CSN TECHNICAL BULLETIN No. 5

Stormwater Design for High Intensity Redevelopment Projects in the Chesapeake Bay Watershed

Version 2.0

January 5, 2011

Important Note: Managing the quality of stormwater runoff from redevelopment projects in highly urban watersheds can be complex and controversial. This Technical Bulletin seeks to reconcile the desire for improved urban runoff quality with the need for achieving smart growth in the Bay watershed. Comments on this version can be e-mailed to Tom Schueler of CSN at watershedguy@hotmail.com. Thanks to several reviewers who provided editorial and technical comments on Version 1.0

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Introduction

The potential for water quality improvements due to redevelopment stormwater requirements is considerable. To achieve these improvements, however, requires creative policy and engineering approaches at the local and state level. The purpose of this Technical Bulletin is to provide stormwater managers with the best available engineering and policy approaches that work in the challenging setting of redevelopment.

It should be noted that this technical bulletin **primarily** applies to high intensity redevelopment projects, where pre-development impervious cover (IC) exceeds 65%. Stormwater practices are much easier and cost-effectively to install at redevelopment projects with less than 65% IC. These less intensive sites have more extensive surface area where LID and traditional stormwater treatment practices can be located.

Section 1
Defining Redevelopment in the Context of Stormwater

Much of the confusion and some of the controversy associated with redevelopment are generated by vague or ambiguous definitions of redevelopment and their associated stormwater treatment requirements. Consequently, this section outlines a clear, measurable and operational definition of what constitutes redevelopment and what are the associated stormwater treatment requirements.

Redevelopment is generally defined as the process whereby an existing development is adaptively reused, rehabilitated, restored, renovated, and/or expanded, which results in disturbance or clearing of a defined footprint at the site. In the context of this guidance, redevelopment normally occurs within urban watersheds that are served by existing water, sewer and public infrastructure. When redevelopment is done properly, it is a key element of smart growth and sustainable development (USEPA, 2005, 2006).

A much more specific and operational definition of redevelopment, however, is needed, to effectively manage stormwater. A good definition has four core elements that establish a:

- *Minimum disturbance footprint* above which redevelopment stormwater requirements are triggered (ranging from 250 to 40,000 square feet)

- *Minimum amount of pre-existing impervious cover* at the site to qualify as a redevelopment project (e.g., 40% IC).

- *Different water quality treatment standards for new and existing impervious cover* created by the redevelopment project

- *Lower stormwater treatment volumes than are required for new green-field projects*, and/or a treatment discounts for redevelopment projects which meet certain smart growth criteria

For example, the State of Maryland defines redevelopment as "any construction, alteration or improvement performed on sites where existing land use is commercial, industrial, institutional or multifamily residential and the existing site impervious area exceeds 40 percent" (MDE, 2008). This definition applies to projects that have a disturbed area in excess of 5,000 square feet.

The regulations also specify that stormwater treatment requirements only apply to the *disturbed area* of a redevelopment project, and not the entire property (e.g., if a strip shopping center is renovated but the parking lot is not disturbed, than stormwater requirements only apply to the building). This unambiguous definition makes it easy to determine and verify what portion of a proposed redevelopment site will be subject to stormwater requirements.

Redevelopment stormwater requirements should also clearly distinguish between *existing impervious cover* and *newly created impervious cover* at a redevelopment site. Stormwater treatment requirements are reduced for existing impervious cover (compared to green-fields), and treatment credits are given if the project reduces the amount of existing impervious cover. The situation reverses if the redevelopment project creates more impervious cover than the predevelopment condition. In this case, the new increment of impervious cover is subject to the higher stormwater treatment standards for new development (e.g., full water quality and channel protection). This creates a strong incentive to prevent creation of new or additional impervious cover at a redevelopment site. For more details on this tiered approach, please consult Appendix D.

Most Bay states only require redevelopment projects to treat a fraction of the water quality volume needed at a new development site, and also generally exempt them from having to meet channel protection volumes. As can be seen in Table 1, redevelopment projects only treat about 10 to 50% of the runoff volume that "green-field" developments are required to treat.

There are two notable exceptions. The District of Columbia is expected to require the same water quality treatment volume for both new and redevelopment (but does not require channel protection). Also, new stormwater requirements for federal facilities do not distinguish between new and redevelopment conditions. West Virginia is unique in the Bay watershed in that it provides water quality treatment discounts for redevelopment projects that meet certain smart growth criteria. Treatment discounts are available for redevelopment projects that exceed minimum thresholds for land use intensity and/or vertical density, involve brown-field remediation, or possess mixed use or transit oriented development elements (WVDEP, 2009).

This bulletin presumes that there are no existing stormwater treatment practices present at the predevelopment site. If they are, these practices can be retrofit to improve their performance.

Table 1.
Comparison of redevelopment and green-field stormwater requirements in the Chesapeake Bay States

Bay States	Redevelopment Requirements		Redevelopment Requirements as a % of "Green-field" Requirements [4]
	Water Quality Requirement [3]	Channel Protection?	
District of Columbia [1]	1.2 inch	No	50%
Delaware [1]	0.5 inch	No	21%
Federal Facilities [2]	1.7 inch	No	71%
Maryland [2]	0.5 inch	No	21%
New York [2]	0.25 inch	No	11%
Pennsylvania [2]	0.2 inch	No	8%
Virginia [1]	0.2 inch	No	8%
West Virginia [2]	0.5 to 1.0 inch [5]	No	21 to 42%

[1] proposed redevelopment criteria, may be subject to change
[2] adopted redevelopment criteria, actually 1"' treatment over 50% of the site,
[3] treating the runoff from a storm of this depth
[4] for purposes of general comparison, "green-field" treatment is defined here as providing water quality and channel protection equivalent to the runoff generated from a 2.4 inch storm. See Section 5 for a complete description of individual state redevelopment requirements
[5] the depth varies depending on the number of redevelopment credits the project qualifies for, see text for an explanation

Section 2
Why Managing Stormwater in Urban Areas is Challenging

It is important to clearly understand the challenges and constraints that the urban environment imposes on stormwater management at high intensity redevelopment projects. The challenges are physical, technological, economic and institutional in nature.

2.1 Physical Challenges and Constraints

Site Constraints. Most infill and redevelopment projects are quite small in area and are already highly impervious. As consequence, the use of traditional stormwater practices is often constrained by a lack of space. In addition, designers are often constrained by the inverts of existing storm drain pipes and conflicts with existing underground utilities.

*Land Costs***.** The cost of land is frequently at a premium at many urban areas, which makes it problematic to use surface land for locating stormwater practices. As a result, many cities have traditionally waived stormwater requirements for redevelopment, or required costly underground vaults and filter systems until now.

Compacted and Polluted Soils. The soils of many urban watersheds have been graded, eroded and reworked by past development, often compacting them to such a degree that runoff cannot be effectively infiltrated. In the most severe cases, legacy problems from past industrial and municipal activity create "brown fields" with such polluted soils that they must be capped to prevent infiltrating runoff from leaching pollutants and/or contaminating soils (US EPA, 2008).

Even sites that are not designated as brown-fields have urban soils that are enriched with trace metals, such as lead, zinc, cadmium and copper, as a result of historical air deposition. For example, research in Baltimore revealed high soil metal levels, particularly in older neighborhoods and adjacent to highways (Yesilonis et al, 2008). Consequently, although infiltration practices are a key tool in runoff reduction, they need to be used with extreme caution in many urban watersheds.

Stormwater Hotspots. In many cases, current or future operations at a proposed redevelopment site can be classified as stormwater hotspots, which produce runoff with higher concentrations of trace metals, toxics and hydrocarbons and/or present a greater risk of spills, leaks or illicit discharges (CWP, 2004). Therefore, it is important to determine whether a redevelopment site has the potential to become a stormwater hotspot in the future, and implement pollution prevention and filtering measures at the site.

Natural Stream Network Is Altered or Buried. Past urbanization often has severely altered, reduced or eliminated the natural stream network (NRC, 2008). This has several implications for redevelopment projects. The urban stream system that remains is often highly degraded and enlarged, and most projects discharge to existing storm drain pipes or conveyance channels rather than streams.

2.2 Technical Challenges Associated with Redevelopment Practices

Another key challenge is that many of the stormwater technologies developed in the suburbs are not applicable to high intensity redevelopment projects, and designers need to shift to alternative practices they do not fully understand.

Limited List of Effective Redevelopment Practices. Many traditional stormwater practices are extremely space intensive and are of marginal value for many intensive redevelopment projects. Practices such as rooftop disconnections, wet swales, filter strips, grass channels, constructed wetlands, extended detention ponds and wet ponds are seldom feasible at redevelopment projects. Even the new micro-LID practices described in Chapter 5 (MDE, 2008) consume too much land to be effective at high intensity redevelopment projects. In general, the list feasible practices at redevelopment sites drops sharply in response to increasing impervious cover, as shown in Table 2.

Table 2
Effect of Redevelopment Intensity on Stormwater Practice Selection

Post Development Impervious Cover at Site			
Less than 40%	**40 to 65%**	**66 to 85%**	**85 to 100%**
Alternate Surfaces	Alternate Surfaces	Alternate Surfaces	Alternate Surfaces
Landscaping ESD	Landscaping ESD	Landscaping ESD	Landscaping ESD
IC Reduction	IC Reduction	IC Reduction	
Micro ESD	Micro ESD		
Disconnections			
Ponds			Underground Sand Filters

Note: this is a generalized breakdown, and some redevelopment sites may depart from this

Alternative surfaces = Green roofs and permeable pavers
Landscaping ESD = foundation planters, expanded tree pits, urban bioretention and green streets
IC Reduction = conversion of pre-existing impervious cover to hydrologically functional pervious cover
Micro-ESD practices = space intensive practices such as micro-infiltration, bioretention, grass channels, wet swales, bioswales etc.)
Disconnections: Credits for disconnecting impervious surfaces and treating them in a grass filter path
Ponds and Wetlands: conventional detention and retention designs

Limited Design Guidance for Redevelopment. Each of the state stormwater manuals across the Bay watershed are inherently biased toward suburban and low density development situations. Most devote only a few paragraphs or pages on how to manage stormwater in redevelopment situations. More importantly, they often lack detailed specifications and design examples for the specialized practices that do work in highly urban watersheds. This technical bulletin is intended to bridge this gap.

Lack of Experience with Urban LID Practices. Surveys indicate that many designers and plan reviewers in the Bay have little or no experience in designing the practices that are most appropriate for redevelopment projects. For example, CBSTP (2010) surveyed more than 200 stormwater professionals in the Chesapeake Bay watershed and found that:

- 70% had never designed a green roof
- 60% had never designed a rainwater harvesting system
- 65% had no experience with soil amendments or impervious cover conversion

- 45% had never designed permeable pavers or dry swales

Designers probably have even less experience with various forms of urban bioretention and green streets, although the survey did not address them. The limited use of effective redevelopment practices can be explained by several factors --they often require specialized design consultants, unique construction materials or experienced installation contractors. Many of the preferred practices also require greater and earlier coordination with architects and site designers. Lastly, many designers express reluctance to use preferred practices due perceived concerns about cost, maintenance, longevity and ability to get projects approved.

2.3 Redevelopment Economics

Another key challenge is the cost and feasibility of complying with stormwater requirements in redevelopment settings.

*Higher Cost of Compliance***.** The cost of constructing LID practices at redevelopment projects in highly urban settings can be 4 times more expensive than installing them at new development projects located in green-field settings, where more surface land is available (See Section 8.2). The cost to install LID practices at high intensity redevelopment sites is projected to be $191,000 per impervious acre, as compared to $ 46,500 per impervious acre at a suburban green-field site. It should be noted that stormwater construction costs are not much different between green-field projects and less intensive redevelopment projects (i.e., less than 65% IC), since a wider range of cost-effective LID practices can be employed.

The alternative approach is to provide underground stormwater treatment, using sand filters or vaults. The underground approach is also extremely expensive, compared to surface treatment at green-field development settings. The cost of stormwater compliance for underground practices is roughly equivalent to the cost of installing LID practices at high intensity redevelopment projects, according to a recent study in the District of Columbia (Leistra et al, 2010).

Difficulty in Compliance. Full compliance with more stringent stormwater requirements cannot always be achieved at high intensity redevelopment projects due to space and feasibility constraints. Developers have argued that this may stop desirable redevelopment projects or require unacceptable reductions in project density. Consequently, it is important to have a "safety valve" to allow the projects to proceed when full compliance is not physically feasible or are prohibitively expensive. These may include offset fees or options for off-site compliance.

Smart Growth Considerations. When viewed from a watershed or regional perspective, high density redevelopment is considered an essential element of smart growth, green infrastructure and sustainable cities. The common theme is that increased density and land use efficiency are desirable in urban watersheds (USEPA, 2005 and NRC, 2008). The use of scarce land for surface stormwater treatment, the high cost of LID practices, or the inability to comply with stormwater requirements all have the potential to act as disincentives to smart growth. Localities need to craft creative and flexible stormwater policies to prevent this from happening.

2.4 Institutional Challenges

The last redevelopment challenge is an institutional one. Few cities in the Bay watershed have a lot of experience when it comes to managing stormwater at high intensity redevelopment sites. Most have traditionally waived, exempted relaxed or otherwise reduced stormwater requirements for redevelopment projects. There are some notable exceptions, such as the District of Columbia and Montgomery County, MD, but most cities in the Bay watershed treat redevelopment in more or less the same manner as the City of Baltimore.

In 2005,the City indicated that of the 476 projects in the city that required grading permits, 418 were exempted from stormwater due to project size and 46 were waived, leaving only 12 projects (or 2%) that were subject to stormwater requirements (COB, 2006). City inspectors indicated that the few stormwater practices that were installed involved less effective pretreatment or proprietary devices.

The key point is that many cities do not yet have a strong culture of stormwater implementation, and some are reluctant to adopt innovative LID practices. The culture will hopefully change as more stringent redevelopment requirements are rolled out in the coming years, but it will require a major shift by stormwater review agencies.

2.5 Changing the Redevelopment Stormwater Paradigm

While the preceding section outlined the many challenges confronting stormwater managers, it is not meant to imply that stormwater treatment should be avoided at high intensity redevelopment sites. Rather, the many challenges demonstrate the need to craft effective stormwater solutions that are specifically tailored to the unique conditions and economic realities found at redevelopment sites. The traditional suburban stormwater design approach needs to be fundamentally re-worked to address the challenges of redevelopment.

Section 3
Why Stormwater Requirements for Redevelopment are Important

This section argues the case for requiring more stringent stormwater requirements for redevelopment projects. In short, redevelopment appears to be increasing as a share of total development in the Bay watershed. The urban watersheds where the redevelopment occurs have poor water quality and are now subject to the TMDL process. These will require localities to achieve significant reductions in stormwater pollutants in the coming years. CSN estimates that about 2 million acres of untreated or marginally treated impervious cover currently exist in the urban areas of the Bay watershed. Localities can significantly reduce their future pollutant reduction liability if they are able to use the redevelopment process to get incremental reductions from existing untreated impervious cover.

