water runoff from development that would otherwise degrade local water quality.

- Minimize the total annual volume of surface water runoff that flows from any specific site during and following development so as not to exceed the predevelopment hydrologic regime to the maximum extent practicable.

- Reduce storm water runoff rates and volumes, soil erosion, and nonpoint source pollution, wherever possible, through storm water management controls and ensure that these management controls are properly maintained and pose no threat to public safety.

Cost Considerations

Municipalities that implement and enforce postconstruction ordinances must budget for the drafting and enforcement of the regulation.

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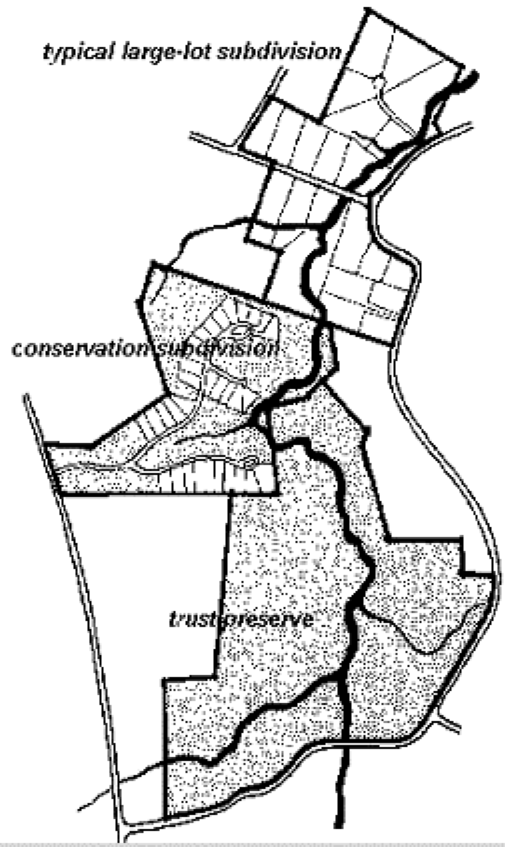
Zoning

Postconstruction Storm Water Management in New Development and Redevelopment

Description

Zoning is a classification scheme for land use planning. Zoning can serve numerous functions and can help mitigate storm water runoff problems by facilitating better site designs. By correctly applying the right zoning technique, development can be targeted into specific areas, limiting development in other areas and providing protection for the most important land conservation areas.

There are numerous types of zoning techniques for better site design, including watershed-based zoning, overlay zoning, floating zones, incentive zoning, performance zoning, urban growth boundaries, large lot zoning, infill/community redevelopment, transfer of development rights, and limiting infrastructure extensions. Table 1 describes each of these zoning techniques and its utility.



Property boundaries differ widely between traditional large-lot zoning, which maximizes the acreage of individual properties, and conservation zoning, which maximizes the amount of shared open space (Source: Arendt, 1996)

Applicability

The type of zoning to apply will depend on management goals. If water or land quality is a primary goal of the zoning technique, then watershed-based zoning can provide a comprehensive approach. At the same time, incentive zoning, performance zoning, and transfer of development rights can be used as protection measures for specific conservation areas.

Implementation

Watershed-Based Zoning: Watershed-based zoning can employ a mixture of land use and zoning options to achieve desired results. A watershed-based zoning approach should include the following nine steps:

- Conduct a comprehensive stream inventory.
- Measure current levels of impervious cover.
- Verify impervious cover/stream quality relationships.
- Project future levels of impervious cover.

