Better Site Design

I. An Introduction to Better Site Design

Few watershed management practices simultaneously reduce pollutant loads, conserve natural areas, save money, and increase property values. Indeed, if such "wonder practices" were ever developed, they would certainly spread quickly across the nation. As it turns out, these practices have existed for years. Collectively called "better site design," the techniques employ a variety of methods to reduce total paved area, distribute and diffuse stormwater, and conserve natural habitats. Despite their proven benefits and successful local application, better site design techniques often fail to earn the endorsement of local communities. In fact, many communities simply prohibit their use.

"Better site design" is a fundamentally different approach to residential and commercial development. It seeks to accomplish three goals at every development site: to reduce the amount of impervious cover, to increase natural lands set aside for conservation, and to use pervious areas for more effective stormwater treatment. To meet these goals, designers must scrutinize every aspect of a site plan—its streets, parking spaces, setbacks, lot sizes, driveways, and sidewalks— to see if any of these elements can be reduced in scale. At the same time, creative grading and drainage techniques reduce stormwater runoff and encourage more infiltration.

Why is it so difficult to implement better site design in so many communities? The primary reason is the outdated development rules that collectively govern the development process: a bewildering mix of subdivision codes, zoning regulations, parking and street standards, and drainage regulations that often work at cross-purposes with better site design. Few developers are willing to take risks to bend these rules with site plans that may take years to approve or that may never be approved at all.

In 1997, a national site planning roundtable was convened to address ways to encourage better site design techniques in more communities. The participants represented the diverse mix of organizations that affect the development process (listed in Table 1) and provided the technical and real world experience to make better site design happen. After two years of discussion, the roundtable endorsed 22 better site design techniques that offer specific guidance that can help achieve one of the basic better site design goals. These techniques are organized into three areas:

1. Residential Streets and Parking Lots
2. Lot Development
3. Conservation of Natural Areas

These techniques are not intended to be strict guidelines, and their actual application should be based on local conditions. The remainder of this article introduces each of the better site design techniques, describes some of the barriers to their wider use, and suggests ways to overcome these impediments.

Residential Streets and Parking Lots

As much as 65% of the total impervious cover in the landscape can be classified as "habitat for cars," which includes streets, parking lots, driveways, and other surfaces designed for the car. Consequently, 10 better site design techniques address ways to reduce car habitat in new developments.

Figure 1: A Neotraditional Community in Gaithersburg, MD
Better site design techniques have been successfully applied in a growing number of communities like the Kentlands.

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Table 1: Organizations Represented at the National Site Planning Roundtable (Source: CWP,1998b)

The following organizations participated in a two-year long process to craft and refine the 22 model development principles. For a full look at the national consensus agreement, consult our web site at www.cwp.org.

- American Association of State Highway Transportation Officials
- American Forest Association
- American Institute of Architects
- American Planning Association
- American Public Works Association
- American Rivers
- American Society of Civil Engineers
- American Society of Landscape Architects
- Chesapeake Bay Program
- Community Associations Inc.
- The Conservation Fund
- Office of Comprehensive Planning, County of Fairfax, VA
- Howard Research and Development Corporation an affiliate of the Rouse Company
- Institute of Transportation Engineers
- International City/ County Management Association
- Land Trust Alliance
- Linowes & Blocher
- Loiederman Associates, Inc.
- Michael T. Rose Company
- Montgomery County Council
- Natelli Communities
- National Association of Home Builders
- National Realty Committee
- Natural Resources Defense Council
- Prince Georges County Department of Environmental Resources
- U.S. EPA Office of Sustainable Ecosystems and Communities
- U.S. Fire Administration
- Urban Land Institute
- Urban Wildlife Resources

Design residential streets for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency, maintenance, and service vehicle access. Street widths should be based on traffic volume.