3.1 Recent Growth in Redevelopment Activity

Historically, new development in the suburbs and rural areas of the Chesapeake Bay watershed has far exceeded the amount of infill and redevelopment, in terms of land consumed and new impervious cover created. In recent years, however, there is evidence that urban sprawl may be cresting as a result of high energy prices, road congestion, falling housing prices, reduced job mobility and other economic forces, including the recent recession. Recent land use statistics show a slowdown in the rate of land conversion for sprawl development in the last five years.

At the same time, there is some evidence that infill and redevelopment are increasing as a share of total development, at least in some portions of the watershed. For example, according to one study, 42% of the land currently classified as "urban" in the United States will be redeveloped by 2030 (Brookings Institute, 2004). More recent statistics show a sharp increase in residential redevelopment projects in core cities and inner suburbs of major metropolitan areas, including five in the Bay watershed (US EPA, 2010b).

The trend is being driven by increasing numbers of urbanites seeking the amenities of city life. This "back to the city" trend is reinforced by surveys of real estate investors that forecast increasing infill and redevelopment activity in coastal cities (ULI, 2010). In any event, the increasing age of existing residential and commercial development in metropolitan areas suggest that much of it will need to be rehabilitated or redeveloped in the future (Jantz and Goetz, 2008).

3.2 Poor Water Quality in Highly Urban Runoff

Some indication of the strength of highly urban stormwater runoff can be found in Table 3, which compares the event mean concentrations of stormwater pollutants from highly urban watersheds in the City of Baltimore to the national median concentration from the National Stormwater Quality Database, which is dominated by more suburban monitoring stations. As can be seen, median pollutant concentrations from the highly urban watersheds are significantly higher than the national average. Given that highly urban watersheds generate higher stormwater runoff volumes, they discharge greater pollutant loadings than their suburban counterparts, even if their pollutant concentrations were identical (Figure 1).

Figure 1 Urban Street Dirt Contains Many Harmful Pollutants

Table 3
Comparison of Stormwater Quality Event Mean Concentrations from Runoff

Stormwater Pollutant	Baltimore City	Suburban National Median
Fecal Coliform Bacteria	36,025 MPN/100 ml	5,091 MPN/100 ml
Total Copper	28 ug/l	16 ug/l
Total Lead	64 ug/l	16 ug/l
Total Nitrogen	2.8 mg/l	2.0 mg/l
Total Phosphorus	0.32 mg/l	0.27 mg/l
Oxygen Demand	19.3 mg/l	8.6 mg/l

Source: Baltimore City Diblasi (2008) Suburban National Pitt et al (2004)

Highly urban watersheds also deliver very high loads of trash and litter to receiving waters (COB 2006), compared to more suburban or rural watersheds.

Increasingly, many cities in the Bay watershed are recognizing that trash is a pollutant in its own right, which strongly influences the public's perception about water quality (or the lack of it) in urban areas. Consequently, several TMDLs have recently been issued to reduce or eliminate trash and debris in the Bay and Baltimore, the District of Columbia and Montgomery County, MD now have specific MS4 permit requirements to meet them.

3.3 Urban Watersheds, Impaired Receiving Waters and TMDLs.

Water quality tends to be poor in the receiving waters of highly urban watersheds within the Chesapeake Bay, as a result of polluted discharges of stormwater and, in some cases, combined sewer overflows. It should come as no surprise that the most polluted receiving waters in the Chesapeake Bay – the Anacostia River, the Elizabeth River, the Inner Harbor, and the Back River – are subject to stormwater discharges from their highly urban watersheds. Monitoring data consistently indicates chronic water quality impairments for multiple pollutants, including bacteria, nutrients, sediment, trash, metals and hydrocarbons. Consequently, most urban receiving waters are listed as being impaired for water quality.

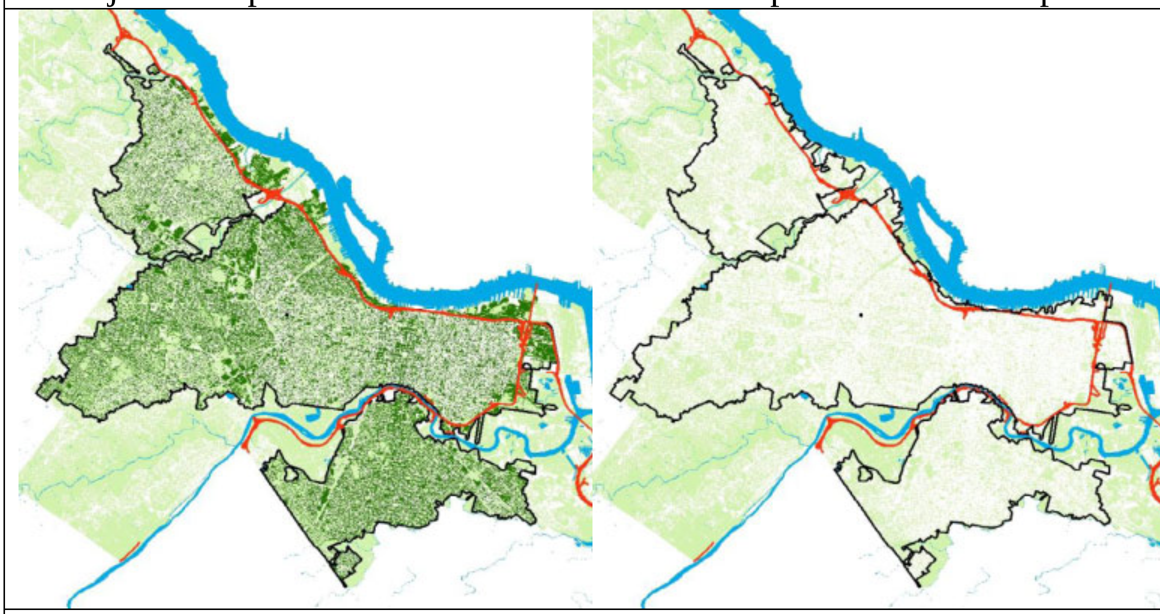
In order to meet water quality standards, localities in these highly urban watersheds are subject to the Total Maximum Daily Loads (TMDL) process for many of their local streams and rivers. In addition, beginning in 2011, localities will need to prepare local watershed implementation plans to show how they will comply with pollutant reductions specified under the Bay-wide TMDL. In both cases, localities are required to achieve major load reductions from existing development for nutrients, sediments, and possibly other pollutants. The precise reductions that must be achieved will differ in each community, and in some cases, are still being worked out. Several early estimates indicate that reductions of as much 40 to 90% may be needed for some pollutants.

Reducing pollutants from existing developed areas is difficult and costly, as it usually entails widespread implementation of retrofits to treat the stormwater from untreated impervious cover, among other restoration strategies. One key strategy that localities should not overlook is the use of more stringent redevelopment stormwater requirements to incrementally treat the quality of runoff from existing, untreated developed land within a community. Over several decades, such requirements can gradually reduce nutrient and pollutant discharges to urban receiving waters – at very little cost to the community.

Some indication of the long term potential for treating stormwater from existing impervious cover through a combination of redevelopment stormwater requirements and green street retrofits is exemplified by the spatial projections developed by the Philadelphia Office of Watersheds (Figure 2). Based on projected trends in redevelopment and green street implementation, the City forecasts that the amount of land treated by effective stormwater practices will increase from 2 to 59% of city land area within three decades.

While it is doubtful that stringent redevelopment stormwater requirements alone can eliminate a city's pollutant load liability under TMDLs (at least with the implementation time frame of the Bay TMDL), they do have potential to sharply reduce that liability, which could save millions of dollars in capital expenditures for retrofits. In addition, offset fees, recovered when compliance with redevelopment stormwater requirements is not possible, represent a significant local revenue stream to help finance watershed retrofits. More details on how to establish offset fees and track nutrient reductions from redevelopment can be found in Sections 8 and 9 of this bulletin, respectively.

Figure 2:
Projected Impervious Cover Treated in Philadelphia via Redevelopment



The green areas depict the expected treatment area over a thirty year period as a result of redevelopment stormwater requirements and green street retrofits (Source, POW,2008)

3.4 Alternative Strategy to Abate Combined Sewer Overflows

Many older cities in the Chesapeake Bay watershed have combined sewers that can discharge untreated sewage and polluted stormwater during rainfall events. Examples include the District of Columbia, Alexandria, Harrisburg, Lynchburg and Richmond. Traditionally, these combined sewer overflows or CSOs require extremely expensive treatment devices such as deep tunnels and swirl concentrators to store and treat the overflows.

In recent years, however, several cities have realized that LID practices installed at redevelopment sites can sharply reduce stormwater inflows into CSOs, and thereby greatly reduce the frequency and magnitude of overflow events to rivers and estuaries (Limnotech, 2007). The practical benefit is that application of LID practices can help reduce the large capital costs associated with CSO abatement. Several examples of cities that are using LID practices as an integral element of their CSO abatement projects include the District of Columbia, Chicago, Portland, Philadelphia and Milwaukee.

3.5 Green Building and Sustainability Movement

Another driver behind the installation of LID practices in urban watersheds has been the green building movement. Designers that seek LEED certification for their green buildings are awarded additional points for use of innovative stormwater practices. Other certification systems such as the Sustainable Sites Initiative (ASLA, 2009) provide even more incentives to install LID practices, as they reward effective stormwater solutions for the entire site, and not just the building itself. Together, these certification systems provide powerful incentives to create innovative stormwater solutions at redevelopment projects.

The green building movement has been supported by a great deal of research, demonstration and experience with specialized LID practices that are specifically adapted for highly urban areas. These new stormwater practices promote larger sustainability objectives such as increased energy efficiency, water conservation, greater building longevity, community greening, safer and more walkable communities and more creative architectural solutions.

Section 4
Unique Stormwater Design Approach for Redevelopment Projects

As was argued in Section 1, the conventional stormwater design approach employed at green-field sites does not work in ultra-urban watersheds, and needs to be extensively modified to meet the challenges of redevelopment sites. This section presents some guiding principles for the design of stormwater practices at high intensity redevelopment projects.

4.1 Understand the Watershed Context

At green-field sites, designers don't need to know much about the watershed in which the project resides. They may have to deal with special watershed performance standards, or address near field issues such as floodplain impacts, but most of the work occurs within the confines of the property.

The situation is much different for redevelopment projects. Designers must fully understand the urban watershed context in which their redevelopment site is located. At a minimum, the designer should be able to address the following watershed questions, and incorporate the specific answers into their stormwater design for the redevelopment site.

- *Does the redevelopment project discharge to receiving water that is impaired?* If so, what are the specific pollutant(s) of concern causing the impairment? The pollutant of concern often dictates which pollutant removal mechanisms should be optimized in the design of stormwater practices.

- *Is the project located in a watershed served by combined or separate sewers?* If the project is located in a CSO watershed, the designer will want to maximize runoff reduction to keep excess stormwater runoff volumes out of the combined sewer system.

- *What is the average age of development in the watershed?* Stream systems in older watersheds (70+ years) often have progressed through the entire cycle of channel incision or enlargement. As a consequence, these "older" streams may have attained a new channel equilibrium and some form of stability. If, on the other hand, the average age of development is a few decades or less, it is likely that that streams in the watershed may still be experiencing channel degradation, which may indicate a need for more runoff reduction, channel protection or downstream channel rehabilitation (Schueler, 2004).

- *What is the habitat condition and aquatic diversity of the receiving stream? Or has it been eliminated altogether?* As noted earlier, many streams in highly urban watersheds have been degraded, altered or buried by past development. Therefore, the current health and restoration capacity of the receiving stream is an important factor in stormwater design for redevelopment. If the stream has been eliminated or interrupted, which frequently occurs when watershed IC exceeds 60% (Schueler et al, 2009 and CWP, 2003), then designers may want to shift their focus from maximizing runoff reduction toward increasing water quality treatment. If, on the other hand, the redevelopment site discharges to a stream segment that is still in fair or good condition, they should definitely select practices that maximize runoff reduction.

- *Does the existing stormwater conveyance system or floodplain have enough hydraulic capacity to safely convey large flood events?* Most urban watersheds are prone to flooding due to aging or undersized stormwater infrastructure. If a redevelopment site discharges to an area that experiences chronic or historical flooding problems, designers may want to manage larger storms to reduce peak flows and flooding.

- *Does a restoration plan exist for the watershed which contains off-site options for stormwater retrofit and stream restoration?* If so, these projects may offer a cost-effective watershed solution, in the event that full compliance at a redevelopment site is either not feasible or prohibitively expensive.

4.2 Conduct Site History Investigation

Green-field sites require very little in the way of site history investigations, apart from some limited geotechnical data. Redevelopment projects, on the other hand, frequently require special environmental site assessment to evaluate soil conditions and determine whether the site is subject to brown field remediation. The assessments typically involve a site history investigation, soil testing and groundwater analysis to determine whether site cleanup or remediation is needed (US EPA, 2001). Stormwater designers can use site history investigations to determine whether:

- Stormwater infiltration should be encouraged or discouraged
- Soils are contaminated and need to be capped
- Existing utilities will constrain stormwater design
- The existing conveyance system has adequate hydraulic capacity
- The depth to groundwater will influence practice design
- Historical drainage paths can be used to treat runoff

The investigations are also extremely useful to map the best locations for LID practices and how they can be connected together as an effective system. Additional stormwater guidance for brownfield sites can be found in US EPA (2008).

4.3 Better Site Design in the Context of Urban Redevelopment

Many of the original principles of Better Site Design were crafted in the context of low density suburban development (CWP, 1998). These principles need to be adapted to meet the unique constraints of the urban built environment where the objective is often to maximize intensity for the sake of land use efficiency (CWP, 2001). In particular, the goal of urban better site design may not be to reduce impervious cover, but rather to promote greater density and smart growth. Some of the key principles of urban better site design include:

- Innovative urban parking management solutions (COE, 2005),
- Municipal green street specifications (SMC, 2009)
- Context-sensitive road design standards to provide stormwater treatment in right of way (MC, 2008)
- Modification of traditional streetscape standards to use street trees as a stormwater filtering device (COPO, 2008 and Cappiella et al 2006).
- Changes in plumbing codes to allow or incentivize the use of rainwater harvesting systems
- Reducing parking demand through mass transit or shared or structured parking (CWP, 2001)
- Integration of stormwater treatment into landscaping (COPO, 2008)

The key to implementing urban better site design is a comprehensive local code review process to make specific code changes or interpretations that enable the use of certain LID practices that are most effective for urban redevelopment projects. Some of the more notable areas of local code to investigate include:

- Plumbing codes to permit rainwater harvesting systems
- Building codes to allow green roofs
- Road codes to allow green streets
- Landscaping codes to promote foundation planters
- Urban street tree requirements to allow expanded tree pits

A good example of a comprehensive local code review to promote more effective use of stormwater practices can be found in Biohabitats (2010).

