GREEN STREETS AND PARKING LOTS

By Coleshill Associates LLC: Shirley Loveless, Ph.D., President

I. The Role of Streets and Parking Lots in Stormwater Management in Watersheds

A. Overview

Roads and streets and paved parking lots have major impacts not only on their immediate surroundings but also on the watersheds in which they are located. ***Road Ecology***, a groundbreaking comprehensive approach to analyzing the mutual effects of roads and road networks and their environments, finds that "the interactions between roads and the ecosystems and watersheds in which they reside fundamentally shape the flows and movements across the land (human activity as well as water and other ecological elements, such as wildlife), in effect determining how the landscape works. Ecological and watershed effects result from both the intended and unintended functions of road systems." (**p. 293**).

Adjacent land uses influence the shape and extent of the road network and the functional classifications of the road segments within the network. As both regional and local development intensify, demands for increased road carrying capacity rise, leading to increases in impervious surfaces as roads are widened or new ones built. As both the road networks and the development surrounding them lead to more impervious surfaces, the ability of the ecology to deal with water flows is progressively impaired. Degradation of stream ecosystems begins to appear when impervious surfaces as a share of total land in a watershed reach 10 percent. When impervious surfaces account for 30 percent or more of land area, deterioration becomes especially severe and almost irreversible. **Table 1** lists features of the relationship between impervious surfaces and stream quality.

The surfaces and geometry of Fort Washington Office Center's streets and parking lots are problematic for stormwater management. In addition to the effects these surfaces have on water flows, the water flows have effects on them. Thus, the nature of street and parking lot surfaces and their geometry can work against the sustainability of these facilities. Such circumstances make analyses of the road/street system and the Office Center's parking lots and the development of appropriate corrections to them critically important to local stormwater management. Sidewalk surfaces and design also need to be considered. Existing sidewalks in Fort Washington Office Center are intermittent and do not serve pedestrian travel well. Most of the existing sidewalks are in deplorable condition and actually contribute to stormwater problems in the Office Center.

Roads and parking lots constitute a major share of impermeable surfaces in developed areas like the Fort Washington Office Center—almost 50% in this case. As such, they work against absorption of excess water in rain events. Worse, they act as conveyors of stormwater flows, especially if the terrain is sloped and the road configurations are essentially straightaways as they are in much of the Office Center.

As noted in ***Road Ecology***, roads or streets can affect water flows by "disrupt[ing] the natural flow and circulation," thereby contributing to flooding problems elsewhere; "Conversely, water can affect roads by (1) flooding, (2) destroying bridges and culverts, (3) eroding unpaved roads and the shoulders of paved roads, (4) inducing landslides onto roads or sliding of the road itself, (5) deteriorating road surfaces through the freeze-thaw cycle in some climates, and (6) discharging ground water, which can saturate roadbeds, making them unstable." (**p. 172**). All six of these effects have been observed in the Fort Washington Office Center.

Beyond direct impacts on stormwater management, interactions of water flows and streets and roads and parking lots can have other adverse effects. Although in nature erosion and sedimentation are natural occurrences, the intervention of human activities, such as development and road-building, typically upsets natural processes and the ability of ecosystems to adjust and sustain themselves. In heavy rain, soil erosion from road edges will lead to downstream sedimentation. The road itself can act as a water speed enhancer, conveying significant loads of soil and debris into the water system. A highway or road drainage system may be constructed with the intent of removing large quantities of water quickly from road surfaces but, without careful consideration of downstream impacts, storm drains and culverts intended to drain roads may overwhelm local streams and wetlands with both huge quantities of water and sediment that will alter their ecology. **(See Figures 1, 2 and 3).**

Poor road drainage also has serious travel safety implications. We are all well-familiar with the impassability and threat to motorist safety of many of the internal roads of the Office Center when there are heavy rain events. But, even minor precipitation events can cause problems. Ponding of water on road surfaces can cause hydroplaning, even when vehicles are not traveling at excessive speeds. The other major safety problem caused by pooling on road surfaces is heavy water spray onto windshields that can temporarily blind motorists. Again, this can happen even at relatively low vehicle speeds and without much depth of water on the road surface.

B. Stormwater Management Best Practices for Streets and Parking

1. General Design and Strategy Principles

Green Streets identifies the following general design objectives: (**p. 39**)

- Minimize the generation of storm runoff by **reducing the amount of impervious surface** within the street rights of way.
- Manage the runoff volume by **infiltrating wherever possible**.
- Provide **detention, retention, infiltration and/or water quality benefits as close to their source as possible,** by incorporating these functions into the overall right of way design.
- Protect stream corridors with buffer areas and design crossings to assure the **minimum impact** on not only the stream channel but to the stream corridor.

Table 2 summarizes and compares "Green Street" concepts for street retrofits and new construction. The ***Green Streets*** manual lists five primary functions served by Green Streets designs. These functions are:

- Runoff prevention
- Detention
- Retention
- Conveyance
- Water quality

Several strategies address more than one of these functions. **Table 3** is a matrix that matches the Green Streets functions with different design solutions.

2. <u>Contextual Land Uses and Design</u>

a. Integrated Land Use and Transportation Stormwater Management Planning

Water flows on streets and surface parking lots are affected by runoff from surrounding land. Drainage from building downspouts, slopes leading down to the streets and lots, inadequate landscaping, soil conditions, and even some drainage infrastructure placed to address a specific local problem, can contribute to flooding problems on streets and surface lots. This is especially likely to happen if stormwater management has been piecemeal and not the result of a comprehensive, regional or subregional plan that considers all of the elements within its geography, both potential impacts to these elements and impacts by them on the hydrology.

Effective on-site building stormwater management can significantly reduce the runoff onto streets and parking lots. "Green roofs," rainbarrel and cistern water collection are examples of such techniques. Where rain gutters are used, attention to location is important. Rain water spouts should be directed so that they avoid sending water downhill to roads or parking lots.

Beyond runoff from buildings in the immediate area, the treatment of the landscape between buildings and roadways and parking lots can have major effects on water flows going into streets and parking lots. Careful attention should be given to grading and contouring the land and to plantings. Use of features such as swales, can be very effective in addressing the effects of topography on water flows and intercepting water before it reaches streets and parking lots. Vegetated swales promote the slow movement of runoff, and absorption significant volumes of water. However, their effective use will depend upon underlying hydrology and geology.

Aesthetic considerations can be addressed within landscape choices for stormwater management, for everything from tree plantings and ground covers, to designs for wetlands, detention ponds, or swales. **Figure 4** shows how a dry infiltration basin can be used, with appropriate landscaping, during dry weather periods as a community open space/meeting place. During periods of inundation, such basins or "extended detention ponds" can hold water briefly and then discharge it to adjacent water sources, or, if the base is a permeable surface, the water can slowly infiltrate. (***Green Streets*, p.46**).

b. Minimizing Impermeable Surfaces

Building features such as patios, should incorporate permeable surfaces whenever possible. Even facilities such as loading docks and aprons can be constructed using permeable surfaces, depending upon the weight and volume of typical vehicles using them. All building features, such as decks and external stairs, should incorporate stormwater removal mechanisms to reduce the impact of locally-generated runoff.

Zoning regulations and incentives should favor multi-story buildings over single-story buildings with large footprints. Single-story structures not only take up a lot of land surface relative to their usable floor space, but their roof area is also a problematic impermeable surface, unless, of course, they have green roofs. Wherever possible, building owners and developers should be encouraged to implement green roofs.

Where economically feasible, parking facilities should be structures with on-site stormwater management facilities, rather than paved surface lots. **(See discussion in Section B.4 below)**

3. <u>Street Design</u>

a. Street Locations

Street location within or adjacent to a floodplain can have a major effect on stormwater management, and conversely, flooding will have significant adverse effects on the roadways themselves. The mere presence of a major road within a floodplain or even a valley floor adds significant impermeable surfaces and reduces the ability of the land to absorb excess water and it also interferes with natural flow and drainage patterns. Floodplains are likely to have substantial groundwater discharge. If roads have not been engineered to withstand upwelling, the roadbed will become unstable and the road will suffer continual deterioration. Virginia Drive in the Fort Washington Office Center is a classic example.

If roads are located on sloped terrain—whether or not they are adjacent to floodplains—they can act as superconveyors of water and sediment. This tends to clog up downstream drains and fill in detention ponds and other stormwater management infrastructure, greatly reducing their effectiveness. When roads are built on sloped terrain, planting to minimize erosion and sedimentation is recommended. Structural controls to control erosion and sedimentation, such as inlet and outlet protectors and check dams, may also be necessary. (***Road Ecology***, **p. 177**).