In some communities, residential streets can be 32, 36, and even 40 feet wide, despite the fact that they only serve a few dozen homes. These wide streets are the greatest source of impervious cover in most subdivisions. Wide residential streets are created by blanket applications of high volume and high speed design criteria, the perception that on-street parking is needed on both sides of the street, and the perception that they provide unobstructed access for emergency vehicles.

Communities have a significant opportunity to reduce impervious cover by revising their street standards to widths of smaller residential access streets. Residential streets widths should be designed to handle expected traffic volumes, provide adequate parking, and ensure access for service, maintenance, and emergency vehicles. Two strategies can help to narrow streets: using queuing streets (see Figure 2) and critically evaluating the need for on-street parking on both sides of the street. Several national engineering organizations have recommended residential streets as narrow as 22 feet in width (ASSHTO, 1994 and ASCE, 1990).

Conventional Street

Queuing Street

(photos by Randall Arendt)

Figure 2: Queuing Streets as a Technique for Minimizing Street Width

While traditional streets are composed of two travel lanes and parking on either side of the road, queuing streets have one designated travel lane and two queuing lanes that can be used for travel or parking.

Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.

It stands to reason that a longer street network produces more impervious cover and greater development costs than a shorter one, yet most communities do not even consider whether a shorter street network can serve individual lots on residential streets. It is generally assumed that the cost of constructing roads is sufficient incentive to assure short street networks. Streets are designed to accommodate rapid, smooth traffic flow, and consequently, total street length is rarely the most important design consideration.

There is no one street layout guaranteed to minimize total street length in residential developments. Instead, site designers are encouraged to analyze different layouts to see if they can reduce street length.

Wherever possible, residential street right-of-way widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains should be located within the pavement section of the right-of-way wherever feasible.

In many communities, a single right-of-way width of 50 feet or more is applied to all residential street categories. While a wide right-of-way does not necessarily create more impervious cover, it requires more clearing and consumes land that could be used for achieving a more compact site design. By redesigning each of the main components of the right-of-way (ROW), the total width of the ROW can be sharply reduced. Techniques include reducing street width, narrowing sidewalks or restricting them to one side, narrowing the distance between street and sidewalk, and installing utilities beneath street pavement. Combined, these techniques narrow the ROW by 10 to 25 feet.

Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should be considered.

Many communities require the end of cul-de-sacs to be 50 to 60 feet in radius, creating large circles of needless impervious cover. There are several different options to reduce the impervious cover created by traditional cul-de-sacs. One option is to reduce the radius of the turnaround bulb. Several communities have implemented this successfully and the smaller radii can range from 33 to 45 feet. Since vehicles only use the outside of a cul-de-sac when turning, a second option is to create a pervious island in the middle of the cul-de-sac, creating a donut-like effect. A third option is to replace cul-de-sacs with loop roads and hammerheads (see Figure 3).

Engineering techniques have improved the performance of conventional roadside ditches.

Where density, topography, soils, and slope permit, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.

Communities often require that curbs and gutters be installed along residential streets, which quickly convey stormwater runoff and associated pollutant loads directly into the stream. In contrast, open channels can remove pollutants by infiltration and filtering, and are also often less expensive than curb and gutter systems.

New engineering techniques have greatly improved the performance of conventional roadside ditches, which have traditionally suffered from erosion, standing water and increased pavement maintenance. One alternative is dry swales, which are designed both to convey the 10 year storm and treat a water quality stream through a sandy loam filter along the roadway (see Figure 4).