4.4 Identify Potential Hotspot Generating Areas

Designers should review future site operations and activities at the redevelopment site to identify potential stormwater hotspot generating areas (HGAs). These may entail loading/unloading areas, fueling areas, outdoor storage areas, exposed dumpsters and compactors, and outdoor maintenance areas, and usually involve only a fraction of the total redevelopment site.

If HGAs are present at the redevelopment site, their contributing drainage areas should be isolated from the remainder of the site (usually by grading and drainage) so that their runoff can be fully treated by a stormwater filtering practice to prevent toxic discharges to surface or ground waters. In other cases, hotspots should be covered by a roof to prevent exposure to rainfall or runoff. In all cases, employees should be trained on routine pollution prevention measures that must be employed at the site (see CWP, 2004).

Designers should also evaluate future activities at the proposed redevelopment site to determine if there is a risk of it becoming a *"trash" hotspot*. It is important to keep in mind that trash loads are not distributed equally across urban watersheds. Indeed, research has shown that higher trash loads are generated by specific land uses, such as commercial areas, fast food outlets, and areas of high development intensity or heavy pedestrian/vehicular traffic (Marias et al, 2004 and EOA, 2007). The practical implication of high trash loads is that they can interfere with the performance of stormwater practices and create a need for more pretreatment and more frequent cleanouts.

4.5 Real Impervious Cover Reduction.

Designers have a strong incentive to reduce existing impervious cover at redevelopment sites. Depending on state requirements, full stormwater compliance can be achieved by reducing pre-redevelopment impervious cover by 20 to 50%. Even a smaller reduction can sharply reduce the size and cost of stormwater practices for the redevelopment project.

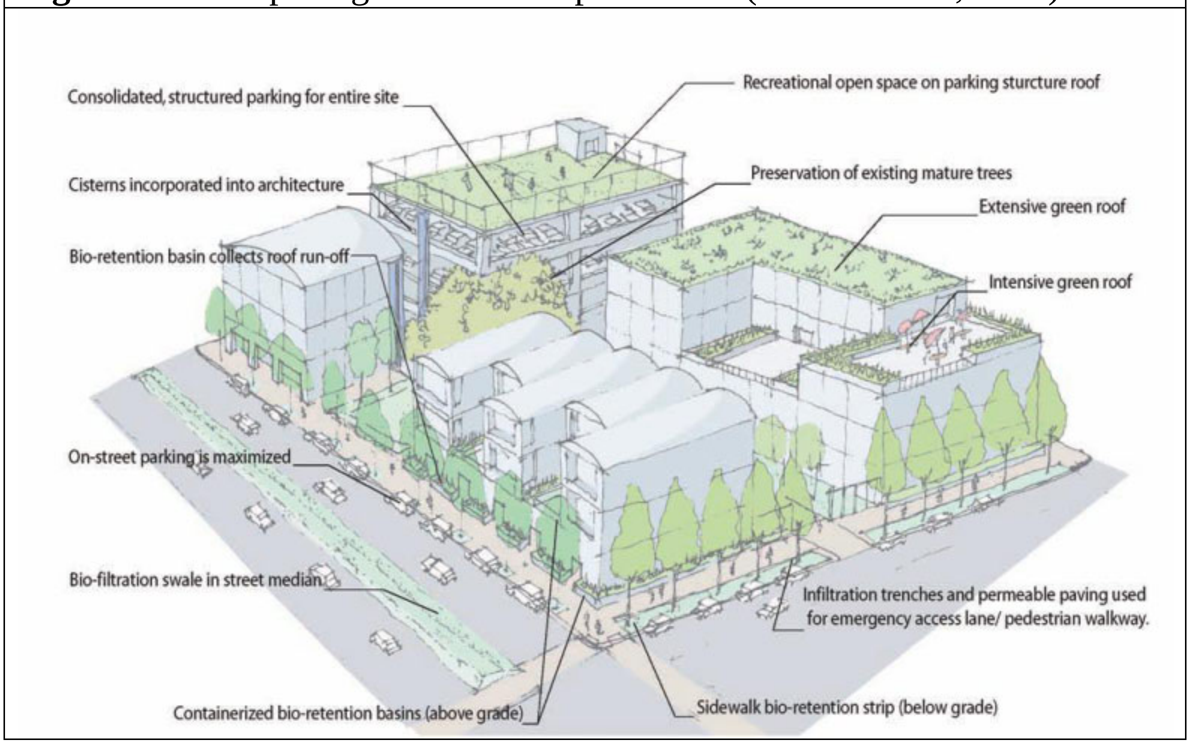
It is important, however, to ensure the conversion of impervious cover is real. Designers should ensure that impervious cover is not only reduced on the site plan, but is actually restored to a truly pervious condition. The new pervious cover should perform hydrologically as if it were un-compacted meadow, and ideally should be used to filter some runoff from remaining hard surfaces.

The new pervious areas at redevelopment sites are likely to be extremely compacted and could still generate high amounts of stormwater runoff and attached nutrients. Consequently, designers may need to deep till, grade and amend the soils with compost or other materials to increase the porosity and water holding capacity of the pervious area. In many cases, runoff from adjacent rooftops can be effectively disconnected over these "improved" pervious areas. More specific design guidance on impervious cover reduction techniques can be found in Section 6.

4.6 Decompose the Site into Smaller Treatment Units

Even with the recent shift to LID practices, most green-field development projects still utilize larger drainage areas that typically range from 20,000 to 100,000 square feet per practice. By contrast, the drainage area of many preferred redevelopment practices is much smaller. In general, designers need to "decompose" or break up redevelopment sites into smaller areas of about 5,000 to 20,000 square feet that serve individual units of surface cover (e.g., roofs, pedestrian areas, streets, open space and parking lots).

Figure 3 Decomposing the Redevelopment Site (Source: COE, 2009)



A unique LID solution is then designed for each small unit. In this manner, stormwater practices are directly integrated into the design of buildings, parking lots and streetscapes, which avoids the need for underground structures or consumption of costly surface real estate. Figure 3 graphically illustrates creative integration of multiple LID practices at dense urban redevelopment sites.

CSN (2010) has released a spreadsheet tool to track progress in meeting stormwater requirements at Maryland redevelopment sites which allow designers to optimize the most cost-effective combination of practices at "decomposed" sites. Other spreadsheet tools are available that help designers optimize the most appropriate LID practices for redevelopment sites (COE, 2005 and VA DCR, 2009). The City of Philadelphia had also developed a series of checklists and worksheets that achieve the same purposes (COPH, 2008). Urban communities in the Bay watershed can easily modify these spreadsheet tools to meet their unique redevelopment conditions.

4.7 "Roof to Street" Design

The preferred stormwater approach in a green-field development is to sequence LID practices in pervious areas on the pathway from the roof to the stream. The space constraints of redevelopment projects render this design approach less practical. Consequently, designers need to integrate a sequence of LID practices ***within*** the built environment, exploiting opportunities from the roof, the building walls, the streetscape and the street itself. The basic "roof to street" design approach uses the following principles to manage runoff:

- Manage rooftop runoff through green roofs, water harvesting, disconnection or storage and release from foundation planters.
- Surface parking should be minimized and designed to reduce, store and treat stormwater using permeable pavements, bioretention or sand filters (SMC, 2009).
- Design urban hard-scapes such as plazas, courtyards and pedestrian areas to store, filter and treat runoff using permeable pavers, stormwater planters and amenity bioretention areas.
- Ensure that all pervious and landscaping areas in the redevelopment project are designed for effective stormwater treatment using practices such as soil restoration, reforestation, and bioretention.
- Design the streetscape to maximize the capture and reuse stormwater runoff using expanded tree pits, street bioretention, curb cut extensions and other "green street" methods (COPO, 2008, COPH, 2008 and SMC, 2009).

4.8 Maximize Forest Canopy and Restore Natural Area Remnants

Conserving forests and natural areas are a key site design strategy for green-field developments. Many of the existing natural areas at redevelopment sites, however, have been lost or degraded by past development. Therefore, a more restoration oriented strategy is needed in urban watersheds to increase forest canopy and improve the hydrological function of natural areas.

The extent of forest cover that remains in urban watersheds is surprising – recent GIS studies have shown than urban cities in the Bay watershed have estimated forest canopy to be 20 to 45% of their total area (CWP and USFS, 2009). Urban forests, fragments and even individual street trees provide ecosystem services, particularly when the forest canopy is located above or adjacent to hard surfaces. The amount of stormwater retained by tree canopy interception is impressive for the smaller storm events that most influence water quality (American Forests, 1999 and 2002).

Stormwater managers now understand that significant stormwater benefits can be realized when they maintain and expand the extent of urban forest canopy to take advantage of the natural stormwater filtering that trees afford. Dozens of cities and counties across the Chesapeake Bay have established numeric goals to increase the extent of urban tree canopy within their jurisdiction in the last five years (CWP and USFS, 2009).

Stormwater design at redevelopment projects that increase the extent of the existing forest canopy can provide incremental stormwater treatment. This may involve stormwater credits for street trees, expanded tree pits in the sidewalk zone, and urban reforestation. Useful guidance on techniques for integrating trees into urban stormwater practices can be found in Cappiella et al (2005 and 2006). In addition, funds recovered from stormwater offset fees can be systematically used to increase forest canopy across the watershed.

Natural area fragments and wetlands typically constitute a small fraction of urban watershed area, due to historical losses from past development, filling and draining. Remnant natural areas tend to be highly degraded due to impacts from stormwater, invasive species and other urban stressors. Even so, natural area remnants are a critical component of the urban ecosystem. If urban wetlands or natural area remnants are present at a redevelopment site, it is important to restore their quality and hydrologic function as green infrastructure. If wetland restoration is feasible at a redevelopment site but stormwater treatment is not, restoration should be considered an acceptable substitute.

4.9 Careful Urban Infiltration and Recharge

It is possible to get a good sense about soil properties at green-field projects by simply analyzing soil surveys and taking a few borings. The basic idea is to find the most permeable soils that allow for runoff infiltration. By contrast, very little is known in advance about the soils located in high intensity redevelopment sites. These sites require much greater investigation to determine whether they are suitable for infiltration or pose a contamination risk.

The primary reason is that most redevelopment projects are located over urban fill soils. Past development has destroyed their original soil structure and compaction has greatly reduced their infiltration capacity. Most soil surveys simply refer to these as ‘urban soils”, which are defined as soils that have been mass-graded and/or significantly cut or filled in past cycles in land development. Soil scientists have only recently begun to study and classify urban soils (Effland and Pouyat, 1997).

They caution that it is hard to generalize about urban soils since they are quite variable in their properties and hydrological response. At one extreme might be a site that has undergone several cycles of grading to a depth of a few dozen feet, with large additions of unknown or rubble fill, a high risk of past soil contamination and extreme surface compaction. The other extreme might be a residential site that experienced only minor grading and whose soils still retain some of their original permeability.

Despite this variability, urban soils are clearly different than their suburban and rural counterparts. Urban soils are more compacted, have a higher bulk density, and are enriched with trace metals which may exceed the EPA sediment soil screening guideline (Yesilonsis et al, 2008 and Pouyat et al, 2007). The hydrologic properties of urban fill soils are also markedly different from undisturbed areas. As a general rule, urban soils produce greater runoff rates and lower infiltration rates than the same undisturbed soil type.

While the NRCS cautions that urban soils cannot be assigned into any hydrological soil group, most practitioners assign them to HSG “D”, which has the greatest runoff response. NJDEP (2009) recommends that they be assigned a default HSG of D as well, unless specific on-site soil testing indicates a higher infiltration rate.

The key management question is whether it is advisable to infiltrate runoff into urban fill soils. As a general rule, infiltration of stormwater runoff should be done with extreme caution in redevelopment projects, given the degree of past soil compaction and pollution in urban watersheds. Some practitioners advise against infiltration since groundwater pathways are poorly understood and could cause unintended damage to adjacent building foundations and underground infrastructure. Other practitioners recommend prohibiting infiltration at sites that are designated as stormwater hotspots and brown-fields in order to minimize the risk of groundwater contamination. Yet other practitioners advocate for some degree of infiltration at certain redevelopment sites in order to recharge the depleted aquifers found in urban watersheds.

To reduce confusion, a four-tiered set of infiltration restrictions is proposed based on redevelopment site history and on-site soil testing, as shown in Table 4, and described below:

- The *first tier* involves cases where existing soils appear relatively un-disturbed and were subject to minor grading and surface compaction in the past. Examples might include older residential neighborhoods or institutional developments, or areas where recent NRCS soil surveys indicate the presence of permeable soils. In these cases, basic infiltration tests should be conducted to see if intentional infiltration is feasible, and practices that result in unintentional infiltration are also permissible. Designers should still be mindful of standard setbacks to building foundations and underground infrastructure when locating infiltration practices.

Table 4
Redevelopment Conditions and Infiltration Restrictions

Site History or Condition	**Risk**	**Infiltration Restriction**
Tier 1: Relatively Undisturbed Soils	Small risk of damage to underground infrastructure and foundations	Infiltration encouraged but confirm infiltration rates and respect setbacks
Tier 2*:* Site Was Previously Mass Graded and Classified as Urban Fill Soils	Geotechnical concerns. Prior compaction suggests poor infiltration rates. Unsure of underlying soil quality and leaching risk	**Unless your on-site testing proves otherwise [1],** avoid intentional infiltration and use "closed" practices that do not interact w/ groundwater (e.g., sand filters, green roof or rain tanks)
Tier 3a: Site Designated as Potential Hotspot	Polluted stormwater can contaminate groundwater	Treat at least half of the treatment volume in closed practice prior to infiltration
Tier 3b: Site Expected to be Severe Hotspot	Risk that polluted stormwater, spills, leaks and illicit discharges can contaminate groundwater	Avoid intentional or unintentional infiltration, and used closed practices
Tier 4: Site is Designated as Brownfield	Infiltration increases risk of pollutants leaching from contaminated soils	Cap or liner, and ensure no intentional or unintentional infiltration over affected area

[1] The recommended guidance for evaluating and testing urban fill soils can be found in Appendix E of NJDEP (2009) Stormwater Manual

- The *second tier* involves cases where soils are classified as urban fill or equivalent (e.g., urban land, cut and fills, or made land). In this situation, the decision to infiltrate or not is based on detailed on-site soil testing, using the protocols and soil test methods of NJDEP (2009). If the testing indicates the soils have acceptable infiltration rates throughout the entire soil profile and there are no signs of suspicious materials, then the site can be considered suitable for infiltration. If the soil tests are negative, then infiltration should be avoided, and closed LID practices or sand filters be used as an alternative. Some unintentional infiltration through under drains may be permissible if soil quality is reasonably good.