Table 1. Zoning techniques (Source: Caraco et al., 1998)

Land Use Planning Technique	Description	Utility as a Watershed Protection Technique
Watershed-Based Zoning	Watershed and subwatershed boundaries are the foundation for land use planning.	Protects receiving water quality on the subwatershed scale by relocating development out of particular subwatersheds.
Overlay Zoning	Superimposes additional regulations or specific development criteria within specific mapped districts.	Requires development restrictions or allows alternative site design techniques in specific areas.
Impervious Overlay Zoning	Specific overlay zoning that limits total impervious cover within mapped districts.	Protects receiving water quality at both the subwatershed and site level.
Floating Zones	Applies a special zoning district without identifying the exact location until land owner specifically requests the zone.	Obtains proffers or other watershed protective measures that accompany specific land uses within the district.
Incentive Zoning	Applies bonuses or incentives to encourage creation of amenities or environmental protection.	Encourages development within a particular subwatershed or to obtain open space in exchange for a density bonus at the site level.
Performance Zoning	Specifies a performance requirement that accompanies a zoning district.	Requires additional levels of performance within a subwatershed or at the site level.
Urban Growth Boundaries	Establishes a dividing line that defines where a growth limit is to occur and where agricultural or rural land is to be preserved.	Used in conjunction with natural watershed or subwatershed boundaries to protect specific water bodies.
Large Lot Zoning	Zones land at very low densities.	Decreases impervious cover at the site or subwatershed level, but may have an adverse impact on regional or watershed imperviousness.
Infill/Community Redevelopment	Encourages new development and redevelopment within existing developed areas.	Used in conjunction with watershed-based zoning or other zoning tools to restrict development in sensitive areas and foster development in areas with existing infrastructure.
Transfer of Development Rights (TDRs)	Transfers potential development from a designated "sending area" to a designated "receiving area."	Used in conjunction with watershed-based zoning to restrict development in sensitive areas and encourage development in areas capable of accommodating increased densities.
Limiting Infrastructure Extensions	A conscious decision is made to limit or deny extending infrastructure (such as public sewer, water, or roads) to designated areas to avoid increased development in these areas.	A temporary method to control growth in a targeted watershed or subwatershed. Usually delays development until the economic or political climate changes.

- Classify subwatersheds-based on stream management "templates" and current impervious cover.
- Modify master plans/zoning to correspond to subwatershed impervious cover targets and other management strategies identified in Subwatershed Management Templates.
- Incorporate management priorities from larger watershed management units such as river basins or larger watersheds (see discussion later in this fact sheet).
- Adopt specific watershed protection strategies for each subwatershed.
- Conduct long-term monitoring over a prescribed cycle to assess watershed status.

<u>Overlay Zoning:</u> The advantage of overlay zones is that specific criteria can be applied to isolated areas without the threat of being considered spot zoning. Overlay districts are not necessarily restricted by the limits of the underlying base zoning. An overlay zone may take up only a part of an underlying zone or may even encompass several underlying zones. Often the utilization of an overlay zone is optional.

<u>Impervious Overlay Zoning:</u> This type of overlay zoning limits future impervious areas. The environmental impacts of future impervious cover are estimated and a limit is set on the maximum imperviousness within a given planning area. Site development proposals are then reviewed in the context of an imperviousness cap. Subdivision layout options must then conform to the total impervious limit of the planning area.

<u>Floating Zones:</u> Normally, a parcel of land will not qualify for the application of the floating zone district unless it is large enough to allow the buffering of its development from the surrounding area. It is important to note that the existence of a floating zone district does not automatically grant rezoning to each landowner whose property complies with the prescribed conditions. Each property owner must have his or her application for rezoning reviewed and approved by the local governing body to determine if it is consistent with a comprehensive development plan.

<u>Incentive Zoning</u>: This planning technique relies on bonuses or incentives for developers to encourage the creation of certain amenities or land use designs. A developer is granted the right to build more intensively on a property or given some other bonus in exchange for an amenity or a design that the community considers beneficial. Developers stand to gain an increase in profits from the more intensive use of the property, while a community might use incentive zoning to promote more compact development, encourage open space designs, or generate other desired amenities such as trails, parks, or totlots.

<u>Performance Zoning:</u> Performance zoning is a flexible approach that has been employed in a variety of fashions in several different communities across the country. Some performance factors include traffic or noise generation limits, lighting requirements, storm water runoff quality and quantity criteria, protection of wildlife and vegetation, and even architectural style criteria.