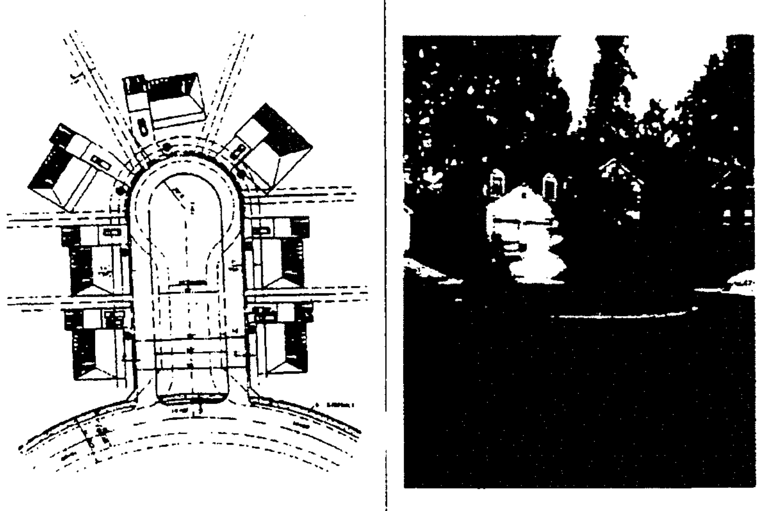

Figure 3: Two Alternatives to the Traditional Cul-de-Sac
A loop road or a pervious island in the middle are two alternatives that can significantly reduce impervious cover.

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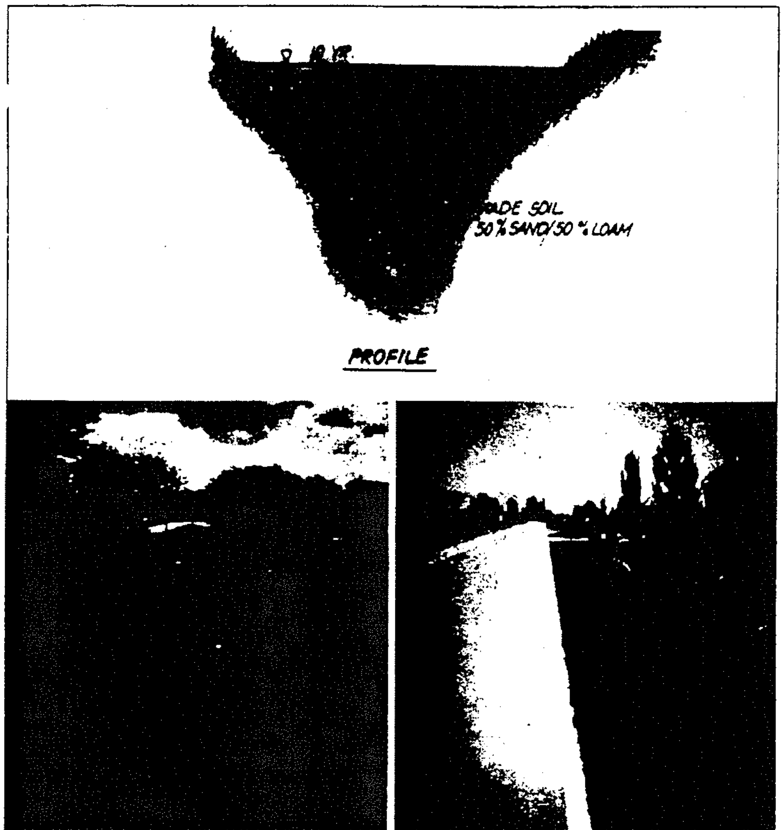

Figure 4: Profile and Two Examples of Open Vegetated Channels

Open vegetated channels allow for infiltration and treatment of stormwater on-site. A dry swale is typically designed to convey the 10 year storm, while treating smaller events with a subsurface composed of a sand and loam filler that treats the runoff before it enters a stream.

The required parking ratio governing a particular land use or activity should be enforced as both a maximum and a minimum in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance, taking into account local and national experience to see if lower ratios are warranted and feasible.

Many communities routinely build more parking spaces than are needed to meet actual parking demands. This is a result of using outdated or overly generous local parking codes to determine minimum parking ratios.

Communities should check their local codes to ensure that both a minimum and a maximum number of parking spaces are set for each building project (see Table 2 for recommended maximum parking spaces). By referring to national, regional and/or local studies, communities can evaluate their parking needs more accurately, thereby reducing the creation of unnecessary parking spaces. Even small reductions in parking can reduce construction and stormwater management costs. As it turns out, shrinking parking lots is critical in reducing the impact of commercial development (see next Feature Article).

Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.

Despite the fact that parking lot size can shrink dramatically if credits for shared parking or mass transit are provided, only a handful of communities require or encourage developers to use these tools. Shared parking allows adjacent land uses to share parking lots if peak parking demands occur during different times of the week. Mass transit can reduce the number of vehicle trips, which translates directly into smaller parking lots.

Despite challenges, several communities have successfully provided parking credits for shared parking for reducing the total number of parking spaces created. One such example is Oakland, California, where a thorough study of short and long term parking demand was conducted. By taking an inventory of existing land uses, parking, and occupancy; and by considering vacancy factors, mass transit access, low auto ownership, and operations of special use facilities, the study concluded that parking rate for office space could be reduced from three spaces to 1.44 spaces per 1,000 gross square feet (ITE, 1995).

Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in the spillover parking areas where possible.

Reducing the size of parking stall dimensions represents another opportunity to reduce impervious cover. The length and often the width of a typical parking stall can often be reduced by a foot or more.

Table 2: Recommended Parking Demand Ratios for Selected Land Uses
(Source CWP 1998b)

Land Use	Better Site Design Parking Ratios
Single Family Homes	2 spaces or less per dwelling unit*
Professional Offices	3.0 spaces or less per 1000 ft²
Retail	4.0 to 4.5 spaces or less per 1000 ft²

* can be accommodated in driveway

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Parking codes can also be amended to require a fixed percentage of smaller stalls for compact cars. Lastly, while permeable parking surfaces can be more expensive to install and maintain, the use of these materials in the 10-20% of the lot that will be used for spillover parking can reduce stormwater treatment costs.

Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.

The type of parking facility in a development site is usually determined by the cost of land balanced against the cost of constructing parking. In suburban and rural areas, the low cost of land makes surface parking more cost-effective than building a garage. In highly urban areas, garages may be a more economical option, since land costs are at a premium.

Vertical parking structures can significantly reduce impervious cover by reducing acreage converted to parking. However, given the economics of surface parking versus garages, it is unlikely that garages will become the norm without incentives. Incentives for defraying some of the costs of parking garages could include tax credits, stormwater waivers or bonuses for density, floor area or building height. A simple way to save on the cost of garages is to incorporate them below or on the first floor of buildings, thereby reducing the structural cost for parking.

Wherever possible, provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

Although parking lots are a significant source of stormwater pollution, many communities do not require developers to provide stormwater quality control. In other communities, opportunities to minimize and treat stormwater runoff at the parking lot are often overlooked. Parking lots can be made more attractive at the same time they treat stormwater. Bioretention areas, dry swales, perimeter sand filters, and filter strips are all effective at treating stormwater within the parking lot. Figure 5 provides a schematic diagram and example of a bioretention facility.