- The *third tier* involves cases where a proposed redevelopment site is expected to become a potential or severe stormwater hotspot. A potential hotspot is considered a redevelopment site where there is minor risk of future spills, leaks or illicit discharges (e.g., a convenience store, fast food restaurant or car dealership). The stormwater strategy at these potential hotspots is to treat one half of the water quality volume with a filter BMP prior to any on-site infiltration. Severe hotspots include redevelopment projects where future activities or operations will have a significant risk of harmful spills or leaks, and/or generate more polluted runoff. Infiltration of any kind (intentional or unintentional) should be avoided at these sites.

- The *fourth tier* involves cases where the site history investigation indicates that the redevelopment site is a brown-field, in which infiltration is prohibited (US EPA, 2008). Contaminated soils should be capped and stormwater practices should treat surface runoff in a "closed" system which does not allow any interaction with groundwater. This typically involves the use of stormwater filtering practices such as sand filters and bioretention that have impermeable bottom liners. Designers should also avoid practices that cause *unintentional infiltration* through the soil (e.g., bioretention or permeable pavers with an under drain that allows for modest soil infiltration).

4.10 Set Appropriate Offset Fee

It is almost always possible to comply with stormwater requirements at green-field development projects because there is enough surface land to locate cost-effective LID practices. By contrast, full compliance at some high intensity redevelopment projects may never be physically or economically possible, at least without sacrificing land use efficiency. Therefore, it is important to develop an offset program to handle these special cases.

Most Bay states allow for a stormwater offset fee in the event that on-site redevelopment compliance is not feasible or cost effective (see Table 5). In most cases, however, it is up to the locality to develop and administer a stormwater offset mitigation fee. It is recommended that the fee be based on a measurable quantity, such as the fraction of untreated runoff volume, impervious cover or phosphorus load generated by the redevelopment site. Several options for establishing offset fees are provided in Section 8, and localities need to examine their development intensity, retrofit possibilities, land prices and redevelopment incentives to set the right price.

It is recommended that the floor for the offset fee should be priced no lower than the equivalent cost to retrofit suburban green-field development (about $ 32,500 per untreated impervious acre). Off-set fees in this range can ensure that the costs of on-site compliance do not become an impediment to redevelopment and smart growth. The funds collected from the offsets are then used to finance effective stormwater retrofit and restoration projects elsewhere in the same watershed.

Section 5
Redevelopment Performance Standards in the Bay States

Most Bay states have established or proposed a performance standard for runoff and/or pollutant reduction for redevelopment projects (see Table 5). As previously noted, the redevelopment performance standards are less stringent that those for new development sites in green-field settings. Redevelopment stormwater treatment standards vary considerably among the Bay States, and some are still in the process of being developed, and could change.

Table 5:
Examples of Redevelopment Stormwater Requirements in the Chesapeake Bay Watershed and in Other Selected Cities [1]

Jurisdiction	Redevelopment Requirement	Min. Area (sf)	Offset?	Status
Maryland	See Table 6	5000	Yes	2010
Virginia	Reduce existing phosphorus load by 10 to 20% depending on redevelopment site area	10,000	Yes	2011
District of Columbia	Reduce or Treat Runoff Volume from 1 inch rainfall event	250	Yes	2011
New York	New IC: Reduce or Treat Runoff Volume from 1 inch rainfall event Existing IC: Reduce by 25% through IC reduction, BMPs or alternative practices	10,000	Yes	2010
Pennsylvania	20% WQ treatment for the site	10,000	?	2009
Federal	Reduce Runoff Volume from the 95th percentile rainfall event (1.2 to 1.9 inches in watershed)	5000	No?	2010
Philadelphia	Reduce or Treat Runoff Volume from 1 inch rainfall event	5000	Yes	2008
Los Angeles	Treat runoff from 0.75 inches of rainfall	5000	?	2007
Austin, TX	Treat runoff from 1.0 inches of rainfall	500	Yes	2006
Chicago	Treat runoff from 0.5 inches of rainfall	Varies	?	2008

[1] Some states and localities may also impose further stormwater storage or runoff reduction volumes for channel protection or flood control purposes, depending on downstream conditions and how much new impervious cover is created at the redevelopment site.

The federal government is leading by example by requiring runoff volume reduction from the 95th percentile rainfall event for redevelopment projects at federal facilities and lands nationwide. This new nationwide stormwater requirement is described in US DOD (2009) and USEPA (2009b), and is derived from Section 438 of the 2008 Energy Independence and Security Act. In the Chesapeake Bay, this LID requirement would apply to about 1.2 to 1.9 inches of rainfall, depending on where the project is located in the watershed.

Table 5 also shows some of the redevelopment stormwater requirements for cities outside the Chesapeake Bay watershed. As can be seen, several cities such as Philadelphia and Los Angeles have established runoff reduction requirements for redevelopment sites that meet or exceed those of the Bay States. Designers should consult the links in Appendix A to find the complete redevelopment stormwater requirements for their state.

The details of the state stormwater requirements for redevelopment are important. Appendix D shows how much stormwater treatment requirements change in Maryland depending on the change in post-development impervious cover. Not much is required when impervious cover is reduced, but a lot more treatment is needed when it increases from the pre-development condition.

Section 6
Selecting Practices for High-Density Redevelopment Projects

This section compares the range of possible stormwater practices in the context of their applicability to high-intensity redevelopment projects and classifies them as preferred, acceptable, restricted or marginal (Table 6).

The technical basis for the classification of stormwater practices is detailed in the notes in Table 7. Since every redevelopment site is unique, the classification should be considered a starting and not an ending point.

As noted in Section 1, there is no definitive design guidance for stormwater redevelopment practices in the Chesapeake Bay. The remainder of this section outlines some core elements to consider when bridging this gap.

The section is not meant to be a full blown redevelopment manual, but rather to show which core elements could be incorporated into forthcoming state design manuals being written in the District of Columbia, Delaware, West Virginia, and Virginia, and eventually, Maryland and Pennsylvania. In addition, several strategies are recommended to improve the acceptance and adoption rates of preferred stormwater practices.

Table 6
BMP Selection for High-Density Redevelopment Projects

Preferred [1]	**Acceptable** [2]	**Restricted** [3]	**Marginal** [4]
Impervious Cover Conversion	Sand Filters	Infiltration	Ponds & Wetlands
Green Roof and Rain Tanks	Bioretention	Proprietary Practices	Wet Swales
Permeable Pavers [5]	Urban Tree Planting	Dry Wells	Grass Channels & Filter Strips
Foundation Planters	Dry Swales		Most MDE ESD Micro-practices [6]
Extended Tree Pits [8]	Restore Natural Area Remnants		Disconnection Credits [7]
Green Street Retrofits [8]			
Soil Restoration & Reforestation			

[1] Provide significant on-site runoff reduction and are ideally suited for most redevelopment projects
[2] An acceptable design solution for many redevelopment sites if some surface area is available or if infiltration restrictions require use of filtering practices (i.e., sand filters)
[3] Use of these practices may be limited due to urban infiltration restrictions or inadequate runoff reduction capability (i.e., proprietary practices)
[4] These practices can seldom be applied at high-intensity redevelopment projects because they are too space- intensive and/or consume too much land. There may be some rare situations where they can be used to comply.
[5] Permeable pavement can be designed with under drains if located in an urban infiltration restricted area
[6] The bulk of the micro-ESD practices in the MDE (2008) design manual supplement, with the exception of green roofs and rain tanks, are space intensive or soil restricted, and have limited feasibility for redevelopment projects
[7] For the same reasons, most of the disconnection credits offered by MDE or VADCR will seldom be feasible in high-density redevelopment projects
[8] These practices often require special permission or approvals from municipal agencies

6.1 Preferred Redevelopment Stormwater Practices

Impervious Cover Conversion involves the removal of existing impervious cover at a redevelopment site, followed by soil restoration such that the new pervious area performs hydrologically as if it were un-compacted grass, and filters runoff from adjacent hard surfaces.

Why Is It Preferred? Impervious cover conversion is preferred since it is a relatively low cost way to change the hydrologic response of a redevelopment site without having to construct a structural practice.

Best Available Guidance: Although every Bay state provides credit for impervious cover reduction or conversion, none have crafted specific guidelines on how it should be done.

Barriers to Overcome: The main barrier is that designers and site planners currently have little or no experience with this practice.

Bay-wide Design Criteria: The following design criteria are proposed for impervious cover conversion:

- The minimum surface area for the impervious cover conversion credit is 250 square feet
- Site plans should show the specific areas where concrete or asphalt will be removed and recycled
- Underlying compacted soils should be deep tilled and amended with compost to restore porosity, using the methods outlined in the Bay-wide soil restoration design specification.
- The new pervious area should be graded to accept runoff from adjacent hard surfaces.
- The designer is eligible for additional treatment credit for the pervious area, if it is designed as a bioretention area.
- The pervious area should be planted with an acceptable vegetative cover, which reflects landscaping objectives and anticipated future uses at the redevelopment site.
- The conversion should be permanent, and accompanied by a deed or covenant that specifies that the area cannot be rebuilt in the future.
- The maintenance plan shall specify that the vegetative condition of the pervious area shall be regularly inspected and must be regularly maintained to ensure no soil erosion is occurring.

Green Roofs (also known as *vegetated roofs, living roofs* or *eco-roofs*) are alternative roof surfaces that typically consist of waterproofing, drainage materials and an engineered growing medium that is designed to support plant growth. Green roofs capture and temporarily store stormwater runoff in the growing media before it is conveyed into the storm drain system. A portion of the captured stormwater evaporates or is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites. The most common design is the *extensive* green roof system which have a shallow growing media (4 to 8 inches), planted with carefully selected drought tolerant vegetation, such as *sedum*. By contrast, i*ntensive* systems have a deeper media layer and can support a wider range of plants, including shrubs and small trees.

Why Is It Preferred? Green roofs are preferred because they incorporate stormwater treatment directly into the architecture of the building, which eliminates the need to consume surface land. They provide modest levels of runoff reduction, and can be major compliance element at many high intensity redevelopment sites. Their high installation cost is compensated by long term savings in energy consumption and roof longevity.

Best Available Guidance: CSN released a Bay-wide design specification in 2010 for green roofs, which can be accessed in Appendix A. The difficulty is that there is no such thing as a generic green roof – each green roof contractor has their own unique recipe for green roof components, which need to be adjusted depending on the nature of the planned roof. Also, the average stormwater designer cannot size, design, specify or install a green roof from scratch, but must consult with architects, structural engineers and specialized green roof experts.

Barriers to Overcome: Several real and perceived barriers need to be surmounted to achieve wider implementation of green roofs in the Bay watershed. By far and away, the single greatest barrier revolves around construction cost, followed by the reluctance of designers to consider them. Lastly, not all buildings are good candidates for green roofs, as they require an informed and engaged building owner.

Fostering Greater Bay-wide Implementation: States and localities can apply several strategies to increase green roof utilization:

- Develop a list of specialized green roof contractors
- Provide greater financial subsidies for green roofs, in terms of lower stormwater utility rates or demonstration grants
- Provide stormwater credits for green roofs, whereby recharge requirements are waived and a certain portion of non-rooftop area is exempted from water quality requirements
- Share updated data on green roof installation costs
- Conduct training workshops for designers that foster greater interaction with green roof specialists
- Modify the design criteria in MDE (2009) to designate green roofs as a micro-ESD practice rather than an alternate surface.

Rainwater Harvesting systems intercept, divert, store and release rainfall for future use. Rainwater harvesting is also known as cisterns or rain tank. Rainwater that falls on a rooftop is collected and conveyed into above- or below-ground storage tanks where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing, fire suppression systems, water cooling towers, ornamental fountains, and laundry, if approved by the local authority.

Why Is It Preferred? High redevelopment intensity often generates higher demand for both indoor non-potable water and outdoor landscape irrigation water, which means that substantial runoff volumes can be reused throughout the year. Installation costs are moderate in comparison to other preferred redevelopment practices at about $15 per cubic foot of runoff treated.

Best Available Guidance: CSN released a Bay-wide design specification in 2010 for rainwater harvesting, along with a sizing spreadsheet, both of which can be accessed in Appendix A. As with green roofs, novice stormwater designers can't size and spec a rainwater harvesting system from scratch right now. They need to get technical assistance from rain tank vendors and support from local plan reviewers to get their systems approved.

Barriers to Overcome: The primary barriers to widespread installation of rainwater harvesting systems are conflicting or restrictive local plumbing or sanitation codes. Some Bay communities require unnecessarily expensive treatment or disinfection requirements for harvested rainfall before it can be used for non-potable purposes. Other communities currently have no guidance on whether rainwater harvesting systems are permissible. Another barrier is lack of knowledge --60% of designers and local plan reviewers in the watershed have never designed or approved a rainwater harvesting system (CBSTP, 2010).

*Fostering Greater Bay-wide Implementation: S*everal strategies could increase the use of rainwater harvesting systems in the watershed:

- Convene state meetings to develop unified standards for model local plumbing and sanitation codes that promote use of non-potable water through rainwater harvesting systems.
- Develop a list of specialized rain tank vendors and contractors
- Provide stormwater credits for rain tanks whereby recharge requirements are waived and a certain portion of non-rooftop area is exempted from water quality requirements.
- Conduct interactive training workshops with designers and local plan reviewers.

Foundation Planters (also known as vegetative box filters or stormwater planters) take advantage of limited space available for stormwater treatment by placing a soil filter in a container located in landscaping areas between buildings and roadways. The small footprint of foundation planters is typically contained in a precast or cast-in-place concrete vault.

Why Is It Preferred? The small footprint of foundation planters allows designer to combine stormwater treatment with attractive landscaping at many high intensity redevelopment projects.

Best Available Guidance: The only Bay-wide guidance on foundation planters is provided in the Urban Bioretention specification that can be accessed from Appendix A. Although the CSN specification includes useful sizing and design criteria, it needs to be augmented with the more detailed information from the recently updated Portland stormwater manual (COPO, 2009). Several other design issues need to be resolved to adapt the practice for the climate and growing conditions of the Chesapeake Bay.

Barriers to Overcome: To date, only a handful of foundation planters have been installed in the Chesapeake Bay, which suggests that most designers and plan reviewers are not familiar with them.

Bay-wide Design Criteria: Several ideas are suggested to refine the existing bay-wide specification for the design of foundation planters:

- Sizing equations need to be developed to reflect the unique performance standards in each Bay state. For example, in Maryland, it is recommended that the micro-ESD practice sizing equation of Pe = 15" x Surface Area/CIDA be used.