<u>Urban Growth Boundaries</u>: Urban growth boundaries are sometimes called development service districts and include areas where public services are already provided (e.g., sewer, water, roads, police, fire, and schools). The delineation of the boundary is very important. Several important issues to consider in establishing an urban growth boundary include the following:

- Public facilities and services must be nearby and/or can be provided at reasonable cost and in a specific time frame.
- A sufficient amount of land to meet projected growth over the planning period must be provided.
- A mix of land uses must be provided.
- The potential impact of growth within the boundary on existing natural resources should be analyzed.
- The criteria for defining the boundary needs to be fair and should consider natural features (versus man-made features) wherever possible. The use of watershed boundaries as the urban growth boundary is one such natural feature.

<u>Large Lot Zoning:</u> Although large lot zoning does tend to reduce the impervious cover and therefore the amount of storm water runoff at a particular location, it also spreads development over vast areas. The road networks required to connect these large lots can actually increase the total amount of imperviousness created for each dwelling unit (Schueler, 1995). In addition, large lot zoning contributes to regional sprawl. Sprawl-like development increases the expense of providing community services such as fire protection, water and sewer systems, and school transportation.

<u>Infill/Community Redevelopment</u>: Infill and redevelopment can be employed in either large or small projects. Some of the existing impediments to more widespread implementation of these types of projects include the existing condition of a potential redevelopment site in terms of environmental constraints, the restrictive nature of many land use regulations, and pressing social and economic issues. Local governments may need to modify local zoning or building codes to make infill and redevelopment a more inviting attraction to developers. In addition, citizen involvement has been demonstrated to be a vital catalyst for leveraging funding or revising codes. Furthermore, lending institutions must be progressive in their view of funding infill and redevelopment projects. One possibility is to partner with local governments or community organizations.

<u>Transfer of Development Rights (TDRs)</u>: The principle of TDRs is based on the premise that ownership of land entails certain property rights. While some of these rights may be restricted by zoning, building codes, and environmental constraints, landowners are "entitled" to use their land for the "highest and best use." TDRs are based on a market-driven incentive program where it is possible to sell development potential (zoned density) without buying or selling land. Landowners in preservation areas are compensated for lost development potential , while conventional down-zoning deprives landowners of this potential value.

Limitations

Some zoning techniques may be limited by economic and political acceptance and should be evaluated on these criteria as well as storm water management goals.

Maintenance Considerations

Some maintenance issues to consider for the long term are the following:

- What are the most economically and politically acceptable zoning technique(s) that can be used to shift or reduce impervious cover among the subwatersheds?

- How accurate are the estimates of the amount and location of future impervious cover in the watershed? Are better projections needed?

- Will future increases in impervious cover create unacceptable changes to a watershed and/or subwatershed?

- Which subwatersheds appear capable of absorbing future growth in impervious cover?

Effectiveness

There are numerous case studies of performance-based zoning used in different communities. Some of these examples are summarized in Table 2.

Table 2. Case examples of performance-based zoning (Source: Porter et al., 1991)