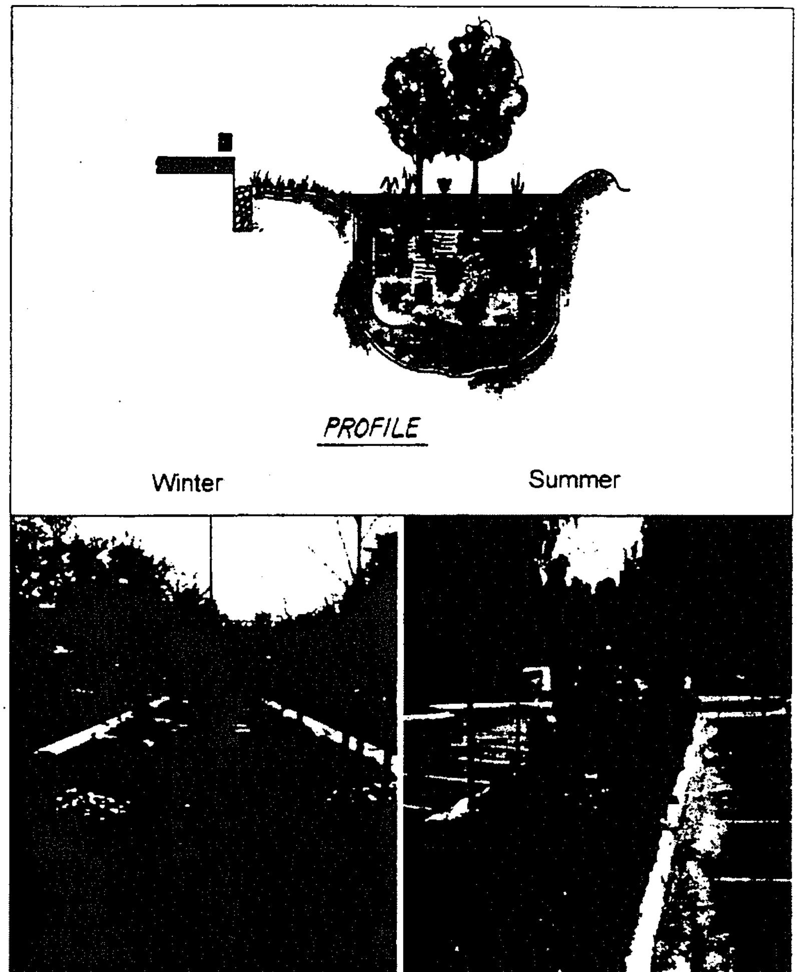

Figure 5: Profile of Parking Lot Bioretention Facilities
Bioretention areas can be designed for parking lots or on-site residential stormwater treatment, and can be an attractive landscaping feature in all seasons.

Lot Development

Many opportunities exist to reduce impervious cover in residential developments by modifying the shape, size, and layout of residential lots. Perhaps the greatest opportunity is to shift from conventional subdivisions to open space or cluster subdivisions.

Advocate open space design subdivisions incorporating smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.

Open space subdivisions cluster houses into a smaller portion of the development site, leaving more of the site as natural open space. Figure 6 illustrates the differences between a conventional and an open space subdivision. Open space subdivisions have been documented to reduce impervious cover, stormwater runoff, and construction costs (see the second feature article in this issue for more details). While open space subdivisions are not always feasible in dense residential zones (more than six dwelling units per acre), communities that can utilize this technique should consider making open space subdivisions a by-right development option.

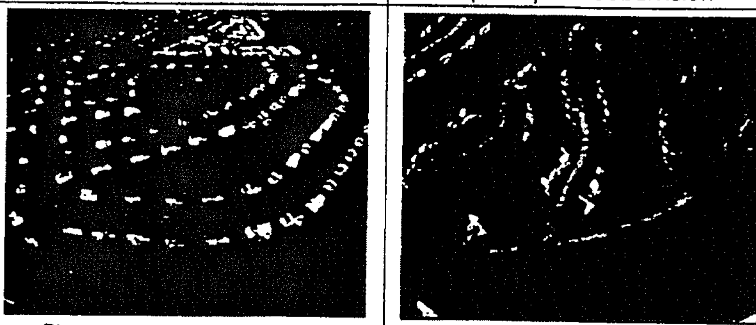

Figure 6: Examples of Conventional and Open Space Site Designs
Many conventional developments are designed using a cookie-cutter approach. Open space site designs preserve more of the existing vegetation and reduce the amount of land that is cleared and graded for individual lots.