- Foundation planters work on a rapid flow-thru design so that they operate more as a filtering practice than a runoff reduction practice, although some evapotranspiration does occur during the growing season. To this end, it is recommended that the planter media should consist of two lifts with different media recipes. The bottom foot should be 100% sand, whereas the top lift should be consist of 80% sand with the remainder as an organic soil compost mix that can meet plant nutrient requirements. The high sand recipe is needed to prevent water logging and to reduce the potential for nutrient leaching from the organic media.

- Greater input is needed from landscape architects on the plant species or cultivars that flourish best in the sand media and moisture conditions of foundation planters, and yet still provide the desired landscape amenities. Although native species are preferred, non-native species should be allowed given the ultra-urban environment.

- Simple maintenance and replanting guidelines also need to be developed so that landscape contractors can maintain the hydrologic function of planter as they conduct their routine seasonal landscaping tasks.

- Each individual planter should be stenciled or otherwise permanently marked to designate it as a stormwater practice. The stencil or plaque should indicate (1) its water quality purpose, (2) that it may pond briefly after a storm, and (3) that it is not to be disturbed except for required maintenance.

Permeable Pavers are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including pervious concrete, porous asphalt and permeable interlocking concrete pavers. While the specific design may vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone reservoir layer and a filter layer installed on the bottom.

Why Is It Preferred? Permeable pavers can be applied at pedestrian and parking areas, plazas and other hardscapes found at many redevelopment sites. As a shallow underground practice, permeable pavers reduce land consumption for stormwater treatment. When designed and installed properly, permeable pavers are a very effective option for portions of high intensity redevelopment sites.

Best Available Guidance: CSN released a Bay-wide design specification in 2010 for permeable pavers which can be accessed in Appendix A. Designers can use the basic specification from scratch, but may want to contact paver manufacturers to get additional product guidance and obtain a list of certified paver installers.

Barriers to Overcome: Many designers and plan reviewers are hesitant to use permeable pavers due to general concerns about past failures, and more specific concerns about the wisdom of infiltrating at redevelopment sites, particularly those with urban fill or hydrologic soil group "D" soils. While there are some infiltration restrictions associated with urban soils (see Section 4.9) they can be designed for extended filtration rather than infiltration (e.g., using under drains when soil infiltration is low or not desirable).

Fostering greater Bay-wide implementation: States and localities can apply several strategies to increase the utilization of permeable pavement:

- Develop a list of specialized permeable paver vendors, suppliers and certified installers
- Modify the design criteria in MDE (2008) to designate permeable pavers as a micro-ESD practice rather than an alternate surface, and eliminate the prohibition of pavers on HSG D soils if they are installed with under drains for extended filtration

- Demonstrate permeable pavers in municipal construction projects to gain more acceptance

Extended Tree Pits are installed in the sidewalk zone near the street where urban street trees are normally planted. The soil volume for the tree pit is increased and used for stormwater treatment. The treatment volume can be increased by using a series of connected tree planting areas together in a row. The surface of the enlarged planting area may be mulch, grates, permeable pavers, or conventional pavement. The large and shared rooting space and a reliable water supply increase tree growth and survival rates in this otherwise harsh planting environment.

Why Is It Preferred? Extended tree pits promote effective stormwater treatment and urban street tree survival in the urban streetscape without sacrificing space or urban function.

Best Available Guidance: The only current guidance on extended tree pits is provided in the Urban Bioretention design specification that can be accessed from Appendix A. Some general concepts on tree pits are also provided in Cappiella et al (2006). With the exception of Virginia, extended tree pits are not specifically included in Bay state stormwater manuals. More detailed design schematics and sizing criteria for tree pits can be borrowed from the Portland stormwater manual (COPO, 2009).

Barriers to Overcome: To date, very few extended tree pits have been installed in the Bay watershed, although some demonstration projects have recently been implemented in the city of Baltimore. The primary barrier to greater use of extended tree pits are concerns among designers about whether tree pits would be approved by the many different municipal agencies, utilities and urban foresters that collectively regulate the design of the urban street right of way. Until standard tree pit specifications are accepted by the local agencies, it is difficult to use extended tree pits to replace traditional urban street tree plantings requirements.

Fostering Greater Bay-wide Implementation: The use of extended tree pits could be expanded if a state or regional work group were convened that was charged with creating unified local standards and details that could be endorsed by local urban forestry experts.

Green Street Retrofits. A private redevelopment project cannot install green streets without major assistance from a municipality. They are an attractive option but require considerable interagency coordination and leadership by a municipality. Given that green streets are still in their infancy in the Bay watershed, they are considered a special category of preferred redevelopment practices, and are described in greater detail in section 7.

Urban Soil Restoration and Reforestation involves restoring compacted soils and planting trees at a redevelopment site with the explicit goal of establishing a mature forest canopy that will intercept rainfall, increase evapo-transpiration rates, and enhance soil infiltration rates. Reforestation areas can be located on existing turf, barren ground, vacant land or impervious cover conversion areas.

Why Is It Preferred? Even small units of soil restoration and reforestation in urban watersheds can help meet local forest canopy goals and provide effective stormwater treatment at the same time.

Best Available Guidance: While there is excellent guidance on urban reforestation (Cappiella et al, 2006b) and a Bay-wide design specification for soil restoration (Appendix A), there is no explicit stormwater treatment credit to combine them together at a redevelopment site or as an offset. Designers in Virginia do get some credit for converting turf into forest, but the credit is loosely defined.

Barriers to Overcome: the primary impediment to wider implementation of this practice is the lack of an approved specification that designers can use to get credit for stormwater treatment. Engineers and urban foresters are encouraged to refine the proposed design criteria that are suggested below, and incorporate the final criteria into local and state stormwater manuals.

Proposed Bay-wide Design Criteria: There is very limited data to evaluate the degree of runoff reduction associated with urban soil restoration and reforestation. An initial analysis of the runoff differential between turf and forest cover suggests that ten acres of soil restoration and urban reforestation is equivalent to one inch of runoff reduction treatment at one acre of impervious cover (Biohabitats, 2009). Put another way, each 5000 square foot unit of restored forest would treat the equivalent of 360 cubic feet of runoff.

Designers can further increase the volume of stormwater treatment if the reforested area is used to disconnect adjacent impervious cover. This additional volume of treatment achieved by disconnection can be computed using the filter strip sizing rules and design criteria outlined in MDE (2009) and VADCR (2009).

Stormwater credits for soil restoration and reforestation are subject to the following qualifying conditions:

- The minimum contiguous area of reforestation must be greater than 5,000 square feet.
- If soils are compacted, they will need to be deep tilled, graded and amended with compost to increase the porosity and water holding capacity of the pervious area, using the methods outlined in the Bay-wide soil restoration specification (Appendix A)

- The proposed reforestation must be for the purpose of reducing runoff. Reforestation required under the Maryland Forest Conservation Act is not eligible for the credit
- A long term vegetation management plan must be prepared and filed with the local review authority in order to maintain the reforestation area in a forest condition.
- Planting plans for redevelopment sites should emphasize balled and burlapped tree stock from 1 to 4 inches in diameter. The primary reason is to quickly achieve the desired tree canopy and ensure that the individual trees are visible enough so they are not disturbed, mowed or otherwise damaged as they grow in the ultra-urban environment.
- The planting plan does not need to replicate a forest ecosystem or exclusively rely on native plant species, but it should be capable of achieving 75% forest canopy within ten years
- The reforestation area must be protected by a perpetual stormwater easement or deed restriction which stipulates that no future development or disturbance may occur within the area, unless it is fully mitigated.
- The planting plan must be approved by the appropriate local forestry or conservation authority, including any special site preparation needs.
- The construction contract should contain a care and replacement warranty extending at least 3 growing seasons, to ensure adequate growth and survival of the plant community. Control of invasive tree species should be a major part of the initial maintenance plan
- The reforestation area shall be shown on all construction drawings and erosion and sediment control plans during construction.
- The reforestation should be permanent, and accompanied by a deed or covenant that specifies that the area cannot be rebuilt in the future, without full mitigation.

6.2 Acceptable Redevelopment Stormwater Practices

Four practices are considered an acceptable design solution at most redevelopment sites – sand filters, bioretention, urban tree planting and natural area restoration.

Sand Filters make sense at redevelopment sites**,** particularly when hotspots are present or infiltration restrictions require use of filtering practices. Several design variants such as the perimeter or underground sand filter can reduce space consumption at high intensity redevelopment sites. A Bay-wide design specifications for sand filters was released by CSN in 2010, but the basic design has not changed much since it was first published in the Maryland stormwater manual (MDE, 2000). Sand filters have reasonable nutrient removal rates, but do not appear to have much runoff reduction capability.

Bioretention can work at all but the most high intensity redevelopment sites, as it requires a surface area of about 5 to 7 % of the contributing drainage area at a highly impervious site. Bioretention is a versatile practice and most designers have a fair amount of experience with it. An updated Bay-wide design specification is available from CSN for both traditional and urban forms of bioretention. Designers should keep in mind that there are some important differences in bioretention design when it is applied at high intensity redevelopment projects compared to lower density suburban areas.

When bioretention is installed in highly urban settings, individual units will be subject to higher public visibility, greater trash loads, pedestrian traffic, vandalism, and even errant vehicles. In addition, the presence of adjacent multi-story buildings subjects individual bioretention areas to a wider range of micro-climates and shading conditions. Designers should anticipate these urban stressors to create a design that prevents or at least minimizes future problems.

- When urban bioretention is used within sidewalks or areas of high foot traffic, the bioretention area should not impede pedestrian movement nor create a safety hazard.

- Designers may also install low fences, grates or other measures to prevent damage from pedestrian short-cutting across the bioretention area.

- The bioretention planting plan should reflect its urban landscape context, which might feature naturalized landscaping, a more formal landscape design, or a serve as a specialty garden. Landscape architects should be consulted to ensure that high visibility urban bioretention areas are adapted for their micro-climate and will be a functional and attractive landscape amenity through all seasons of the year.

- Urban bioretention also requires more frequent landscaping maintenance than more suburban applications in order to remove trash, check for clogging, and maintain vigorous vegetation.

Urban Tree Planting is essentially treated as a disconnection. The only available guidance on the stormwater benefits of urban trees is that each mature street tree is assumed to remove the equivalent of 100 square feet of impervious cover from a redevelopment (or about 15 cubic feet of runoff, COPH, 2009). Recommended criteria for effective urban tree planting are described in considerable detail by Cappiella et al (2006b). While the technical basis for the street tree credit is rather limited, it can help provide a small fraction of treatment at high intensity redevelopment projects.

Restore Natural Area Remnants As noted in Section 4.8, restoration of urban wetlands and natural area remnants at a redevelopment site should be considered an acceptable stormwater compliance alternative particularly if the remnant current receives runoff generated from the site. Specific techniques for assessing urban wetland condition and restoration potential can be found in CWP (2005 and 2006).

Urban wetlands are an important element of green infrastructure, and their restoration can enhance hydrological function in small watersheds. The key problem is that designers cannot compute the precise runoff quantity or quality benefit achieved by an individual urban wetland restoration project. Given the importance of the remaining natural areas in urban watersheds, however, it is recommended that designers be granted a credit for wetland restoration (either as a preferred offset or a one to one area credit).

6.3 Restricted Redevelopment Stormwater Practices

Proprietary Practices include manufactured devices that use various hydrodynamic and/or filtration technologies to treat the stormwater flows from small areas. In general, they are designed to treat a rate of flow rather than a defined runoff treatment volume. Consequently, most have very low runoff reduction rates. In addition, reliable data on pollutant removal performance are lacking for most proprietary practices, and relatively few are accepted for more than pretreatment purposes by Bay state stormwater agencies. Until better performance data becomes available, designers should restrict use of proprietary practices at redevelopment sites to those that have received state approval and have defined runoff and pollutant reduction rates.

Infiltration practices are restricted in some redevelopment situations because of brown-field, hotspot or urban soil considerations, as described in Section 4.9. Otherwise, infiltration practices are an acceptable option, although it is advisable to provide extra pretreatment at high intensity redevelopment sites.

Dry wells are the most common infiltration application at residential redevelopment sites. Experience has shown that they appear to work effectively when properly located on permeable soils. The basic design of dry wells has not changed much since they were introduced in Schueler (1987). A significant improvement in basic dry well design, however, was recently issued by CC BRM (2010, p. 45). The improved design includes a simple but more effective pretreatment system, and standardized “plumbing” components that are readily available from most hardware stores and can be put together easily.

6.4 Marginal Redevelopment Stormwater Practices

Several space-intensive stormwater practices are seldom feasible at high intensity redevelopment projects, and are therefore classified as being of marginal value. They practices include:

- Most rooftop and non-rooftop disconnections credits
- Micro-ESD practices, as described in MDE (2008), such as landscape infiltration, submerged gravel wetlands, rain gardens and micro-bioretention
- Wet swales
- Filter strip
- Grass channels
- Constructed wetlands
- ED ponds
- Wet ponds

The fact that these practices are classified as marginal is not meant to categorically exclude their use at redevelopment sites, but simply indicate that they will rarely be feasible, except in a limited number of special cases.

There are unique design variants of some marginal practices that might work at redevelopment sites. For example, while space is seldom available for conventional constructed wetlands, the regenerative conveyance system (RCS) wetlands may be a useful option if runoff discharges to an eroded zero- order stream or ravine. In addition, several marginal practices such as ponds and constructed wetlands are ideally suited for storage retrofits in highly urban watersheds (Schueler, 2007).

Section 7
The Municipal Role in Green Street Retrofits

Green streets utilize bioretention and other vegetative practices within the public street right of way. They are gaining popularity in other parts of the country as an attractive option to treat stormwater runoff in highly urban watersheds. Green streets provide many urban design benefits and create a more attractive and functional urban streetscape (COE, 2005, COPH, 2008, COPO, 2008, SMC, 2009). The linear nature of green streets also make them a very efficient LID practice in that they can treat several acres of impervious cover in a high density areas (compared to the much smaller drainage areas treated by other preferred redevelopment LID practices).

To date, however, green streets have not been widely used within the Chesapeake Bay watershed. Less than a dozen green street retrofit projects have been installed, although several more are currently in the design phase. This section summarizes the experience gained so far in initial demonstration projects in the City of Baltimore and in the Washington suburbs.

7.1 Interagency Coordination and Leadership

A key lesson from the first generation of green streets is that they require an enormous amount of interagency coordination to get final approval. The design of urban streets and their rights of way are fundamentally shaped by dozens of competing demands and interests. Examples include water, wastewater and telecommunication utilities, street lights, traffic engineering, pedestrian movement and safety, street trees, urban design, merchant visibility, on-street parking (and meters) and many others. Only recently has stormwater treatment arrived on the scene to compete on this crowded stage.