The effects of roadways on water are considerable but they have often been underestimated in roadway planning and construction. As ***Road Ecology*** summarizes these effects:

> Roads may intercept surface and subsurface flow and reroute it along roadside ditches. The water intercepted by roadside ditches may be routed to streams, thus effectively increasing the density of stream channels in a watershed. This rerouting of water could potentially accelerate flows in the entire stream drainage network during rainstorms, thus increasing flooding. Roads may divert stream flow

from one small drainage basin to another, thus increasing discharge in a receiving channel and increasing the potential for localized erosion. In places, ditches may intercept groundwater flow, adding more water to a ditch network designed only to remove excess surface water. (**p. 179**).

The siting decisions for roads and streets are often dictated by topography, cost, or other constraints. Older streets and roads were often sited without regard to stormwater management or road preservation concerns, as those concerns tend to be more recent than much of our existing street and road systems. Moving the most problematic sections of a road or street may be a desirable goal but cost or other factors may make this impossible. Further, if careful attention is not paid to potential effects of changing the road location or raising it, one problem may be solved but a lot of new ones created. Ideally, in new developments or redevelopment of existing developed areas, street and road locations should be guided by stormwater management considerations. But, for existing roads and streets that cannot be moved, making some modifications can still greatly improve stormwater management. In considering the pluses and minuses of moving road sections, the costs of continual "stop-gap" measures (including repaving and even reconstruction) and negative impacts on property values over a reasonable long period of time should be measured against the costs of relocating and building new road sections.

b. Street Geometry

Street geometry—that is features including curves (or lack thereof), street/road longitudinal slopes, crown heights (cross-sectional slopes from road centers to edges), intersection angles, medians, and "traffic calming" devices, such as roundabouts, speed tables, and chicanes—all have effects on stormwater flows and volumes. As much as possible, roads should follow natural land contours. Paving against natural topography sometimes may seem desirable from the perspective of road construction costs, but it can lead to costly stormwater management costs downstream.

Straightaways are prone to ponding on their surfaces if there is inadequate drainage, particularly if the horizontal road surface is flat or nearly so. Even a slight crown on a roadway can direct water flows to the road's sides and reduce the likelihood of pooling. Straight roads on longitudinal inclines accelerate water flows downstream. Increased water speed increases the risks of erosion and overwhelming the storm drainage system. Although excessive roadway curves,--especially sharp ones are not desirable-- breaking straight line water flows helps reduce water speed and assists stormwater management. **Figures 5 and 6** show "before" and "after" conditions in a Madison, Wisconsin suburb, where streets were deliberately reconfigured from straight lanes to gently curved lanes. Pre- and post-change measurements of water flows and sedimentation showed dramatic reductions.

Street intersections present both opportunities and challenges for incorporating stormwater management. Retrofits are especially difficult, where intersection configurations are already set and the intersections are key to meeting regional travel needs. Trying to balance stormwater control with transportation needs may mean sub-surface culverts are the only option (***Green Streets*, page 82**). **Figure 7** shows possible stormwater treatments at intersections. Opportunities for additional stormwater management strategies arise when intersection designs include roundabouts with islands and bulbouts to reduce intersection crossing distances for pedestrians and for traffic-calming. Roundabout islands can incorporate a variety of stormwater management techniques including infiltration trenches and detention basins. Bulbouts generally involve less surface area than roundabout islands, but can still be designed to provide infiltration.

Transit stops provide another set of opportunities and challenges. **Figure 8** shows a variety of stormwater design solutions to consider for reducing stormwater impacts. (**p.83**)

c. Street Edges/Shoulders

There are three basic types of street edges: (1) unpaved shoulders/edges; (2) paved shoulders/edges without curbs; and (3) paved shoulders with curbs. The three types have different stormwater impacts.

How unpaved road surfaces behave in heavy stormwater flows depends upon soil texture, structure, and permeability, and vegetative cover. Soils can be categorized by their infiltration rates as "low-runoff" (high infiltration sandy/gravelly soils) or "high-runoff" (slow infiltration clay soils). Moderate rainfall percolates through the former and seemingly disappears. The latter cannot handle high water volumes. Even fairly light precipitation will result in puddles and pooling. Places where there are mainly clay soils with high-runoff characteristics present a particular stormwater management challenge. They are somewhere between impermeable paved surfaces and low-runoff soils in their capacity to handle stormwater flows, but more like the paved surfaces than the latter.

Unpaved road surfaces also contribute to soil erosion and sedimentation. The edges of roads and streets can be major factors in soil erosion if there is exposed soil on their shoulders and vehicular intrusions, and occasionally road maintenance practices, prevent vegetation growth. If the soil is bare, erosion and sedimentation are likely. As noted in **Section 1.A**. above, the transported deposits can clog drains, culverts, and streams, adding to flooding problems.

Paving the shoulders is not always the recommended action to prevent soil erosion, particularly if the roadway is not a major highway with heavy traffic. Paving with asphalt or concrete will cover soil but will do nothing to slow water flows through absorption. Appropriate plantings and infiltration trenches may be a better solution. Unlike paved surfaces, vegetation can both absorb significant water and hold the soil in place.

Road Ecology identifies vegetation cover as "the most critical factor influencing erosion" and cites six major benefits of vegetation:

1. Reduced raindrop impact
2. Reduced runoff velocity
3. Improved structural integrity of the soil, through the root system
4. Filtration of chemical pollutants and sediments from runoff
5. Increased water infiltration into the soil

6. Increased evapo-transpiration. (**p. 175**).

On-site sediment control is recommended where possible, rather than depending on downstream treatments. This is especially important for preserving the capacity of an existing stormwater management system which may already be stressed.

Permeable pavements are another option for road shoulders. ***Green Streets*** defines "permeable pavements" as "any load-bearing surface that has capability of infiltrating runoff into the underlying reservoir base coarse (with at least 40 percent void space) and soil." (**p. 51**). There are pros and cons to permeable surfaces; they are not suitable in all cases. Permeable surfaces would not work for heavy traffic volumes and/or heavy vehicles. Road shoulders, because they are not travelways, might be appropriate for permeable surfaces, though considerations, such as road maintenance practices, must be taken into account. Subgrade drainage (low-infiltration soils) conditions may rule out the use of permeable pavements.

Retrofitting with permeable surfaces can be difficult, due to soil compaction from previous construction and usage, though exfiltration might mitigate this. Installing permeable surfaces in new construction is usually easier.

Green Streets identifies six basic types of permeable surfaces (**p. 52**):

- **Pervious concrete**—permeable material. Has the appearance of exposed aggregate concrete.
- **Porous asphalt**—comprised almost entirely of stone aggregate and asphalt binder with very little fine aggregate; has a "popcorn-like" appearance.
- **Unit pavers/bricks/stone**—durable and attractive surfaces that are permeable if spaced to expose a permeable joint and set on a permeable base.
- **Turf block**—example of an "open cell" unit paver; can be filled with vegetation or gravel; does not provide for a comfortable walking surface and is best suited for low-traffic surfaces.
- **Crushed aggregate**—long history of use; must be bounded by rigid edging; variety of aggregates available.
- **Cobbles—**best suited for very low traffic areas and provide a low maintenance alternative to landscaping. Requires rigid edging. **(See Fig. 6** for illustrations).

The **AASHTO *Green Book (Geometric Design of Highways and Streets)*** recommends "clear zones" (vehicle recovery zones) of 10 feet from the edge of the through-traffic lane on each side for urban collector roads without curbs. AASHTO prefers that these clear zones have no unyielding obstructions, such as mature trees. Therefore, ground covers and low shrubs are recommended for these areas. Such vegetation would have the benefit of making a clear distinction for the road edge and would also assist in stormwater management and erosion control

Curbs serve the function of keeping vehicular traffic areas distinct from pedestrian areas by providing a vertical separation. In terms of stormwater flows, however, they have the effect of concentrating runoff and channeling it into the stormwater system. Curb design can mitigate the water flow concentrating effects, but the choice of curb type is constrained by type and intensity of land use and the volume and speed of traffic. Higher road design speeds and traffic volumes, especially in contexts where there is also pedestrian traffic, tend to favor more definitive demarcations between vehicular and pedestrian traffic.