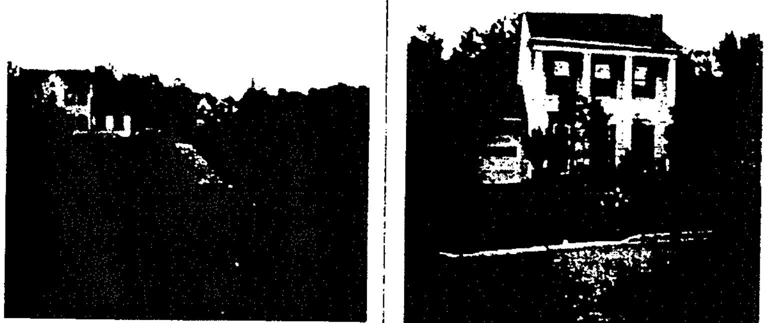

Figure 7: Examples of Long and Reduced Front Setbacks
Smaller front setbacks can reduce site impervious cover, but many current subdivision codes have strict requirements that govern setbacks.

Although open space subdivisions (also known as cluster design) have been advocated by planners for many years, they are often prohibited or severely restricted by local zoning regulations. In 95% of communities surveyed by Heraty (1992), clustering is a voluntary, rather than a mandatory, development option. In addition, open space subdivisions often require a special exception or zoning variance (i.e. they are not a by-right form of development) which requires more review time. Consequently, open space designs are not always widely exercised by developers.

Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.

Many current subdivision codes have very strict requirements that govern lot geometry, including setbacks and lot shape. These criteria constrain site planners from designing open space or cluster developments that can reduce impervious cover. Smaller front and side setbacks, often essential for open space designs, are typically not allowed or require a zoning variance that may be difficult to obtain.

Relaxing setback requirements allows developers to create attractive, compact lots that are marketable and livable (see Figure 7). For example, side yard setbacks can be as close as five feet from detached housing without specific fire protection measures. Often, fears about fire safety, noise, parking capacity and sight distance impairment are cited as impediments to shorter setbacks, but the reality is that these concerns can be overcome with careful design.

Promote more flexible design standards for residential subdivision sidewalks. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.

Most subdivision codes require sidewalks on both sides of residential streets, constructed of impervious concrete or asphalt, 4-6 feet wide, and 2-10 feet from the street. While these codes are intended to promote pedestrian safety, sidewalks should not be designed so rigidly. Instead, the general goal should be to improve pedestrian movement by diverting it away from street traffic. Often, a sidewalk on one side of the street is sufficient. In fact, in a study of pedestrian accidents associated with sidewalks, there was a negligible difference in accident rates when sidewalks were reported on just one side of the street versus sidewalks on both sides of the street (NHI, 1996).

Communities should also consider reducing the sidewalk width of sidewalks to 3-4 feet and placing them further from the street. Sidewalk design should emphasize the connections between neighborhoods, schools, and shops, instead of merely following the road layout (Figure 8). In addition, sidewalks should be graded to drain to front yards rather than the street. These alternatives reduce impervious cover and provide practical, safe, and attractive travel paths.

Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.

Most local subdivision codes are not very explicit as to how driveways should be designed. Most simply require a standard apron to connect the street to the driveway but do not specify width or surface material for driveways. Typical residential driveways are 12 feet wide for one car driveways and 20 feet wide for two. Shared driveways are discouraged or prohibited by many communities.

Shared driveways can reduce impervious cover, and can work when maintenance agreements and easements can be enforced. By specifying narrower driveways, promoting permeable paving materials, and allowing two-track driveways or gravel and grass surfaces, communities can sharply reduce the typical 400 to 800 square feet of impervious cover created by each driveway (see Figure 9).

Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space.

Open space subdivisions encourage the preservation of common areas that must be effectively managed. Surveys of local open space regulations, however, revealed that open space was poorly defined in most communities (Heraty, 1992). Less than a third required that open space be consolidated. Only 10% required that a portion of open space be maintained as natural cover, and few specified which uses were allowed or excluded in the open space areas. Some communities are wary of open space because they feel that community associations may lack financial, legal, or technical resources to effectively maintain their common areas.

In reality, open space maintained in a natural condition costs up to five times less to maintain than lawns. Communities should explore more reliable methods to assure that responsibility is taken for open space management. Effective methods include creating a community association, or shifting responsibility to a land trust or park through a conservation easement.

Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.

Often, local codes discourage the storage and treatment of rooftop runoff on individual lots, thus bypassing opportunities to promote filtering or infiltration in the front or back yard. Most subdivision codes require that yards have a minimum slope to ensure drainage away from homes. The slope helps move runoff away from the home to prevent nuisance ponding, basement flooding, or ice formation on driveways or sidewalks. However, these concerns are only significant within 10 or 15 feet from the home foundation.

Sending rooftop runoff over a pervious surface before it reaches an impervious one can decrease the annual runoff volume from residential development sites by as much as 50%. Techniques to treat rooftop runoff in the yard include directing flow into small bioretention areas that encourage sheet flow across vegetated areas (see Figure 10) or infiltrate runoff in trenches, dry wells, or french drains.

Conservation of Natural Areas

Conservation of natural areas is integral to better site design, and the last six techniques deal with conserving and managing natural areas at the development site. These techniques include stream buffers, clearing and grading, tree conservation and stormwater treatment. To fully utilize these techniques, communities may need to offer developers both flexibility and incentives.

Create a variable width, naturally vegetated buffer system along all perennial streams that also encompasses critical environmental features such as the 100-year floodplain, steep slopes and freshwater wetlands.

This technique establishes a three-zone buffer system to protect streams, shorelines and wetlands at the development site (Figure 11). These three zones

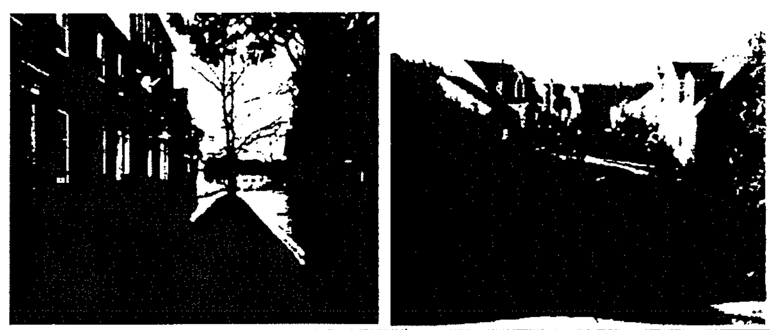

Figure 8: Using Flexible Design Standards for Sidewalks
Creating sensible pathways can produce safe, pedestrian friendly communities.

Figure 9: Examples of Different Types of Shared Driveways
Shared driveways can help reduce the amount of impervious cover created for parking.

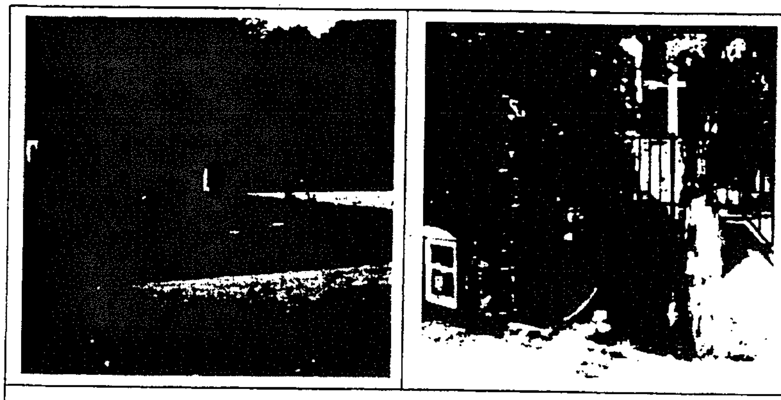

Figure 10: Alternative Runoff Management
Two alternatives for managing rooftop runoff are bioretention areas and rain barrels.