Significant municipal leadership is needed to motivate agencies and utilities to come to the table to arrive on consensus about green street design. The next stage involves a round of initial demonstration projects on a few street segments to test green street concepts and convince the skeptics. The third stage involves changing local street codes to allow a standard green street option. The last stage is to create a green street delivery program so that they are the preferred option for municipal capital budgets for neighborhood revitalization, street improvements and urban streetscapes. Many communities in the Pacific Northwest have evolved their green street programs through all four stages, but Bay communities are now just progressing through the first two stages.

7.2 Public Support for the Green Street Product

Experience elsewhere indicates that once the public sees the green street product, they really like it, and express strong grass roots support to build more of them in their cities and neighborhoods. While the public may not fully understand the role of green streets in stormwater mitigation, they clearly perceive strong benefits in the form of expanded tree canopy, attractive streetscapes, cleaner air, revitalization of neighborhoods and communities, safer and more pedestrian-friendly streets, and most importantly, increased property values. Public acceptance of green streets is so great in urban areas of Pacific Northwest that individual neighborhood associations compete for privilege of getting a green street retrofit.

The problem in the Bay watershed is that there is not yet a lot of green street product for the public to see. Philadelphia has found success in developing before and after “photos” of the amenities that green streets afford (COPH, 2009).

7.3 Initial Demonstration Projects Are Costly.

The cost to install the first generation of green streets in our region is about $167,000 per impervious acre treated. While this is roughly 3.5 times the cost of implementing LID practices at green-field developments, it is slightly less than the private sector cost of installing LID practices at high intensity redevelopment projects (Table 8).

A major reason for the high cost is the "prototype effect" that is encountered when a new technology is constructed for the first time. For example, more than half of the total cost for the initial demonstration projects was devoted to project design, engineering, permitting, interagency approvals, neighborhood consultation and traffic management planning.

For example, Stack (2010) reports that nearly a dozen municipal permits or sign offs were needed to get final approval for demonstration green street projects in the City of Baltimore. Many city agencies were reviewing items they had never seen before which greatly delayed the final approval process. Some of the key approvals included sign offs on the use of city right-of-way, highway design, parking, street lighting, traffic engineering, erosion and sediment control, wastewater engineering and stormwater compliance. In addition, contractors bidding on the project were building green streets for the first time, and probably bid higher to cover unexpected contingencies.

Green street costs should begin to decline on a unit basis as more standardized design templates are developed and contractors gain more experience in building them. In addition, more analysis is needed to determine if there is any incremental cost difference between green streets and traditional street-scaping projects.

7.4 Specialized Construction Issues for Green Streets

The highly urban setting of green street constructions creates some unique issues that drive up costs:

- *Neighborhood Disruption.* The time frame to construct green street retrofits in Baltimore averaged 10 to 30 days, which means that the public access to streets, parking driveways, sidewalks was severely curtailed. Consequently, it was important to notify and consult adjacent residents about these impacts prior to construction to minimize complaints and problems.

- *Maintenance of Traffic.* Early experience suggests that green street construction requires temporary closure of at least two travel lanes. These changes to traffic patterns and on-street parking availability require the contractor to budget for traffic control throughout the construction process to keep workers safe, which can be a significant project expense.

- *Ongoing Coordination with Utilities and Other City Agencies.* Most of the advance permits secured to construct green street projects include specific provisions to inspect existing city infrastructure during and after construction to ensure it is not damaged or degraded (e.g., street lights, parking meters, utility pipes, streets, adjacent pavement surfaces, etc). The project manager and contractor can expect multiple inspections during the course of construction.

- *Tough Construction Environment.* Green streets pose several challenges that drive up the cost of construction. For example, there is not a lot of extra space at green street projects to store equipment and construction materials and stage the full sequence of construction. Security at many sites is poor, which means equipment may need to de-mobilized each day to prevent vandalism. Finally, most projects involve a lot of cut and virtually no fill, so that contractors face the added expense of hauling excavated soils and other materials away from the job-site.

7.5 Local Green Street Design Templates and Unit Specs

The ultimate goal of demonstration projects is to learn lessons about real world implementation that can be used to craft enhanced green design standards, as has been done elsewhere (COPO, 2008, COPH, 2008 and SMC, 2009). Each city and county in the Bay watershed has its own unique set of standards (except for Virginia, where the state DOT still retains much of the authority for local street standards). A few communities in the Bay watershed have made some progress toward better street standards, most notably Montgomery County, Maryland (MC, 2008).

Given the variability of existing urban street conditions, it is not wise to seek a single road and right of way specification that applies to all green street retrofits. Rather, it makes more sense to develop a series of general green street design templates for a range of typical traffic, parking and sidewalk conditions (SMC, 2009). Each template would then show the recommended combination of LID "unit" practices that can be applied in the retrofit (e.g., foundation planters, expanded tree pits, permeable pavers, etc.). Ideally, there would be a locally adapted and approved design specification for each of these unit practices.

While each locality may ultimately need to draft their own green street standards, it makes sense to form a Bay-wide workgroup composed of highway engineers, stormwater designers and other urban street stakeholders. Such a group could greatly reduce local costs to create their own templates and specifications from scratch. The workgroup could advance green streets by trading ideas about what has worked (or not), and sharing model language, design schematics and construction specifications. The workgroup could also assemble a visual library of green street demonstration projects across the Bay watershed to show both the public and skeptical city planners that the concept can be successfully imported to our region.

Section 8
Setting up Local Stormwater Offset Fee Programs

The argument for establishing local stormwater offset fee programs to accommodate redevelopment when full compliance is not physically or economically possible was described in Section 4.10. Nearly every Bay state authorizes localities to charge a stormwater offset fee for redevelopment projects. To date, however, relatively few localities in the Bay watershed have actually developed offset programs. Staff are often unsure what price should be charged and how and where the offsets should be administered. This section provides local stormwater managers with several simple options to get an offset program off the ground.

8.1 Experience to Date with Local Stormwater Offsets

About a third of Maryland *co*mmunities currently offer stormwater offset programs that apply to redevelopment (RKK, 2010), which also seems to be consistent with the frequency they are offered in other Bay states. The first generation of stormwater offsets occurred in the 1990s, and applied primarily to projects within the 1000 foot Maryland Critical Area. The recommended offset fee was based on the actual cost to remove a pound of phosphorus using stormwater retrofits (CAC, 2003). The offset fee ranged from $22,500 to $29,000 per pound of phosphorus mitigated (Note: the cost to remove a pound of phosphorus is roughly equivalent to the cost to treat one acre of impervious cover, using the Simple Method to predict phosphorus loads, and assuming an average of 50% TP removal rate).

Virginia has proposed a similar offset fee in its proposed stormwater regulations of $22,900 per pound of phosphorus (VA DCR, 2010). Stormwater offset fees in Maryland (outside of the Critical Area) are generally expressed using the unit of impervious acres requiring treatment. An unpublished survey of seven Maryland communities reported a mean offset fee of $24,000 per acre of impervious cover requiring treatment, with range of $5,000 to $43,500 (RKK, 2010).

In nearly every case, revenues collected from off-set fees are used to construct public sector retrofits, and a few communities set them based on their past capital budget experience with retrofit construction. The majority, however, appear to set the offset fee based on the projected private sector cost to construct stormwater practices at new development sites. Most of the offset fees that are currently levied appear to be too low to recover the full cost to provide an equivalent amount of treatment elsewhere in the watershed.

8.2 Updated Urban Stormwater Cost Data

This section analyzes the cost to provide stormwater management for six different land development scenarios, to establish the range of potential offset fees for redevelopment sites where full compliance is not possible. The six scenarios were used to project typical costs to treat stormwater at:

- Ultra-urban redevelopment sites, using LID practices
- New development in a green-field setting, using traditional stormwater practices (e.g., MDE, 2000)
- New development in a green-field setting, using LID practices to the full maximum extent practicable.
- Retrofitting green-field development using storage retrofits
- Retrofitting ultra-urban development using green streets
- Comprehensive stream restoration

The six stormwater design scenarios enable local stormwater managers to set an appropriate fee based on the kind of development they experience and the mitigation methods they intend to employ. The methods, sources and assumptions used in the cost analysis are discussed in detail in Appendix B. Several interesting findings are evident from the cost analysis which is summarized in Table 7.

Table 7
Cost to Treat One Acre of Impervious Cover in Maryland[1,2]

Stormwater Management Scenario	Sector	$ [3]
New Development Pre-ESD (MDE 2000 manual)	Private	$ 31,700
New Development, ESD to MEP (MDE, 2009)	Private	$ 46,500
Urban Redevelopment Using LID (IC >85%)	Private	$ 191,000
Storage Retrofits in Urban Watershed	Public	$ 32,500
Green Street Retrofits, Highly Urban	Public	$ 167,100
Stream Restoration, Nutrient Equivalent	Public	$ 35,600

[1] also equivalent to reducing one pound of total phosphorus.
[2] Costs in other states will be slightly different, based on their sizing requirements in their stormwater regulations
[3] costs expressed in 2010 dollars

- The shift from traditional stormwater practices to LID practices at new development sites appears to have increased compliance costs from $31,700 to $46,500 per acre of impervious cover treated (or about 47%). Some of the cost increase can be attributed to increased sizing requirements, but most of it is due to the higher unit cost of LID practices, in comparison to traditional ponds. It should be kept in mind, however, that ESD designs may significantly reduce the size and cost of the conveyance and detention components of the stormwater system for a site.

- This finding suggests that localities that have based their offset fees on the private sector cost to construct stormwater practices at new development sites may need to sharply increase them. For example, existing offset fees in the $22,000 to $29,000 range (Section 8.1) may need climb to about $45,000 to $50,000 per impervious acre to reflect current design requirements.

- The cost to install LID practices is much higher at high intensity redevelopment sites – an estimated $191,000 per impervious acre treated. The cost differential is almost entirely due to the high unit costs for LID practices at high intensity redevelopment practices, given that the redevelopment stormwater treatment requirements are much lower than those encountered at green-field sites. It is extremely important to place this very high cost estimate in its proper context. The cost scenario was developed assuming the urban redevelopment project has 85% or more impervious cover, and virtually no surface area for LID practices.

- The cost differential between redevelopment and new development narrows when post-development impervious cover in the 65 to 85% range, and appears to become virtually non-existent for redevelopment projects with less than 65%, since these can generally use the same surface LID practices that are used at green-field projects.

- Three stormwater cost scenarios were developed to assess common offset options which involve the public sector cost to find, design, permit, contract, construct and maintain a restoration project.

- Storage retrofits involve creating new runoff storage in a new or existing stormwater facility, usually in the form of a constructed wetland, pond or filter. At $32,500 per impervious acre treated, storage retrofits are an attractive offset option, although the number of candidate projects may be limited in ultra-urban watersheds.

- Stream restoration is also cost-effective at about$35,600 per nutrient equivalent impervious acre treated. This cost scenario equates the nutrient reduction associated with stream restoration due to reduced bank erosion and increased in-stream processing load reductions achieved by retrofit treatment (Biohabitats, 2010).

- The public sector cost for green street retrofits is approximately $167,000 per impervious acre treated, which may be on the high side for reasons outlined in Section 7.3. This offset option best applies to highly urban communities with extremely limited potential for storage retrofits or stream restoration practices.

8.3 Basic Principles for Stormwater Offset Programs

The following principles are offered to develop effective and accountable programs to handle stormwater offsets for redevelopment projects.

*Offsets should be Municipally Driven and Administered***.** It is strongly recommended that stormwater offset programs should be municipally-driven (i.e., the locality collects the fee and uses it to find and install qualifying projects elsewhere in the same watershed). There are several reasons why it makes sense for localities to take responsibility for their offset program:

- It provides a revenue stream to help reduce the future local nutrient liability confronting a locality under the Bay TMDL and/or the next MS4 permit.
- Localities are often in the best position to identify the most strategic and cost effective projects across their watershed.
- Localities can generally provide better quality control and delivery of retrofit projects over time.
- Redevelopers can obtain project approval quicker, removing a potential barrier to smart growth.

In theory, it is possible to shift the responsibility for finding and building offset projects to the developer, but this may not be a great idea in practice. First, designers incur high transaction costs to search for an acceptable offset within a locality. If the offset is on private land, it will be difficult to find a third party willing to accept the cost of future maintenance and other liabilities associated with the proposed offset project. If the offset occurs on public land, designers can expect lengthy negotiations with the local land management agency and face the perception that scarce public land is being sacrificed for developers. The search for an acceptable private sector offset has the potential to sharply increase compliance costs and injects delays and uncertainty into the project approval process

*Offsets Should be Simple to Administer and Verify***.** The offset fee should be expressed in simple unit terms that can be directly computed from redevelopment site data and/or stormwater spreadsheet computations. In most states, this common unit will be:

- Pounds of phosphorus load remaining above a benchmark or baseline annual load (Virginia)
- Fraction of an acre of remaining untreated impervious cover at the site (Most of Maryland)
- Per cubic feet of untreated water quality volume (Possibly the District of Columbia and West Virginia)

Offsets Must Occur Within the Same Sub-Watershed, which is operationally defined as the scale associated with the USGS 12 digit hydrologic unit code mapping systems. These subwatersheds normally range from 15 to 75 square miles in area in the Bay watershed. For smaller cities, this scale means the offset project can occur pretty much anywhere in their jurisdiction. In a larger county, this scale ensures that there is a linkage between where the redevelopment impact occurs and where it is mitigated.

*Offsets Should Require Some On-Site Treatment***.** Offsets should only be allowed if the designer can demonstrate that a reasonable effort has been made to install LID practices at the site. The basic idea is that they can't just write a check to avoid the entire cost of LID implementation. On-site LID practices can always be implemented to some degree at nearly every redevelopment site (e.g., a foundation planter, impervious cover conversion, urban tree planting).

It is therefore a reasonable expectation to only to grant an offset if the project exceeds a minimum level of the total water quality treatment requirement for the site. It is recommended that the treatment threshold be:

- 10% of the treatment volume for projects with 85% post-construction IC
- 15% of the treatment volume for projects with 75 to 84% IC
- 20% of the treatment volume for projects with 65 to 74% IC
- Offsets should generally not be granted for redevelopment projects with less than 65% IC since they have sufficient surface area to meet the full water quality requirement.

Acceptable Locations for Offsets Should be Clearly Defined. Localities need to decide where it is permissible to install offsets, based on land ownership and maintenance capability.

- Should the offsets be exclusively located on public land or is it permissible to locate them on private land?
- Can a locality upgrade or retrofit existing stormwater practices that are owned by homeowner association or a private landowner?
- Is it acceptable to subsidize LID retrofits on individual residential properties?

In most cases, the local charter or budget rules specify where offset fees can be expended. If offset funds can be spent on private land, it is advisable to do so, since it provides greater flexibility in meeting future offset needs.