Green Streets describes the curb zone as "the interface between the roadway and a particular stormwater design solution." (**p. 54**). The choice of curb type should be dictated by the surrounding land uses and traffic conditions as well as the stormwater situation. ***Green Streets*** identifies five basic curb types (**p. 54**):

- **Invisible curb with "lip"**—retains road surface but allows runoff to flow into either an infiltration trench or swale. A shallow half-inch lip will promote shallow ponding and sediment settlement that can later be removed by street cleaning equipment.
- **Double invisible curb with sediment trench**—appropriate where street cleaning is not part of regular maintenance; a sediment trench back-filled with coarse aggregate can catch sediment over a long period of time and keep it out of the filtration strip or swale.
- **Rumble strip with sediment trench**—a variation of the curbless option, creates a "rumble strip" along the edge of the roadway as a tactile warning to drivers veering too close to the edge of roadway. Bicycle safety needs to be considered. A perforated pipe may be installed to convey water to particular "entry points" if biofiltering swale is used.
- **Prefabricated curb inserts**—appropriate for new construction or retrofitting, these custom inserts could be placed within a curb (or curb and gutter) and still maintain the integrity of the curb. The shallow lip would allow sediment to settle out and be picked up by traditional street cleaning methods. If inlets are close enough together, energy-dissipating cobbles are not necessary in the trench to avoid erosion.
- **Precast perforated curbs**—for new development, curbs can be installed that have perforations already cut into them, allowing both easy flow and the presence of a curb. A simple lip would allow the settling out of sediment on the roadway for future clean up. Not for use in heavy traffic areas or areas where tight maneuvering may be required. (**Note: sediment collected on the roadway must be removed quickly to prevent its travel further downstream or into drain systems where it might clog infrastructure).**

(See **Figs. 9-13 for illustration of each of these curb types).**

As noted above, retrofitting road and parking surfaces with permeable paving may be difficult or impossible where soils are compacted.

d. Sidewalks/Trails/Bicycle Lanes and Paths

Depending on local soils and hydrology, sidewalks may be constructed with permeable surfaces. Because of ADA requirements, sidewalk surface choices must accommodate wheelchairs and walking aids, and, therefore, have even, smooth textures. Five feet is the minimum width required for two people to walk comfortably past each other. When sidewalks are not separated from streets by landscaped edges, Dan Burden recommends a minimum 6 foot sidewalk width. (***Healthy Neighborhood Street Design,* page 33*)***

Whether paved with permeable materials or not, there should be drainage considerations for the sidewalks themselves. For several of the sidewalks in Fort Washington Office Center, such as the sidewalk on Commerce Drive next to the Temple University-Fort Washington facility, ponding is so severe the sidewalk actually acts as a reservoir for stormwater. The pooled water may take a few days to evaporate after a heavy rainfall.

Trails are generally used more for recreation than for pedestrian travel. If they are not intended to carry bicyclists, they can have a rougher surface than sidewalks. They can even be gravel-covered. Trails can be constructed in ways that serve stormwater drainage purposes as well as their primary recreational purpose. The location choices and construction of trails should aim to avoid accumulation of surface water. Where they cross wetland areas, trails can be constructed as elevated paths or bridges.

Construction of new trails or reconstruction of existing trails must pay close attention to water flow patterns and topography and natural drainage that is dictated by soils and hydrology. Going 'against nature' is almost certain to lead to trail deterioration and ultimately, destruction.

Bicycle lanes that are part of the roadway and not a separate facility, can be accommodated on road shoulders. However, they must be relatively smooth-surfaced to allow bicycle riders to travel safely. When bicycle routes are separated from roadways, they can be constructed with permeable surfaces, so long as they are smooth enough to avoid causing bicyclists to lose control.

e. Street Surfaces

Traffic volumes in the Office Center dictate paved surfaces for all heavily-traveled streets and road. As noted above, streets handling high traffic volumes, particularly heavy-weight truck traffic, are not candidates for permeable surfaces. However, some of the access lanes may be appropriate for permeable paved surfaces.

The primary concern associated with porous pavements is subgrade drainage. In a floodplain, this is almost certain to preclude permeable surfaces. **(See discussion of permeable surfaces under Section 3. c. Street Edges/Shoulders).**

Current street planning best practices encourage minimizing street widths wherever possible. Many roads are considerably wider than they need to be to handle the volumes and types of traffic they are intended to carry and they often fail to acknowledge their context—they don't fit well in their surroundings. Context sensitivity should guide street geometry. Roads serving primarily internal traffic do not need to emulate high-speed arterials. Even roads carrying significant through traffic, such as Virginia Drive, do not need to be configured specifically to speed traffic through. Indeed, slower speeds are important to creating more of a sense of place than the Office Center now has. A speedway running through it is a dangerous detraction from this. While traffic volumes on Virginia Drive make standard lane widths necessary, lower volume streets could have narrower travel lanes, as narrow as nine to ten feet in width. The reduction of street width by even a foot on each side makes possible the elimination of a considerable amount of pavement over the length of a road.

Figures 14 and 15 compare cross-sections for AASHTO "ideal" street widths for a regional boulevard and a regional street, with "absolute minimum" widths, as set forth in ***Green Streets***. (**pages 79-80**). The first example shows a 70 foot wide paved area reduced to 66 foot wide paved area, with no elimination of desirable design elements and transportation capacity. The second example shows the reduction of width of paved surfaces for a regional street from 60 feet to 52 feet. In all cases multiple travel modes are accommodated, along with stormwater management systems in the median.

f. Street Drainage Mechanisms

i. Landscaping Drainage Solutions

Filter Strips and Swales
These techniques both use grassy vegetation to remove sediment and to absorb stormwater. However, their capacities, and therefore their appropriate uses, are quite different. Filter strips are gently sloped grassy areas, appropriate for treating light sheet flow runoff (about 0.5 inches). They are best sited in transitional areas between impervious surfaces, such as roadways and parking lots, and swales or infiltration areas. Swales are vegetated channels, wider and shallower than ditches usually are. They are meant to handle flow depths up to about 3 inches. Both swales and filter strips are limited in their effectiveness by their lengths and slopes. Swale slopes should be between one percent and six percent. Steeper slopes would lessen contact surfaces between water and vegetation. Planning for swales and filter strips should also include overflow bypass facilities and discharge facilities to minimize burdens on receiving waters. (***Green Streets***, **p.57**). Bio-filtering swales can be used in wider road medians, as well as along road edges.

There are important maintenance issues associated with filter strips and swales. These include setting mowing schedules to preserve the desired height of vegetation (usually twice a year) and keeping swales and filter strips clear of leaf litter and debris.

Rain Gardens

Rain gardens can assist in absorbing runoff, in much the same way as shallow swales or filter strips. Placed parallel to road edges, they can intercept some stormwater runoff before it reaches the road surfaces. Choice of appropriate plants and soils is key to the amount of runoff that can be absorbed. Rain gardens also can have significant aesthetic value. **Figures 16 and 17** show a street with rain gardens in a suburb of Madison, Wisconsin.

Street Trees

Adding appropriate types of street trees is an investment with multiple payoffs. In addition to their role in local stormwater management, street trees serve many diverse functions, such as moderation of ambient temperatures and energy conservation, improvement in air quality, and visual enhancement that translates into higher property values. Stormwater treatment functions include: runoff reduction and detention (through interception and evapotranspiration); conveyance attenuation; and water quality mitigation (through reduction of stormwater runoff temperature and absorption and stabilization of pollutants from street runoff). (***Green Streets*, p. 50).**

Street trees do require attention to potential conflicts with traffic, such as vertical clearances (AASHTO recommends 11 feet above a residential travel land and 15 feet for highways and regional streets), and clear zones for higher speed roads (Roads within Fort Washington Office Center do not need the AASHTO preferred 32.8 foot clear zone, but planting distance from curbs should be at least 2 feet).

There are also maintenance requirements, including: regular street sweeping, especially in the fall, to keep debris from clogging street drains; pruning branches to preserve vertical clearances; use of root barriers in confined rights of ways, to prevent tree roots from damaging sidewalks.

Street Tree Wells

This is a detention option suitable for most urban streets. Because street trees are usually in rights of way, they are generally consistent with on-street parking, transit stops, and pedestrian and bicycle travel. Although their direct detention capacity is limited, street tree wells can be designed to be part of a system for taking sidewalk runoff or runoff from other sources, and to work with filter swales, as check dams and flow spreaders.

As is the case with other 'natural' drainage mechanisms, regular maintenance is important, particularly the removal of debris from outlet structures and/or culverts, and deposited sediment. (***Green Streets*, p. 62**). **Figures 18, 19 and 20** illustrate street wells.

ii. Constructed Drainage Solutions.

Infiltration Trenches

Infiltration trenches are simple, back-filled trenches, layered with coarse aggregate and filter materials. Placed next to road edges, they can help control road runoff. They are not stand-alone mechanisms, however; they must be used in combination with filter strips, swales or other sediment removal techniques, to prevent clogging and to treat stormwater. They must be constructed to infiltrate at a minimum rate of 0.5 inches per hour. **Figure 21** shows a cross section of a typical infiltration trench.