Location	Performance Zoning Provisions	Notes
Fort Collins, Colorado	Planned Unit Development (PUD) options are applied to all parcels in city. Developers may choose conventional zoning or the optional PUD. PUD proposals must meet a point value for an absolute criterion and a relative criterion.	Applications are discussed at a conceptual stage where suggestions are made to improve scores. The local planning board has quite a bit of latitude to use discretion to require special conditions.
Largo, Florida	The Land Use Plan defines uses and densities. Four overlay "policy"districts (environmental conservation, management, redevelopment, and downtown) define general standards and prohibited uses. Each land use within a policy district falls into a one of three classes (allowable, allowable with special mitigating measures, or prohibited).	A variety of uses are permitted within the 4 policy districts when applying the special mitigating measures. The city also has a five-tiered system of review and approval that facilitates fast reviews for many common applications and a more involved process for projects that require mitigation.
Hardin County, Kentucky	The land development ordinance allows agricultural and single family uses by right. All other uses must be evaluated by a three-step process. At the first step, the agricultural and development potential is evaluated using a point system. If the site scores a minimum threshold value, than it moves onto the second step, a compatibility assessment. The final step involves typical review of subdivision standards and requirements.	The program places a special emphasis on preserving agricultural uses. The process involves a unique feature that calls on citizen consensus for each step. This decision making process might be considered highly discretionary, but with a widespread interest by most Hardin County citizens in seeing development proceed, there have been few complaints.
Bath Charter Township, Michigan	The township's ordinance provides five zoning districts: two traditional districts for rural, low-density residential; and three applied to existing settlements/expected development corridor. These three districts allow a range of uses either "by right" or with special permits for certain uses.	The ordinance is a compromise between complex, inflexible zoning and no zoning at all. The process allows for extensive review and individual decisions for individual controversial cases.

Table 2. (continued)

Location	Performance Zoning Provisions	Notes
Buckingham Township, Pennsylvania	The ordinance contains typical zoning districts but provides cluster and performance standard development provisions. It aims to preserve natural resources by clustering housing on the least environmentally sensitive areas.	Development of cluster and performance standards are "by rights," and as such, do not require public hearings. The sensitivity of natural areas makes the zoning more flexible in unrestricted areas but less flexible than most conventional zoning in placing restrictions for protecting natural areas.
Duxbury, Massachusetts	Two new categories of development (planned developments and cluster) were created in addition to existing traditional zoning. Both types are allowed in different portions of the town under a special permit process.	Termed "impact zoning," the ordinance aimed to create incentives for developers to build more diverse and environmentally sensitive housing. Developers are choosing standard subdivisions over the optional techniques to avoid lengthy and complex reviews.

Cost Considerations

Subwatershed planning for better site design zoning involves many costs. Mapping, photography, delineations, and involving the public are some of the items typically in such a budget (Table 3).

Table 3. Unit prices for subwatershed planning (Adapted from CWP, 1998)

Budget Item	Estimated Unit Cost	Assumptions
Aerial Photography	$500 per photo	Includes aerial flyover and developing of one color photograph.
Base Mapping	$500	For Subwatershed Management Map using USGS 7.5 minute Quad. Sheet. Includes, subwatershed delineation, overlaying land use, monitoring stations, and transportation routes.
Base Mapping	$5,000	For Aquatic Corridor Management Map, using aerial topography at 2' contour interval. Includes, aerial topography at 1" = 200', locating existing utilities, floodplain, wetlands, and riparian cover from existing maps (no field walk and no topo. survey control).
Floodplain Delineation	$5,000	Detailed analysis beyond FEMA, cross-sections plotted at 1000 ft on-center, topo spot-checked, road crossings evaluated, includes report, assumes flow data are available.
Geographic Information System (GIS)—start-up	$15,000	High end work station and software (e.g., ARC/INFO), includes approx. 2 weeks of training for operator. Does not include data layers
GIS—Obtain or Digitize Data Layers	–	Data layers include impervious cover, topography (5' C.I.), zoning, utilities, vegetative cover (broad categories)
Impervious Cover Measurement—Actual	$3,000	Uses digital orthophotography, impervious layer clipped at subwatershed boundary, algorithm to calculate impervious area

Table 3. (continued)

Budget Item	Estimated Unit Cost	Assumptions
Impervious Cover Estimation—Land Use	$600	Uses land use designations or zoning and measured areas compared against tables, requires review of aerial photo (not included) to estimate build-out.
Impervious Cover Projection—Based on Future Land Use	$800	Uses zoning or master plan and measured areas compared against tables, requires assessment of future build-out
Public Attitude Survey	$15,000 per survey	1000 homes contacted by telephone, includes survey questionnaire preparation and data analysis.
Stakeholder Involvement Program	$15,000	Plan and hold four public and four community meetings, direct mail to 20,000 people, staff time and direct expenses included.

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