Decide Which Types of Offset Projects Are Eligible in Your Community. The next decision involves determining what types of projects will qualify as offsets. The universe of potentially eligible offset options is fairly long and includes:

- Storage retrofits
- On-site LID retrofits
- Green street retrofits
- Major maintenance upgrades for existing stormwater practices
- Urban stream restoration
- Urban wetland restoration
- Soil restoration and reforestation
- Other projects that can reduce runoff and/or remove nutrients

While it is tempting to use the entire list, each offset option differs with respect cost, availability and nutrient reduction capability. The key point is to select just a few options to start with that are well understood, cost effective, and have proven nutrient reduction capability. The list of qualifying projects can always be expanded in the future as a community gains more experience with different retrofit or restoration options. It is also important to define the kinds of projects that **do not** qualify for offsets. The most common example would be for ongoing programs and operations that are already required under a municipal stormwater permit, such as street sweeping or illicit discharge investigations.

Choose an Efficient Method to Deliver Offsets. Localities will need to make careful choices as to what mechanism(s) will be used to deliver the offset projects over time. Most localities will use the capital construction budget as the primary delivery mechanism, but there are other strategies that could also work effectively to pool funds to provide:

- Tax credits to homeowners that install LID practices of their property
- Mini-grants to local watershed groups to support implementation of small-scale restoration projects, such as reforestation, as part of an overall watershed plan.
- Direct subsidies to partially defray the cost of installing experimental practices such as green roofs to increase local experience and drive down unit costs.
- Provide technical assistance and cost-sharing to implement stormwater treatment and/or pollution prevention practices at individual businesses or stormwater hotspots.

Local Stormwater Offset Programs Should Be Accountable. Stormwater offset programs are regarded with some suspicion by both developers and environmental advocates, much in the same way as wetland mitigation banking was regarded in its formative years. Therefore, it is critically important to craft an offset program that is transparent and can quantitatively demonstrate that it is providing an equivalent degree of runoff reduction or pollutant removal. A good local offset program has the following accountability elements:

> *Dedicated Account:* All funds collected from offset fees should be deposited in a dedicated fund for the sole purpose of constructing qualifying offset projects. The fund should be restricted so that it cannot be tapped to meet other municipal needs.
>
> *Fiscal Accountability:* A locality should track offset fees collected and funds disbursed for offset projects over time, and provide the annual balance and financial status in their NPDES MS4 annual report.
>
> *Reversion Clause:* If the locality accumulates offset fees but does not expend them within a five year time period, the funds should automatically revert to a pre-defined state agency, foundation or watershed group with capacity to expend them on restoration projects.
>
> *Watershed Restoration Inventory:* The program should have a current watershed restoration inventory that identifies priority retrofit and restoration projects for offset implementation. Most urban communities in the Bay watershed have completed watershed restoration plans in the past. In some cases, the plans may need to be re-evaluated to find the projects with the greatest nutrient or runoff reduction benefit.
>
> *Retrofit Registry.* The locality should develop and maintain a retrofit registry that tracks the status of offset project implementation and the number of acres of impervious cover treated. The registry should also track the cumulative acres of impervious cover for which offsets have been granted. The registry can be configured to show whether there is a surplus or deficit in offset treatment, and should be prominently displayed in the annual NDPES MS4 report. Localities are also advised to link their retrofit registry with their overall nutrient accounting system to meet their pollutant load reduction requirements under their Bay-wide nutrient TMDL allocation or MS4 permit.

*Offset Fees Should be Equitable***.** Localities should charge an offset fee that is reasonably equitable, so that it does not unduly penalize redevelopment projects compared to new development projects. At the same time, the fee should not be so low that it undercuts the need to provide some LID at most redevelopment projects (i.e., the offset fee should not be cheaper than cost of full LID compliance at new development sites).

Offset Fees Should be Indexed for Inflation. One of the most common mistakes is to include a fixed offset fee schedule in a local stormwater ordinance that cannot be increased unless the statute is re-enacted. Within a few short years, revenues collected from offset fees can no longer recover the full cost to the public sector to build the projects. Therefore, the offset fee schedule should be indexed for construction inflation so that it can keep up with the true cost of retrofit implementation over the years. The accepted industry index to cite is the annual construction inflation index published by the *Engineering News Record*.

8.4 Establishing the Optimum Local Offset Fee Schedule

The cost analyses presented in section 8.2 suggest that local offset fees could range anywhere from $30,000 to $200,000 per impervious cover treated**.** Setting the price for offsets should always be a local decision, given that each is unique with respect to its existing development intensity, expected redevelopment activity, retrofit opportunities, staff capability, business climate and future nutrient reduction liability. With this in mind, six different options are offered below to help local managers decide which fee level to charge:

Option 1: Public Sector Cost for Retrofits/Restoration in Suburban Areas
$32,500 to $35,600 per untreated impervious acre or pound of phosphorus removed.

> This first option is the lowest offset fee, since it takes advantage of the economies of scale associated with building storage retrofits and/or stream restoration on larger parcels of public land in the watershed. This option works best in larger counties with moderate development intensity, abundant retrofit opportunities and past experience in delivering watershed retrofits. The option is not recommended for larger cities that are already intensively developed, since they often lack the abundant and less expensive storage retrofit opportunities of their suburban counterparts. This option may also be questionable for small towns and cities since they may not have the redevelopment activity or staff capability to operate a local retrofit program.

O*ption 2: Private Sector Cost of Full LID Compliance at Greenfield Sites*
$46,500 to $50,000 per untreated impervious acre or pound of phosphorus removed.

> The second option may be the most equitable approach, since it ensures that the cost of compliance will be no different at redevelopment sites than at new green-field sites. This option dispels the smart growth argument that stormwater compliance costs would dictate where growth occurs in the region. The higher revenues recovered under this fee schedule would still be used to finance public sector retrofits, and would allow a more diverse range of storage and LID retrofits to be considered. In this sense, it may be attractive to less intensively developed communities with little

experience yet in finding and delivering offset projects. The fee is not high enough, however, to fully recover offset project costs in intensively developed cities.

Option 3: Midpoint between New Development and Redevelopment.
$100,000 to $120,000 per untreated impervious acre or pound of phosphorus removed.

This middle option might apply to a community with a moderate to high development intensity that wants to maximize on-site LID compliance at their redevelopment sites. Their concern is that a low offset fee would discourage designers from incorporating innovative practices into their urban projects, since the cost of meeting the standards on-site is nearly double the cost of writing a check not meeting them. This fee schedule may also appeal to cities and towns that have a high nutrient reduction liability in the future, and are not sure they possess adequate retrofit opportunities to meet them.

Option 4: Public Sector Cost for Green Street Retrofits
$150,000 to $170,000 per untreated impervious acre or pound of phosphorus removed.

The fourth option makes sense for cities with high development intensity, high land prices and a high rate of future redevelopment activity. In these situations, there are likely to be many high intensity redevelopment projects that need offsets, but few if any acceptable retrofit offsets to build. In this case, the city uses the funds recovered to systematically retrofit green streets. The fee schedule is hefty enough to make most designers work extremely hard to comply on-site, but is marginally cheaper than the full private sector cost for on-site LID at high intensity redevelopment projects.

Option 5: Private Sector Cost of Full High Intensity Redevelopment Compliance
$190,000 to $200,000 per untreated impervious acre or pound of phosphorus removed.

This approach is essentially designed to make offsets an option of extreme last resort. The basic idea is that a tough standard will drive major improvements in LID technology, and that on-site compliance costs will drop over time as designers learn how to apply new technologies more cost-effectively. Given the current business climate, it is doubtful whether many communities will elect to use this aggressive (and initially costly) option.

Option 6: Waiving Offset Fees in Select Areas.

A locality may elect to designate some limited areas within its jurisdiction where the offset fee is effectively set at zero – essentially waiving the need to provide any redevelopment stormwater treatment. Potential examples might include economic revitalization zones or historic districts where a locality wants to bundle economic incentives to attract new businesses. Within relatively narrow limits, it is certainly a rational decision to promote economic development, although localities should recognize that the subsidy may impact future budgets, since they may need to expend more funds for watershed restoration projects elsewhere in their jurisdiction to compensate for the “lost” nutrient reduction.

Section 9.
Documenting Redevelopment Nutrient Credits

Localities in the Bay watershed have a keen interest in determining how much nutrient reduction can be attributed to their various stormwater treatment and watershed restoration actions. This has become even more critical as localities confront the need to document their nutrient reductions in a local Watershed Implementation Plan (or WIP). Localities will need to craft their own WIP plans in 2011 to show how they intend to meet their load allocation in the Bay-wide nutrient TMDL.

CSN is currently writing guidance on stormwater nutrient accounting for bay communities, which is scheduled for release in the first quarter of 2011. The guidance will be in the form of Technical Bulletin No. 9, which will present a comprehensive approach to accurately track stormwater loads from new, existing and redevelopment sectors within each Bay community.

To date, there has been no specific guidance on how to credit nutrient reductions associated with the adoption of more stringent redevelopment stormwater requirements. This section proposes a simple tracking approach that should be reasonably accurate and yet easy to administer.

The first step would be for the locality to track the cumulative number of impervious acres that are redeveloped each year and meet or exceed the local and/or state stormwater redevelopment requirements. This includes projects that treat stormwater on site and/or reduce pre-existing impervious cover through acceptable conversion techniques (Section 6.1).

The treated area of each individual redevelopment project can only be added to the local database if it has received a post-construction certification that it is actually working as designed. In addition, a municipality can only receive the credit if it meets the minimum state or permit standards for on-site maintenance inspections and enforcement.

The second and final step is to multiply the qualifying impervious acres by the nutrient reduction credits shown in Table 8. The nutrient credits reflect the different levels of stormwater treatment required at redevelopment sites in the Bay states, as well as the extent to which on-site runoff reduction is implemented across a locality.

Larger communities with high redevelopment rates and stringent stormwater requirements could expect to see substantial nutrient reduction which they can deduct from their Bay nutrient liability.

Table 8
Nutrient Reduction Credits for Redevelopment Stormwater Practices [3]

Annual Load Reduced Per IC acre Treated Lbs/acre/year	Rainfall depth for which stormwater treatment is computed (inches)											
	0.25		0.50		0.75		1.0		1.25		1.5	
	LO[1]	HI[2]	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
TP	0.4	0.6	0.6	0.9	0.75	1.1	1.0	1.5	1,25	1.65	1.4	1.8
TN	3.3	4.5	5.1	6.8	6.3	8.4	8.4	11.3	9.9	12.3	11.1	13.5

[1] Practices employed employ stormwater treatment but have low or no runoff reduction capability
[2] Practices employed maximize runoff reduction and designed to VADCR Level 2
[3] See Appendix C for methodology used to derive the credits

The technical assumptions and computational methods to derive the nutrient credits are described in detail in Appendix C. An alternate method to compute credits in Virginia and Maryland would be to track nutrient reductions from individual redevelopment sites, using the compliance spreadsheets (CSN, 2010), and then aggregating them into a tracking database.

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Appendix A. Redevelopment Web links

Link to CSN Bay-wide Design Specs that Pertain to Redevelopment

- Permeable Pavers
- Vegetated Roofs
- Urban Bioretention
- Rainwater Harvesting
- Soil Restoration
- Dry Swales
- Sand Filters

http://www.chesapeakestormwater.net/baywide-design-specifications2/

Link to Rainwater Harvesting Design Spreadsheet
http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html and then scroll down several pages to find Excel spreadsheet

Link to Urban Tree Canopy Guidance
http://www.forestsforwatersheds.org/urban-tree-canopy/

Philadelphia Stormwater Manual. Version 2, *released in 2008, Best on the East Coast for Redevelopment Practices.*
http://www.phillyriverinfo.org/Programs/SubprogramMain.aspx?Id=StormwaterManual

Portland Stormwater Manual. *Also updated in 2008, this manual provides excellent design schematics and maintenance info for ultra-urban practices*
http://www.portlandonline.com/bes/index.cfm?c=43428

San Mateo County: Design Manual for Green Streets and Parking Lots. 2009. *This is one of the better design manuals for green street design, from California.*
http://www.flowstobay.org/ms_sustainable_streets.php

Stormwater guidelines for green dense redevelopment in Emeryville, CA, *2010. This document outlines a useful approach for effectively managing stormwater in ultra-urban watersheds*
http://www.epa.gov/dced/emeryville.htm

Guidance on Smart Growth and Stormwater*. 2009. This EPA policy report presents strategies to integrate stormwater and smart growth.*
http://www.epa.gov/dced/stormwater.htm

Stormwater and Brownfield Sites*, 2009. This EPA report provides guidance on managing stormwater from brown-field sites*
http://epa.gov/brownfields/tools/swcs0408.pdf

Appendix B
Technical Documentation of Cost Estimates Used to Derive Stormwater Offset Fees

Caveats and Sources of Cost Data

It can be a challenge to estimate the actual cost to comply with stormwater requirements, as they vary with respect to development intensity, drainage area treated, the type of practices used and the complexity and constraints of individual development or redevelopment sites. Consequently, it is not surprising that there are greatly contrasting projections about the incremental cost to comply with new LID or ESD requirements, with some sources indicating little or no increased costs (US EPA, 2007 and MacMullan and Reich, 2007), and developers and some consultants responding that compliance costs will increase enormously.

Four primary sources of cost estimating data were used in this analysis. The first source was a large survey of actual retrofit costs contained in Schueler (2007) which included both storage and LID retrofit projects from the Chesapeake Bay and Pacific Northwest. The retrofit cost database included both the base construction costs, and costs incurred for design, engineering and permitting. The second source was updated unit cost equations for a range of stormwater practices serving new development, as reported in Appendix E of Schueler (2007). The unit costs were developed from three independent studies of stormwater costs, and were updated to reflect construction inflation. The third source was actual bid costs to construct green streets obtained from Montgomery County, MD and Baltimore City. The source for stream restoration costs was Schueler (2005), and was based on historical cost surveys in the East Coast.

The total cost for stormwater compliance was based on the volume of stormwater (cubic feet) that must be treated for a unit acre of impervious cover. The treatment volume was then multiplied by unit treatment cost that reflects the typical combination of stormwater practices that would be employed in the development scenario. The resulting construction cost was then adjusted upwards to reflect costs related to design, engineering and permitting. Additional costs were added to public sector construction, to reflect costs for project contracting and future maintenance. Land costs were not considered in any scenario, however, the mix of practices in each scenario were selected based on reasonable assumptions of land consumption, (particularly with respect to redevelopment). It should also be noted that costs for stormwater conveyance and any detention storage needed for flood control were not computed in this analysis.

The remainder of this appendix describes the specific assumptions associated with each scenario and the projected total cost.