Linear Detention Basins

Linear detention basins act as temporary stormwater storage mechanisms. They are appropriate in areas with higher runoff rates, though they are not intended to eliminate the need for flow control mitigation. They can also function as infiltration basins in areas with suitable soils, so long as filtration is effective enough to prevent clogging.

Linear detention basins can be constructed in street medians, to help control road runoff. AASHTO recommends use of linear detention basins only with low-volume, low-velocity roadways, though it acknowledges that the basins could be used on high-volume, high-velocity roads, provided such roads had sufficient right of way to accommodate safety slopes.

4. Parking Facility Design

a. Parking Maximum Requirements versus Parking Minimum Requirements

In most cases, municipalities have parking minimum standards set forth in their zoning codes, instead of parking maximums or parking caps. These minimum standards are geared to auto-dominated development and generally result in excess parking capacity. This is because the standards are set for maximum parking demand periods, which means more capacity is constructed than is needed most of the time. Parking standards are also often set on a "one-size-fits-all" basis by general building type, instead of on a context-appropriate basis. For example, senior housing has a lower parking need than other housing with the same density, but this is often not reflected in local parking requirements. One common standard used for shopping malls is capacity to meet the demand on the tenth busiest day of the year. Building capacity required to meet this demand means acres of unused spaces for most of the rest of the year. To make matters worse, municipalities often agree to allow more parking than code minimums, as a draw to attract development. Particularly in suburban areas, there is an underlying assumption that parking is cheap to supply and because most malls and suburban employers do not charge for parking, users tend to think parking is "free." Such attitudes have fostered the proliferation of large, paved surface parking lots that often are half-filled, at best.

The American Planning Association's ***Parking Standards*** gives a range of 1 space per 500 square feet to 4 spaces per 1,000 square feet for office buildings **(p. 137**). The latter ratio is a very common one for office parks, and yet, some office developers push for 5 spaces per square foot, without clear evidence supporting demand for such parking supply.

Current planning "best practices" encourage review of true parking demand, pricing parking, and adopting parking maximum standards to minimize the amount of land given over for this purpose. One increasingly popular strategy is "shared parking," where two or more land uses utilize a single parking facility on a staggered or complementary basis. An example would be a parking lot that serves parking demand for an office building during the day and a theater and perhaps restaurants at night. Instead of providing parking for each land use, the same spaces can serve both day and evening demand. The main obstacles to shared usage are locating such complementary land uses in proximity and having single use zoning that prohibits mixed uses.

Parking "cash-out" is another strategy to minimize parking demand. This strategy typically presents employees the choice of: 1) free or subsidized parking; 2) a transit or vanpool subsidy equal to the value of the parking (of which up to $100 per month is tax-free under current federal law); or 3) a taxable payment approximately equal to the value of the parking, essentially cast to commuters who bicycle or walk to work. (***Parking Spaces/Community Places***, **page 30).** Parking cash-out has been implemented successfully in California for many years, with reported reductions in solo driving of between 7 and 17 percent. and corresponding reductions in demand for parking spaces. (***Parking Spaces/Community Places*****, page 31).**

Parking cash-out has at least three benefits: 1) it reveals the relative value of parking and makes it clear that it is not "free;" 2) it can free up land for higher value uses, e.g., building expansion; and 3) it encourages transit usage and carpooling as an alternative to solo driving and parking.

Another strategy to lessen the provision of parking is to charge developers 'in-lieu' fees instead of requiring each of them to provide on-site parking. These fees can be used to construct centrally-located parking lots or garages that serve multiple users. This in effect, creates some "shared parking" because individual properties are not required to meet excessive parking minimums. In practice, some in-lieu fee revenues have been set aside to provide shuttle services. Because of the distance between the heart of Fort Washington Office Center and the SEPTA Fort Washington train station and the poor pedestrian travel conditions, shuttle service could reduce parking demand and increase train usage. In-lieu fees could at least partially support such service.

b. Parking Structures versus Surface Parking Lots

Many more parking spaces can be accommodated in a multistory parking garage than a parking lot with the same size footprint. The primary drawback of structured parking versus parking lots is construction cost. The per stall cost of structure parking is five to ten times the cost of a surface parking space. (***Parking Spaces***, **p. 69**). Once built, the maintenance costs of a stall in a parking garage are relatively less than a parking space in a surface lot. Depending on the amount of traffic, local weather conditions, and effectiveness of lot stormwater drainage, a surface lot may require regularly scheduled repaving, as well as snow and debris removal.

From a stormwater management perspective, parking structures are preferable to parking lots, even those that have permeable pavements. A parking structure may avoid drainage problems that would face a parking lot in the same location, particularly if the site in question is in a floodplain, as many of the parking lots in Fort Washington Office Center are. Parking garages incorporate their drainage systems for stormwater within the structure, with connections to external stormwater systems, either directly into local stormwater drainage systems or into separate stormwater and sanitary systems. (***See discussion in Section 4.c.).***

Both parking structures and parking lots pose aesthetic as well as stormwater management design problems. Natural ventilation requirements of parking garages means there must be some openings in exterior walls in order to have adequate air exchange. (***The Dimensions of Parking*, p. 77**). How to provide this in ways consistent with a desirable façade presents a design challenge. Parking structures have an advantage in that they can be a positive element in the streetscape, especially if the ground floor has store fronts. Parking lots, if they are not located behind buildings, can interrupt the street façade and may not represent the highest value use of the land they occupy. In instances where office uses are not combined with retail, new office buildings should be built with parking included within the building footprint, with either ground level or subterranean parking, where hydrology and soils are suitable for the requisite stormwater drainage systems.

c. Stormwater Management Considerations for Parking Structures

Part of the major cost of construction of a parking garage is due to provisions for internal and external drainage. Internally, there must be a drainage system to remove surface water from accumulating on each parking level. Wastewater coming from vehicles is contaminated with corrosive elements that can undermine the structural integrity of the parking garage. Consequently, parking garages are often required to have internal washdown systems and these would need to drain into special wastewater removal systems. Roof drainage from parking garages can be substantial, unless the roof is a "green roof." Whether a structure's roof is a "green roof" or a conventional roof or open parking level, planning for drainage will require knowledge of local rainfall intensities, to insure adequate drains.

d. Stormwater Management Considerations for Parking Lots

Proper preparation of surface parking lots and the choice of surface material are critically important to the serviceability, sustainability, and minimization of the stormwater runoff of these parking facilities. First, the lot should be sloped to facilitate positive drainage. This is likely to require installation of surface drains and drain lines. (***The Dimensions of Parking*, p. 52**). A minimum 2 percent slope toward facilities such as drain inlets, catch basins, and curb inlets, is recommended.

The base should have well-graded aggregate compacted on top of compacted soil. Pavement choice and thickness will depend on local weather, soil and hydrologic conditions. Permeable pavements are not suitable for heavy traffic volumes or heavy vehicles. They are also not suitable in areas where the water table is very close to the ground surfaces, such as floodplains.

i. Landscaping Drainage Solutions

Wherever possible, landscaped buffers should separate rows of parking and lots can be bordered with the same types of landscaped drainage solutions used for roadways, such as biofiltering swales. The landscaped areas between rows should have trees and ground covers that help retain soil and absorb moisture.

ii. Constructed Drainage Solutions

Landscaped buffers between parking rows can include constructed drainage mechanisms such as infiltration trenches. (**See Figure 22** for an example of a bioretention strip in parking islands between rows of parking at the Anacostia Navy Yard outside of Washington, D.C.)

II. The Fort Washington Office Center Case

A. Street and Parking Lot Audit

1. Scoping the Streetscapes and Lotscapes

An examination of the landscape surrounding parking lots and streets can tell us a lot about existing drainage conditions and guide the selection of landscape techniques and materials to improve stormwater management. An audit of conditions should include both dry weather and wet weather observations.

The audit of street conditions takes note of the road surface conditions, presence of street trees, stormwater drains, gutters, road slope and the slopes of land on either side of each road. The audit includes sidewalks, where they exist,. The audit of parking lots records existing surface conditions, drainage, and general occupancy levels in several key parking lots within the Office Center.

2. Summary of Street and Parking Lot/Garage Conditions

a. Streets

Table 4 summarizes information for each of the following streets.

Pennsylvania Avenue
Indiana Avenue
Commerce Drive

Pinetown Road
New Jersey Drive
New York Drive
Maryland Drive
Delaware Drive
Virginia Drive
Highland Avenue
Camp Hill Road
Office Center Drive
Office Center Drive West
Susquehanna Road

The general condition of the roads within the Office Center reflects the overall impression of deterioration of the Center. Just as there are a few new or renovated buildings, there are some recently improved stretches of roadway. However, even the roadways in relatively good condition suffer from design and construction problems that cause them to be significant contributors to flooding in the Office Center. Undoubtedly, this is at least partly due to the haphazard development of the Office Center over the last fifty years. It is very difficult to retrofit parts of the Office Center one property at a time, especially without an overall redevelopment plan. Likewise, it is difficult to achieve a road system with integrated stormwater management without the benefit of a comprehensive stormwater management plan.

Further aggravating inherent stormwater problems due to the local topography, geology, and hydrology, is the excess amount of paved surfaces. Parking lots are much larger than they need to be to meet existing demand, and many of the paved road surfaces are wider than necessary to carry Office Center traffic. Again, the lack of comprehensive and "best practices" planning for the Office Center contributes to this disproportionate amount of pavement. Reduction of paved surface area is probably the single most helpful Green Streets technique to reduce stormwater runoff.

All of the roads within the Office Center suffer from some stormwater management disadvantages, but the major thoroughfare—Virginia Drive as it morphs into Delaware Drive and then Commerce Drive—is beset with stormwater problems. The Virginia Drive portion is so bad that most, if not all, of the "Green Streets" best practices would be of no help. The Virginia Drive road surface is in deplorable condition, and as several signs warn, it is subject to flooding. When flooding occurs, not only through traffic connecting to the E-Z Pass Turnpike access is curtailed, but many of the Center's properties are unreachable. At the other end, where Commerce Drive intersects Pennsylvania Avenue, flooding conditions again block access to Office Center properties. (**See Figures 23 -24**.*)* All of Delaware Drive is in the floodplain and some of it is in the floodway. Again, few if any, of the "Green Streets" best practices would be able to reduce runoff here to any significant amount.

Road drainage systems within the Office Center are minimal and not well-maintained. (**See Figures 25-26).** There are no real gutter systems so runoff tends to remain on the road surface or in the case of sloped roads, run where gravity will take it, that is, into low areas and waterways. In heavy rainfall, the runoff overwhelms the drains that are the only real existing stormwater management measures.

Road edge treatments for stormwater management are also rather minimal. There are few street trees of appropriate size and in appropriate locations to contribute to reducing stormwater runoff. Ideally, trees should be part of a part of a constructed drainage system, such as shown in **Figure 20**. There are some good examples in the Office Center of landscape treatments that work to intercept runoff before it reaches roads and enters the stormwater drain system. (See **Figures 27-28).** These are in stark contrast to the numerous places where nothing has been done to absorb stormwater.

Curbs, where they exist in the Office Center, appear mainly to serve as vertical separators between street traffic and pedestrian traffic or between the roadways and private property and have no intentional role in stormwater management. Many are of minimal height and are in serious disrepair. (See **Figure 29)**

Even a cursory look at the sidewalk system within the Office Center reveals sidewalks in terrible condition. Aside from poor surface conditions, many sidewalks appear to have been constructed with no regard for drainage. Many of them are depressed, relative to their surroundings. The sidewalks on Commerce Drive bordering the Temple/Ambler-McMahon Associates facility are a case in point. They remain water-filled even a day or more after a rain event and caked with mud for days after. Many of the sidewalks are practically unusable. They are beyond cracked and uneven. With chunks of concrete missing, they are a safety hazard to people who might attempt to use them. **Figures 30 – 31** illustrate some of the problems.

A comprehensive sidewalk development plan is a critical piece to a successful revitalization of the Office Center. Connectivity has to be a guiding principle of such a plan. Such a comprehensive plan would create more sidewalk surfaces but such surfaces do not have to be concrete or asphalt-paved. There are permeable surfaces that are smooth enough to meet ADA standards and still improve stormwater management.

b. Parking Lots and Garages

Table 5 summarizes observations of several of the larger lots and the larger parking structures. (There are two facilities with open parking on the ground level, with the building structure above not included in this Table).

In general, parking lots within the Office Center either slope to drain toward roads and land bounding the properties or toward central drains within the parking lot. This sloping would be consistent with best practices for accommodating runoff, if, in the first case, the surrounding land and roadways are capable of handling typical amounts of runoff and, in the second case, internal drains are sufficient to accommodate stormwater runoff. The Office Center's flooding history suggests that many of the parking lots do not meet these qualifications. In some instances, the surrounding land actually contributes to the runoff problems of the lots themselves. **Figures 32 – 33** illustrate this predicament.

Virtually every parking lot in the Office Center is obviously over-designed for existing parking demand. On any given workday, the larger lots are barely half-filled, if that. The main exceptions to this are the lot shared by Temple University-Fort Washington and McMahon Associates, and the LA Fitness lot but even in these lots, there is usually empty parking space. This parking over-supply has resulted in acres of unnecessarily paved surface, all of which aggravates local stormwater problems. Some of the lots are good candidates for permeable surfaces as they do not have traffic from heavy vehicles. Soil and hydrology testing are necessary first, however. Permeable surfaces are not appropriate for poor drainage areas. For almost all lots in the Office Center, runoff control could be improved by adding more drains, infiltration trenches in islands between rows of parking and various edge drainage treatments, as well as eliminating unneeded parking spaces and removing the paved surfaces. In some lots, maintenance to improve the function of existing stormwater drains is needed (**See Figure 34).**

There are two parking decks in the Office Center. They are both simple, two-level facilities.. The one accessed from Office Center Drive has an undesirable slope situation on the side nearest Susquehanna Road. (**See Figure 35**). The facility would have to include drains to take heavy runoff from this slope to avoid inundation of the ground level. (It was not possible to access the interior of this facility to determine neither how effective the drainage system is nor whether the design and the drain capacity meet the usual standards for internal runoff in parking garages).

B. Recommendations of Alternatives for Modeling Analyses

● Reduce paved surfaces of all large parking lots by 10 percent, by 20 percent
● Redesign lots to include islands between parking rows with lined bioretention strips as in **Figure 22.**
● Redesign drainage systems of lots to include more drains and/or direct runoff into on-site retention facilities.
● Convert all parking lots not in the floodplain or with known water table problems to permeable pavement.
● Reduce street widths to minimums as shown in **Figures 14 and 15.**
● Insert linear detention basins in center islands on all streets wide enough to accommodate this
● Insert street trees with tree wells at recommended intervals on all streets.
● Regrade slopes to direct runoff away from streets and parking lots (unless existing street and parking lot drains have proven adequate capacity) and/or construct swales and infiltration trenches to intercept some stormwater before it reaches roads and parking lots.

C. Cost Comparisons

Table 6 shows comparative costs of standard road treatments and "green streets" for new construction of a regional boulevard and for the retrofit/reconstruction of a standard four-lane arterial. The examples are specific to road standards in Washington County, Oregon in the first instance, and Multnomah County, Oregon, - for the second. It is important to bear in mind actual costs in all cases will depend on price structures and road standards in a given area. Local/state road standards vary considerably so one must look closely at what is included in each case. The standard four-lane arterial in Multnomah County does not include signalized intersections or landscaping and maintenance costs but the "green streets" treatment does. In spite of the caveats, the examples can be indicative of relative orders of magnitude and component cost proportions.

The two cases show a relatively much higher cost for retrofitting an existing four-lane arterial to "green streets" standards, compared to simple reconstruction to local arterial standards than for building a "green streets" regional boulevard compared to building a typical regional boulevard. The retrofit case shows a cost 852% of reconstruction of the non-"green streets" four-lane arterial. New construction of a "green streets" regional boulevard would be 128% of the cost of building a new regional boulevard to the basic standards of Washington County.

REFERENCE LIST

Burden, Dan et al 1999, ***Street Design Guidelines for Healthy Neighborhoods***. Sacramento, CA: The Center for Livable Communities.

Childs, Mark. 1999. ***Parking Spaces. A Design, Implementation, and Use Manual for Architects, Planners, and Engineers***. Boston, Massachusetts: McGrawHill.

Davidson, Michael and Fay Dolnick, Eds. 2002. ***Parking Standards***. Chicago: American Planning Association.

Forman, Richard T.T. et al. 2003. ***Road Ecology. Science and Solutions***. Washington, D.C.: Island Press.

Metro (Portland). 2002. ***Green Streets. Innovative Solutions for Stormwater and Stream Crossings.*** First ed. Portland, OR: Metro.

Urban Land Institute. 2001. ***The Dimensions of Parking.*** Fourth edition. Washington, D.C.: ULI—The Urban Land Institute.

U.S. Environmental Protection Agency. 2006. ***Parking Spaces/Community Places***. (EPA 231-K-06-001). Washington, D.C.

C. **Tables:**

TABLE 1

Changes expected in streams once hard-surface cover of contributing watershed land uses exceeds about 10% .