Scenario 1
New Development, Pre-ESD (2000 Manual)
Cost to Treat One Impervious Acre

Scenario Assumptions:

- New Development
- Suburban residential subdivision with moderate impervious cover and high turf cover
- Site designed to water quality and channel protection sizing requirements contained in the 2000 MDE design manual
- A composite of BMPs is used to treat the water quality volume (3630 cubic feet), and an ED Pond is used to meet the channel protection volume (assumed to be equivalent to be 1.2 times the water quality volume- see Figure 1.3 in Schueler, 2007)
- The composite BMP used to treat the water quality volume includes an equal split of bioretention (@ $ 18,150 per impervious acre) and a dry swale (@ $ 25,400 per impervious acre) for a mean unit cost of $21,775 per impervious acre. To this is added the cost of constructing an ED pond for the channel protection volume (@ $3800 per impervious acre) to arrive at a base construction cost of $25,575
- The new development unit cost equations contained in Table E.2 of Appendix E of Schueler et al (2007) were used
- Design, engineering and permitting for new development projects are assumed to 25% of construction cost

Based on these assumptions, the unit cost to treat runoff at a typical new residential development under the 2000 Maryland stormwater rules is approximately **$31,689** per impervious acre

Scenario 2
New Development Using ESD to the MEP
Cost to Treat One Acre of Impervious Cover

Scenario Assumptions

- Same basic residential subdivision layout described in scenario 1
- A composite of micro-ESD practices are used to collectively treat a Pe of 2 inches at the site (7260 cubic feet), as shown in the Table below.
- 25% of the treatment volume is achieved through disconnection credits, although some engineering costs are incurred to increase filtering and infiltration in the filter path or strip.
- The design, engineering and permitting for ESD practices at new development projects are expected to be slightly higher, and are assumed to be 30% of the base construction cost

Composite ESD Practices Applied in the New Development Scenario		
ESD Practice	Percent of Site Treated	Unit Cost ($/imp acre) [2]
Bioretention	25%	25,400
Infiltration	25%	25,000
Dry Swale	25%	18,150
Disconnection Credit [1]	25%	3,000
	100%	17,888
[1] This is a rough estimate of expected costs for filter strip improvements (grading, soil amendments, berms, etc) [2] Derived from new development unit cost equations contained in Table E.2 of Appendix E of Schueler et al (2007)		

Based on these assumptions, the unit cost to treat runoff at a typical new residential development under the new 2010 Maryland ESD stormwater rules is approximately **$46,509** per impervious acre. At first glance, it would appear that the ESD requirements increase the cost of compliance by about 45%, compared to the pre-ESD stormwater design era (Scenario 1).

It should be kept in mind, however, that the ESD design is expected to significantly reduce the size and cost of the conveyance and detention components of the stormwater system at the site, compared to the pre-ESD design era.

Scenario 3:
Redevelopment Using ESD Practices
Cost to Treat One Impervious Acre

Scenario Assumptions:

- High Density Urban Redevelopment Project (85 to 90% impervious cover)
- No Increase in Impervious Cover from Existing Condition
- Infiltration of stormwater is not possible due to past soil disturbance
- A composite of ESD practices is used to treat the redevelopment water quality volume (i.e., 0.5 inch of runoff, or 1815 cubic feet of water quality volume per acre of impervious cover)
- The unit costs contained in Table E.4 in Appendix E of Schueler et al (2007) were used
- A composite of five space intensive ESD practices was applied to the redevelopment site, with unit costs as shown in the Table below.
- Costs for design, engineering and permitting were assumed to 40% of base construction cost, which is consistent with regional and national surveys.

Composite ESD Practices Applied in the Redevelopment Scenario		
BMP	Percent of Site	Unit Cost ($/cf)
Permeable Paver	20%	120
Green Roof	20%	170
IC Removal	20%	20
Street Bioretention	20%	30
Foundation Planter	20%	26
	100%	75.2

Based on these assumptions, the unit cost to treat runoff at a redevelopment site in Maryland is approximately **$190,938** per impervious acre

Scenario 4
Public Sector Cost to Install Storage Retrofits
One Acre of Existing Impervious Cover

Scenario Assumptions:

- Locality constructs storage retrofit on public land
- Storage retrofit treats the full water quality volume (3630 cubic feet per acre of impervious cover).
- Locality seeks to recover the full retrofitting cost, including planning, design, engineering permitting, contract administration, installation and ten years of future maintenance.
- Storage retrofit costs as described in Table E.1 of Appendix E of Schueler et al (2007) that reflect a split between existing and new pond retrofits.
- The costs for retrofit investigations based on data presented in Schueler (2005)
- Costs for contract administration and maintenance from local sources
- DEP costs derived from retrofit cost database in Schueler (2007)

The public sector cost for each stage of the retrofitting process is thus estimated at:

A. Cost to Find Retrofits:	$ 1,500
B. Storage Retrofit Installation:	$ 15,000
C. Design, Engineering, Permitting (40% of B)	$ 6,000
D. Municipal Contracting /Inspection (7.5% of B+C)	$ 1,600
E. 10 years Maintenance (4% of B +C x 10)	$ 8,400

Based on these assumptions, the unit cost to construct storage retrofits to treat runoff from existing, untreated suburban development is approximately **$32,500** per impervious acre.

Scenario 5
Public Sector Cost for Green Street Construction
One Acre of Impervious Cover Treated

Scenario Assumptions

- Municipal construction of green streets that treat the water quality volume (3630 cubic feet per impervious acre)
- Construction costs based on median value reported from ten green street construction bids in Baltimore and Montgomery County, MD.
- Locality seeks to recover the full green street implementation cost, including planning, design, engineering permitting, contract administration, and installation. These costs were directly estimated from the actual municipal costs incurred in the demonstration projects.
- No data were available to estimate whether green streets have additional maintenance costs compared to traditional streets. Consequently, the debatable assumption was made that green streets had no additional future maintenance costs.

The public sector cost for each stage of the green street implementation process is thus estimated at:

A. Cost to Find Candidate Streets	$ 2,785
B. Green Street Installation:	$ 111,415
C. Design, Engineering, Permitting (40% of B)	$ 44,566
D. Municipal Contracting /Inspection (7.5% of B+C)	$ 8,356
E. Maintenance (Same Level)	$ -0-

Based on these assumptions, the unit cost to construct green streets to treat runoff from existing, untreated and highly urban development is approximately **$167,123** per impervious acre. It should be noted that initial green street projects are subject to the "prototype" effect associated with many new technologies, in that the unit cost generally drops over time as designers, contractors and reviewing agencies gain more experience and standardize construction methods

Scenario 6
Public Sector Cost for Comprehensive Stream Restoration
Per Equivalent Acre of Impervious Cover of Nutrient Loading

Recent field studies by BDPW (2006) have evaluated the degree of nutrient reduction achieved by comprehensive urban stream restoration when compared to the in-stream nutrient load generated from un-restored and degraded urban streams. This allows one to equate stream restoration with impervious cover, at least on a nutrient loading basis. For example, the nutrient load from one acre of impervious cover can be computed using the Simple Method (Schueler, 1987).

- TP Load from One Acre of IC = 2.0 lbs/yr
- TN Load from One Acre of IC = 15.4 lbs/yr

The Baltimore stream research indicates that each linear foot of comprehensive stream restoration reduces TP loads by 0.068 lbs/yr, and TN loads by 0.20 lbs/yr. This is accomplished through enhanced in-stream nutrient processing and reduced stream bank erosion of nutrients. This suggests that:

- Each 75 linear feet reach of stream restoration would reduce TN by 15 lbs/yr
- Each 30 linear feet reach of stream restoration would reduce TP by 2 lbs/year

The nitrogen loading rate should be used as a more conservative number, and as a factor of safety, it was increased to 100 feet equals one acre of impervious cover (since there is some question as to whether nutrient reductions would persist after a degraded urban stream reached some kind of equilibrium).

Comprehensive stream restoration is defined here as using natural channel design on an entire urban stream reach that is still actively enlarging in response to upstream development. The typical application is on first or second order streams.

The public sector cost for comprehensive stream restoration was estimated as follows, using data obtained from municipal stream restoration projects in Maryland.

A. Cost To Find Candidate Streams:	$ 1,500
B. Comprehensive Stream Restoration, 100 @ $200 per lf	$ 20,000
C. Design, Engineering, Permitting (40% of B)	$ 8,000
D. Municipal Contracting /Inspection (7.5% of B+C)	$ 2,100
E. 10 years Maintenance (2% of B x 10)	$ 4,000

Based on these assumptions, the public sector cost to construct urban stream restoration that provide a nutrient reduction equivalent to that generated by one acre of impervious cover is approximately **$ 35,600** per impervious acre, which is roughly the same as the public sector cost for installing storage retrofits.

Making Sense of the Numbers

Depending on the scenario selected, the level of the offset fee could range from $32,500 to nearly $191,000 per impervious acre treated. Each community needs to balance equity with revenue recovery, and select the scenario that best reflects their development intensity and available restoration opportunities.

Appendix C
Methodology Used to Derive Redevelopment Nutrient Credits

The following methods and technical assumptions were made to derive the nutrient credits for variable levels of stormwater treatment at redevelopment sites.

Step 1: Compute Baseline Nutrient Load for Unit Acre of Impervious Cover.

The Simple Method (Schueler, 1987) was used to compute annual nutrient loads, using standard assumptions for annual rainfall in the region, and regional event mean concentration for nutrients. The resulting annual stormwater load was computed to be 2 and 15 lbs/acre/year for TP and TN, respectively.

Step 2: Define the "Anchor" Reduction Rate for a Composite of Redevelopment Practice.

An annual mass removal rate was computed using a composite of eight different preferred or acceptable redevelopment stormwater practices (see Section 6) using the runoff reduction data provided in CWP and CSN (2008). The practices included rain tanks, green roofs, permeable pavers, urban bioretention, bioretention, dry swales, sand filters, and impervious cover removal with soil amendments. The mass removal rates are specific to the treatment of one inch of rainfall in Virginia, and the Level 1 and 2 approach was used to distinguish between the amount of runoff reduction an individual design achieved (Lo or Hi, as defined in CWP and CSN, 2008).

Step 3: Adjust the Anchor rate for Other Rainfall Depths Treated

The anchor rate was then adjusted for the 0.25, 0.50 and 0.75 inch rainfall depths, by estimating the untreated bypass volume from regional rainfall frequency curves, relative to the anchor rate (see Table c-2). For example, if the runoff from 0.25 inches of rainfall is treated, only 40% of the annual runoff volume would be treated (compared to 90% for the one inch event). The annual treatment volume was then used to define a lower nutrient reduction rate, based on the lower capture volume. The same basic approach was used to define maximum mass nutrient reduction rates for the 1.25 and 1.5 inch storm events.

Step 4: Determine the Final Redevelopment Credit.

The baseline nutrient loads computed in Step 1 were than multiplied by the corresponding removal rate for each combination of runoff treatment and runoff reduction, as shown in Table C-1 to arrive at the recommended credits, as shown in Table C-2.

Table C-1
Nutrient Removal Estimates For Volume and Type of Treatment

Mass Removal Rate	Rainfall depth for which stormwater treatment is computed (inches)											
	0.25		0.50		0.75		1.0		1.25		1.5	
	LO[1]	HI[2]	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
TP	20	30	30	45	38	56	**51**	**74**	63	82	70	90
TN	22	30	34	45	42	56	**56**	**74**	66	82	74	90

[1] Practices employed employ stormwater treatment but have low or no runoff reduction capability
[2] Practices employed maximize runoff reduction and designed to VADCR Level 2

Table C-2
Nutrient Reduction Credits for Redevelopment Stormwater Practices [3]

Nutrient	Rainfall depth for which stormwater treatment is computed (inches)											
	0.25		0.50		0.75		1.0		1.25		1.5	
	LO[1]	HI[2]	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
TP	0.4	0.6	0.6	0.9	0.75	1.1	1.0	1.5	1,25	1.65	1.4	1.8
TN	3.3	4.5	5.1	6.8	6.3	8.4	8.4	11.3	9.9	12.3	11.1	13.5

[1] Practices employed employ stormwater treatment but have low or no runoff reduction capability
[2] Practices employed maximize runoff reduction and designed to VADCR Level 2
[3] expressed in annual load reduced per IC acre treated (lbs/acre/year)

Appendix D
Stormwater Math for Maryland Redevelopment Projects

The basic standard for redevelopment sites is that (a) you must treat or reduce the pre-existing impervious cover at the site by 50% (b) any increment of new impervious cover created at the site must meet the higher new development criteria for recharge, water quality and channel protection, using the ESD to MEP standard and (c) use of ESD practices is highly encouraged to treat pre-existing impervious cover, and mandatory to treat new impervious cover.

This definition creates three possible cases when it comes to redevelopment requirements.

Case 1: Proposed IC <= Existing IC/2

The first, and most unlikely case, is when the pre-existing IC is reduced by 50% or more, in which the stormwater requirement can be met without any practices.

Thus, for a hypothetical redevelopment site with 10 acres of impervious cover (IC):

The redevelopment project design is expected to result in only 5 acres of IC. Therefore:

(10 acres IC /2) = 5 acres IC and the goal is met

Case 2: Existing IC/2< Proposed IC <= Existing IC

The second case is where there is a small reduction in IC as a result of the redevelopment project, going from 10 acres of IC to nine. In this situation, the site would be subject to a smaller water quality volume, but is exempt from any recharge (Rev) and channel protection requirements.

WQv = 1.0 inch * (Proposed IC-Existing IC/2)

Therefore, in our example:

WQv = {1.0 inch* 9 ac - (10ac/2)}/10 = 0.40 inches over the total site area.

Case 3 Proposed IC > Existing IC

The final case is when the redevelopment project creates new impervious cover at the site. For our example, let's assume that the IC for our hypothetical site climbs from 10 acres to 12. In this situation, the required stormwater volumes are split between the existing impervious cover (10 acres) and the new increment of impervious cover (2 acres).

Computing the water quality volume for the *existing* impervious cover is fairly straightforward:

WQv = 1.0 inch * Existing IC/2

WQv = {1.0 inch* (10ac/2)}/10 = 0.5 inches over the total site area

The *new increment of impervious cover* (2 acres) is computed using new development sizing criteria. Thus, the additional water quality volume is:

WQv = 1.0 inch * 2 acres = 0.2 inches

which is then added to the existing IC WQ requirement

Total site WQv = 0.5 + 0.2 inches = 0.7 inches over the total site area

The two acres of new IC would also be subject to recharge (Rev) and channel protection (Cpv) requirements, as well.

By comparison, if the site were a new development project, the required WQv for the site would be 1.0 inches over the total site area.

Note: the ESD to MEP compliance spreadsheet (CSN, 2010) automatically computes the redevelopment treatment requirements