Water—Hydrology	●Increased flood peaks ●More frequent bank-full flows ●Lower stream flow during dry-weather periods
Stream Habitat Structure	●Widening and/or deepening of the stream channel ●Increased streambank and channel erosion ●Increase in artificial channels relative to natural ones ●Fewer logs and braches in streams ●Loss of pool-and-riffle structure ●Reduction in stream habitat diversity ●Decline in streambed quality due to sediment deposition
Water Quality	●Increase in stream temperature ●Higher stormwater pollutant loads and concentrations
Floodplain	●Fragmentation of riparian forest corridor ●Decline in wetland plant and animal diversity

Source: Adapted from Table 12.1, p. 326, in ***Road Ecology***

TABLE 2
Summary of "Green Street" concepts for street retrofits and new construction

Issue	Retrofit	New Construction
Planning Implications	Installation of appropriate designs are restricted to existing ROW, easements onto private property need to be negotiated. Existing street system may not correspond to the conditions, thereby restricting the range of designs available.	Creation of new road system that incorporates designs can lay framework for new development. A "system" of treatment facilities can be designed from the outset to adhere to particular site conditions and existing natural drainage systems (streams).
Right of way requirements	ROW restricted by adjacent development. Must ensure that installation of designs does not come at expense of pedestrian and bicycle facilities.	Dedication of new ROW can incorporate designs. Pedestrian and bicycle accommodations can be incorporated form the outset of street design.
Edge of roadway condition	Substantial modification to edge of roadway may be met with public resistance. Costs may be an issue.	Edge treatments can be designed in accordance with chosen stormwater design.
Street trees	Proposed system must adapt itself to existing street trees due to expected public resistance to tree removal. Provides opportunity for increased street planting but location and species choices should reflect available planting area.	Tree placement and species can be fully incorporated into the system.
Utilities	Installation of designs would generally have to "work around" existing utilities due to prohibitive expense in moving utilities.	Utilities can be consolidated and localized to eliminate conflict with designs.
Overflow contingencies	Existing storm drain system can serve as overflow carrier.	Overflow regime must be considered.
Costs	Structural BMP retrofit of existing development is expensive requiring retrofit to existing storm drain facilities, to existing municipal open space (i.e., detention ponds) or to other developed sits (i.e., underground storage in downtown areas). Retrofits are typically funded by a municipality	With exception of major streets, structural designs for new development are typically funded by a private land developer.
Stream crossings	Replace culverts with clear-span bridges (or at a minimum, bottomless culverts).The abutments should be set back from the river bank and outside the active floodplain* so that the edge remains undisturbed and flood risks are not increased. The extra costs of the structure can be offset by working 'in the dry' (not in the river), and therefore unrestricted by the season.	Opportunity for clear-span bridges set back from the river bank and outside the active floodplain*, preferably with an arch to increase span/depth ratio and resulting high aesthetic appeal. The extra costs of the structure can be offset by working 'in the dry' (not in the river), and therefore unrestricted by the season.

*This criterion to be expanded to apply to varying types of crossings and valley topography

Source***: Green Streets***, Table 5-1: "Application of Green Street Concepts for Street Retrofits and New Construction," page 40.

TABLE 3
Stormwater Management Functions of Green Streets Design Solutions

*typically located outside of the right of way
Source: ***Green Streets***, Table 5-2: "Stormwater Management Functions of Green Streets Design Solutions," p 28.

GREEN STREETS DESIGN SOLUTIONS	RUNOFF REDUCTION	DETENTION	RETENTION	CONVEYANCE	WATER QUALITY
Street trees	X	X			X
Reduced imperviousness	X				
Permeating or eliminating curb and gutter	X				X
Vegetative filter strips				X	X
Swales		X		X	X
Linear detention basin		X		X	X
Infiltration trench		X	X		X
Infiltration basin*		X	X		X

TABLE 4
Road and Sidewalk Survey Summary

ROAD	WIDTH				SLOPE		DRAINAGE			SURFACE		CURBS		VEGETATION	STREET TREES	SIDEWALKS					
	No. of Lanes	*Lane Width*	*Shoulder Width*	*Total Cartway Width*	**Grade*	*Crown*	*# Storm Drains*	*Width of Gutters*	*Condition of Gutters*	*Material*	*Porosity*	*Height*	*Type*	*Type*	**Stormwater Mgmt Contrib**	*None, One-Side, Two-Sides*	*Width*	*Material*	*Condition*	*Edge Treatment*	*Connectivity*
Camphill Road	2	10'	n/a	20'	<10%	none	0	n/a	n/a	asphalt	poor	n/a	n/a	brush	dense in places-residential, sparse elsewhere	0	n/a	n/a	n/a	none	n/a
Commerce Drive	4	11'	n/a	44'	1%	slight	18	n/a	n/a	asphalt	poor	5"	basic	grass/sod	occasional, insignificant	2	42"	concrete	poor	none	fair
Delaware Drive	4	11'	n/a	44'	1%	slight	0	n/a	n/a	asphalt	poor	5"	basic	grass/sod	occasional, insignificant	2	38" - 60"	concrete	good in front of 420, otherwise poor	none	fair
Highland Ave	2	9'	2' - 6'	30'	1% - 4%	slight	0	n/a	n/a	asphalt	poor	n/a	n/a	grass	intermittent plantings, minor effects	0	n/a	n/a	n/a	none	n/a
Indiana Ave	2	10'	n/a		>2%	slight	1			asphalt	poor	n/a	n/a			?	?	?	?	?	
Maryland Drive	2	15'	n/a	30'	4%	slight	7	n/a	n/a	asphalt	poor	3" - 4"	basic	grass/sod	few, insignificant	2	47"	concrete	fair	none	fair
New Jersey Drive	2	16'	n/a	32'	2%	slight	2	n/a	n/a	asphalt	poor	3" - 4"	basic	grass/sod	few, insignificant	2	46"	concrete	poor	none	fair
New York Drive	2	16'	n/a	32'	1%	slight	3	18"	poor-choked	asphalt	poor	2" - 3"	basic	grass/sod	few, insignificant	2	45"	concrete	poor	none	poor
Office Center Dr	2, 4, 6	12--24'*	n/a	72'*	8- 10%	slight	10	n/a	n/a	asphalt	poor	4"	basic	grass/sod	several in upper end, moderate effect, few, insignificat in lower end	2 (intermittent)	60"	concrete	good	none	good to fair
Office Center Dr W	2	22"*	n/a	44'*	2%*	none	8	n/a	n/1	asphalt	poor	4"	basic	grass/sod	few, insignificant	2	60"	concrete	good	none	good to fair
Pennsylvania Ave	4 to 5	12*	n/a	??	0% to 8%	none	10	n/a	n/a	asphalt	poor	8"	basic	grass/sod	few, insignificant	2 (intermittent)	54"	concrete	fair	none	poor
Pinetown Road	3 incl,turn	10'	n/a	30'	>1%	slight	13	n/a	n/a	asphalt	poor	5"	basic	grass/sod	few, insignificant	2	47"	concrete	fair	none	good
Susquehanna Rd	3**	16'*	12'6"	60'6"	<5%	moderate	21	n/a	debris-clogged	asphalt	poor	8"	basic	grass/sod	few, insignificant	2	72"	concrete	new	none	poor
Virginia Dr	4	11'	n/a	44'	level	none	33	n/a	debris-clogged	asphalt	poor	5"	basic	grass/sod	generally few, insignificant, some near Rapp Run	2 (intermittent)	48"	concrete	poor	none	poor

Notes:
*Estimates
**one NB lane, two SB lanes, one intermittent turning lane

Notes:
*Estimates
**one NB lane, two SB lanes, one intermittent turning lane

TABLE 5

Parking Lot/Structure Summary (Selected Major Lots and Parking Structures)**

Lot Location	Surface material	Surface condition	Edging			Drainage			Other comments
			Slope	Vegetation	Type of edge	Storm drains	Islands	Other drainage	
LA Fitness (Virginia Dr.)	asphalt	good to fair	steep	grass	partial curbing	a few storm drains in lot surface	a few islands w/small trees	adjacent linear detention basins, incl.parallel to Virginia Dr	two-level driveways over linear detention basin
DeVry University, 1140 Virginia Dr	asphalt	good to fair	moderate	grass	partial curbing	storm drains in lot, some clogged	a few islands w/small trees	rip-rap in infiltration trench	upper lot empty on wkday, lower lot; debris, sedimentation around some drains
1300-1301 Virginia Dr, Maplewood Office Park	asphalt	good to fair	steep	grass/some plantings	partial curbing	storm drains in lot	a few islands w/small trees	swales at Virginia Dr end	grossly underutilized parking - upper end almost empty on wkday
Subway/Palace of Asia, 285 Commerce Dr	asphalt	fair to poor	slight	grass	grass	few storm drains in lot	n/a	n/a	lot underutilized, even at noon on wkdy
GMAC lot, Virginia Dr	asphalt	good to fair	moderate to steep	grass	partial curbing	storm drains in lot	a few islands w/small trees	swales at Virginia Dr end	lot underutilized, upper lot almost empty on wkday; steep slope on upper lot
Temple/McMahon Assoc.lot, 425 Commerce Dr	asphalt	fair to poor	slight	grass	partial curbing	storm drains in lot	npne	swales & infiltration trench	storm drains in poor shape; 420 Delaware Dr. slopes into this lot
URS - 335 Commerce Dr	asphalt	good	slight	grass	full curbs	storm drains Iot	several w/small trees		
275 Commerce Dr (Liberty Trust prop.)	asphalt	good to fair	slight	grass	partial curbing	storm drains in lot	a few islands w/small trees	n/a	phragmites at one end suggest wetland characteristics
260 New York Dr.	asphalt	fair	moderate	grass	partial curbing	storm drain at bottom of driveway	islands only as separation of lot from sidewalk/road	back lot edge landscaped to drain onto parking lot	sedimentation obvious
Parking deck #1, (Office Center Dr.)	concrete	?*	n/a	n/a	n/a	?*	n/a	n/a	2-story, simple deck construction; slope down from
Parking deck #2, (Office Center Dr. W)	concrete	?*	n/a	n/a	n/a	?*	n/a	n/a	2-story, simple deck construction;
Under bldg pkg,, Best Western/Palace of Asia, 285 Commerce Dr	asphalt	fair to poor	level	n/a	n/a	n/a	n/a	n/a	~30 spaces

* Could not inspect -trespassing signs

**Small parking lots were not included as individually they have a small impact on the overall stormwater management of the Fort Washington Office Center.

TABLE 6
COMPARATIVE "GREEN STREETS" COSTS

A. New construction of a regional boulevard

Components	Metro regional green street blvd. as a proportion of costs of Washington Co. stds	Estimated costs in 2001 $
Preparation/misc.	0.75	$74,443
Signalized intersections	0.75	$74,910
Unsignalized interesection	1.21	$61,167
Restricted intersections	1.15	$126,336
Street construction	1.10	$428,861
Storm drainage - runoff treatment	1.93	$21,500 (swale)*
Storm drainage - pipes	1.19	$175,129
Landscape/maintenance	38.07	$264,583
Signals and signs	1.01	$195,865
TOTAL	**1.28**	**$1,422,093**

* Proportional construction and operations and maintenance cost estimate of a quarter-acre, 5-foot-deep, off-site detention pond attributed to this segment. Comparison is based on a representative 98-foot right of way along a 1,380 foot (1/4 mile) segment.Land price not included.

Washington County design standard c*ross-sectional elements:*

- *Four 12-foot-wide travel lanes*
- *Fourteen-foot wide center turn lane (no raised median)*
- *Six-foot wide bicylce lanes on each side (no parking)*
- *Five and a half-foot sidewalks on each side*
- *Six and a half-foot landscape strips on each side (no trees)*
- *Collection system to an off-site treatment facility, i.e., detention pond*

Cross-sectional elements of the regional green street boulevard design include:

- *Thirteen-foot biofiltering swale with landscape and trees*
- *Four 11-foot travel lanes*
- *Seven-foot-wide on-street parking lanes with street trees within extended curbs on each side*
- *Six-foot wide bicylce lanes on each side*
- *Ten-foot wide sidewalks with trees and grates on each side*

B. Retrofit of four-lane arterial

Components	Standard Metro regional green street as a proportion of costs of Multnomah Co. stds.	Estimated costs in 2001 $
Preparation/misc.	8.65	$91,295
Signalized intersections	*	$37,717
Unsignalized interesection	1.06	$46,364
Street improvements	14.65	$312,523
Storm drainage - runoff treatment	1.60	$24,500 (swale)**
Storm drainage -pipes	3.68	$211,567
Landscape/maintenance	*	$351,674
Signals and signs	*	$183,628
Miscellaneous	*	$4,409
TOTAL	**8.52**	**$1,263,677**

* Not included in Multnomah Co. urban arterial standards

**Proportional construction and operation and maintenance cost estimate of a quarter-acre, 5-foot-deep, off-site detention pond attributed to this segment. Comparison is based on a 1,890-foot portion of an actual street in Multnomah Co.Land price not included.

Retrofitting and upgrading to green streets standards design elements:

- *Thirteen-foot biofiltering swale with landscape and trees (with left turning pockets)*
- *Four 11-foot travel lanes*
- *On-street 7 foot-wide parking lane on one side of the street only*
- *Six-foot-wide bicycle lanes on each side.*
- *Ten-foot-wide sidewalks with trees and grates on each side*

Source: Metro. 2002. *Green Streets. Innovative Solutions for Stormwater and Stream Crossings, pages 121-122.*

D. Figures:

1. Green Streets and Parking

Figure 1

Drain pipes smashed by excessive water flow
(Photo credit: Roger Bannerman, WI Dept. of Natural Resources,
"Solutions to Environmental Impacts of Roadways."
Slide presentation August 21, 2002, Madison, WI)

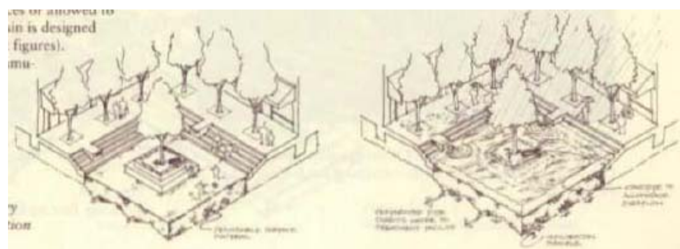
Figure 2

Stream choked by sedimentation.
(Photo credit: Roger Bannerman, WI Dept. of Natural Resources, "Solutions to Environmental Impacts of Roadways." Slide presentation August 21, 2002, Madison, WI).

Figure 3

Algae growth resulting from change in stream flow resulting from sedimentation
(Photo credit: Roger Bannerman, WI Dept. of Natural Resources, "Solutions to Environmental Impacts of Roadways." Slide presentation August 21, 2002, Madison, WI).

Figure 4



Dry pond during dry weather (left) and inundation (right)
(*Green Streets*, Figure 5-6, page 46)

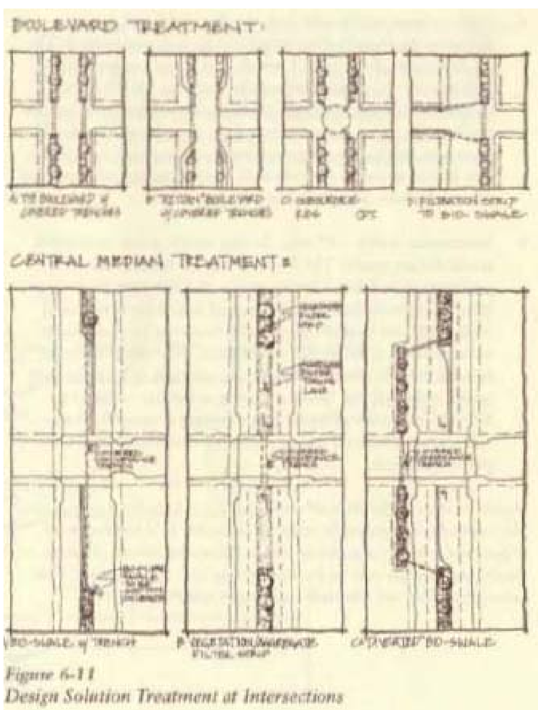
Figure 5

Pre-Reconfiguration of Suburban Madison, WI Street (Photo credit: Roger Bannerman, WI Dept. of Natural Resources, "Solutions to Environmental Impacts of Roadways." Slide presentation August 21, 2002, Madison, WI).

Figure 6

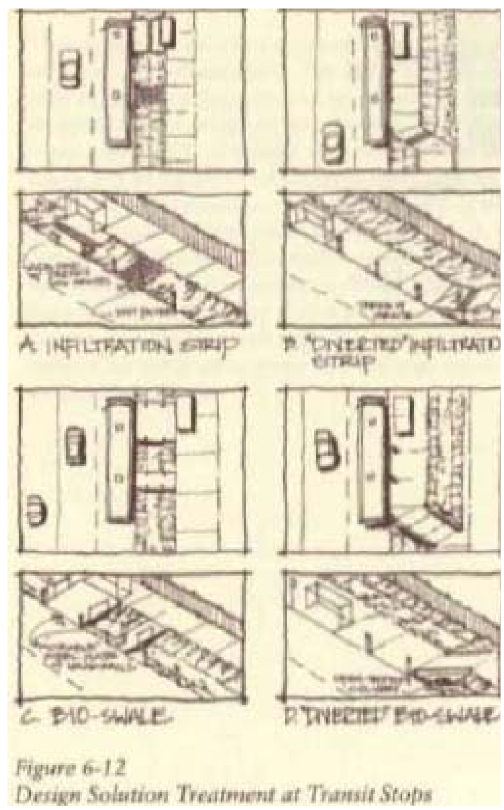
Post-Reconfiguration of Suburban Madison, WI Street (Photo credit: Roger Bannerman, WI Dept. of Natural Resources, "Solutions to Environmental Impacts of Roadways." Slide presentation August 21, 2002, Madison, WI).
Figure 7

Figure 7



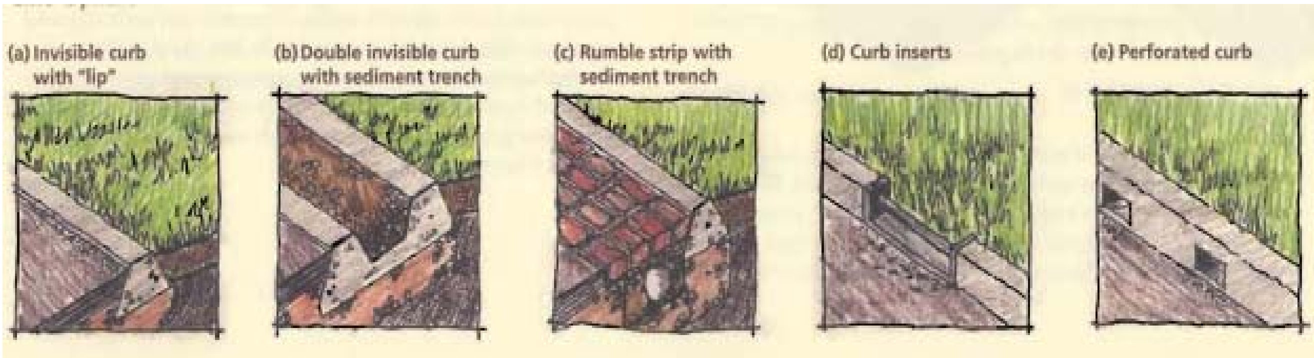
Intersection treatment for boulevards (*Green Streets*, Figure 6-11, p. 82)

Figure 8



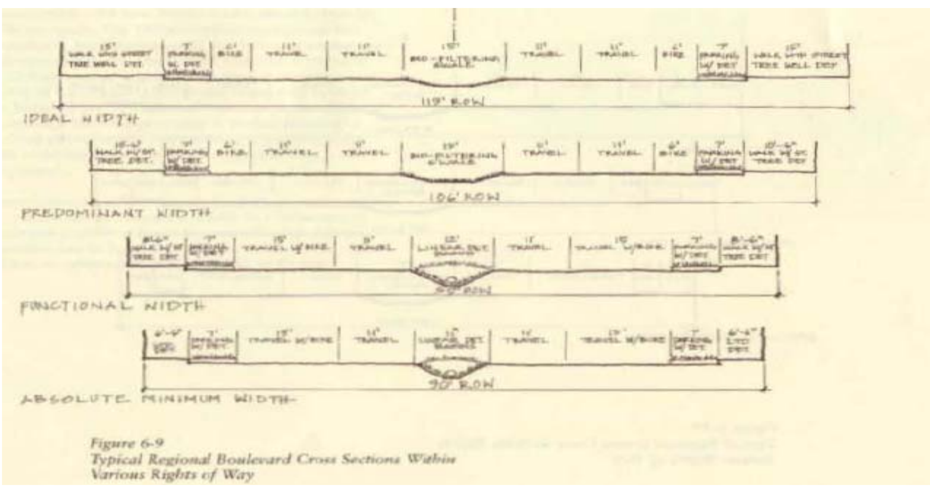
Stormwater treatment design options for transit stops (*Green Streets*, Figure 6-12, p. 83)

Figures 9-13



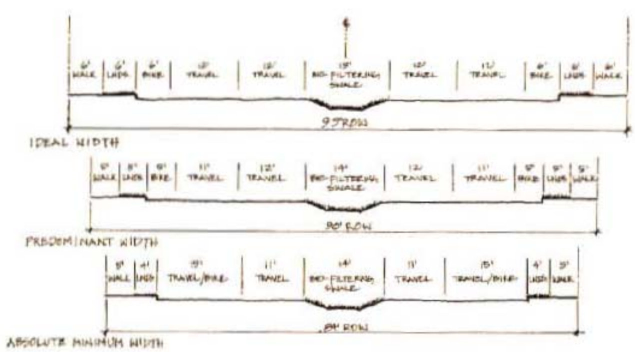
Curb Options
(Green Streets, Figure 5-10, page 54)

Figure 14



Cross-sections of options for reducing ROWs for a regional boulevard
(*Green Streets*, Figure 6-9, page 79)

Figure 15



Cross-sections of options for reducing ROW for regional streets

(*Green Streets*, Figure 6-10, page 80)

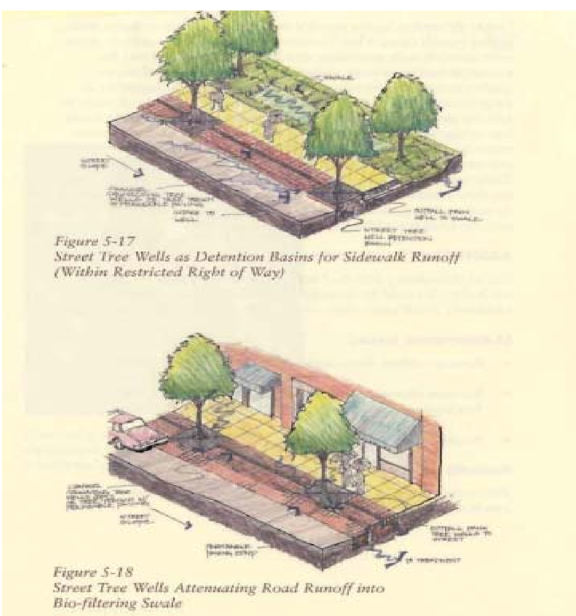
Figure 16

New rain gardens in early spring, in suburban Madison, WI
(Photo credit: Roger Bannerman, WI Dept. of Natural Resources, "Solutions to Environmental Impacts of Roadways." Slide presentation August 21, 2002, Madison, WI).

Figure 17

Mature rain garden, suburb of Madison, WI
(Photo credit: Roger Bannerman, WI Dept. of Natural Resources, "Solutions to Environmental Impacts of Roadways." Slide presentation August 21, 2002, Madison, WI).

Figures 18 and 19

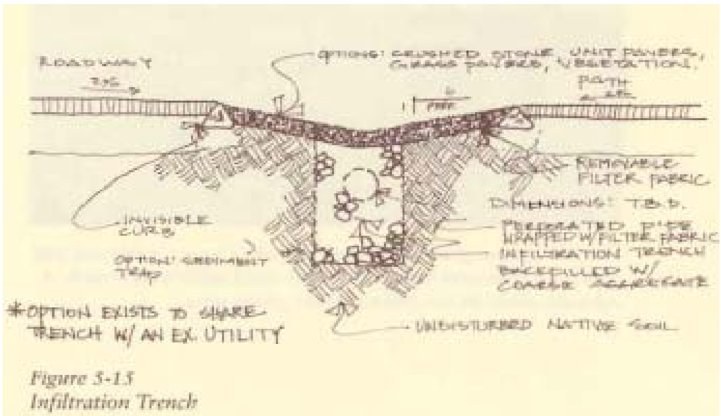


Street tree wells
(*Green Streets*, Figures 5-17 and 5-18, page 62)

Figure 20

Street Tree Filter (Anacostia Navy Yard)

Figure 21



Cross-section of an infiltration trench (*Green Streets,* Figure 5-15, page 59)

Figure 22

Parking area at Anacostia Navy Yard, Maryland

Figure 23

Commerce Drive entrance to Fort Washington Office Center (2006 rain event)

Figure 24

Turnpike exit to PA 309 (August 2007 rain event)

Figure 25  Clogged storm drains - Commerce Drive	**Figure 26**  Battered storm drain – New York Drive
Figure 27  Swale and infiltration trench – New York Drive	**Figure 28**  Swale and infiltration trench – Maryland Drive

Figure 29  Curb failure – New York Drive	**Figure 30**  Poor sidewalk conditions – Commerce Drive
Figure 31  Cracked sidewalk to nowhere – New York Drive	**Figure 32**  Drainage discharge onto parking lot- New York Drive