Shoreline Buffer	A Forested Buffer

Figure 11: Development vs. Buffer
A buffer is more than a setback from the stream or shoreline. Native vegetation cover should be retained within part of the buffer to protect the water quality, treat stormwater, and enhance natural beauty.

are distinguished by the types of allowable uses unique to each zone. In addition, the buffer should incorporate the 100-year floodplain, steep slopes, and freshwater wetlands to fully protect the water quality of streams, help treat stormwater, and enhance the quality of life for residents (Schueler, 1995).

Buffers are noted for their economic benefits as well, including include increased property values, reduced flood damages, and sediment removal costs savings. A model stream buffer ordinance and regional samples can be downloaded from our website at www.cwp.org.

The riparian stream buffer should be preserved or restored with native vegetation. The buffer system should be maintained through the plan review delineation, construction, and post-development stages.

While establishing a buffer is paramount to better site design, assuring that the forest buffer is safeguarded from clear cutting is just as essential. Many communities have stream buffer ordinances, but a line drawn on a map is virtually invisible to contractors and landowners. Few communities require that buffer lines be marked. A strong buffer ordinance should outline the legal rights and responsibilities for management and maintenance during construction and for the long term. An effective buffer program should also indicate who is responsible for these issues and address measures to reestablish buffers using native vegetation. Figure 12 illustrates two techniques for preserving and maintaining natural areas and buffers.

Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access, and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.

Most communities allow the entire development site to be cleared and graded, with a few exceptions in specially regulated areas such as jurisdictional wetlands, steep slopes, and floodplains. Since areas that are conserved in their natural state retain their natural hydrology and are not exposed to erosion during construction, it is desirable to conserve as much original soil at the site as possible. Clearing should be limited to the minimum area required for building footprints, construction access, and safety setbacks. Existing tools that could be adapted to limit clearing include erosion and sediment control ordinances, grading ordinances, forest conservation or tree protection ordinances, and open space development. One study has shown that providing grassed lots can add $750 to the value of a lot as compared to bare lots (Harbor and Herzog, 1999). For more information on clearing and grading, see Technical Notes 80, 81, 107 and 108.

Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and conserving native vegetation. Wherever practical, incorporate trees into community open space, street rights-of-way, parking lot islands, and other landscaped areas.

Few communities require that a percentage of trees and native vegetation be conserved during the development process. In fact, many communities promote the use of lawns instead of native vegetation. However, native trees, shrubs, and grasses contribute to the quality of the environment, create a sense of place, and increase property values. Tools that can be used for tree conservation include adopting forest conservation ordinances, encouraging open space design, planting street trees in the rights-of-way,

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adopting clearing and grading restrictions to preserve trees and native vegetation, and adding landscaping requirements for parking lots.

Incentives and flexibility should be encouraged to promote conservation of stream buffers, forests, meadows, and other areas of environmental value. In addition, off-site mitigation should be encouraged where it is consistent with locally adopted watershed plans.

A small number of communities require conservation of non-regulated areas such as stream buffers, forests, and meadows. Even fewer provide meaningful incentives for developers to conserve more natural areas than they are required to. To combat this problem, communities may want to offer increased flexibility and incentives to reward developers for conserving natural areas.

Methods to encourage conservation include by-right open space development, buffer flexibility, property tax credits, density bonuses, transferrable development rights, and providing credits for reduced stormwater management requirements. Stormwater credits exist for natural area conservation, disconnecting rooftop runoff, and routing sheetflow to buffers (MDE, 2000).

New stormwater outfalls should not discharge unmanaged stormwater into jurisdictional wetlands, sole-source aquifers, or sensitive areas.

Stormwater runoff generated from impervious cover can represent a significant threat to the quality of wetlands, surface water and groundwater. While many communities are beginning to require stormwater quality practices, they are often poorly matched to site conditions and watershed objectives.

Stormwater practices can be designed to be effective, attractive and relatively easy to maintain. A well-designed stormwater practice should add value to a community while meeting stormwater management objectives. For new criteria on the design of stormwater practices, refer to the Maryland Stormwater Manual available online: http://www.mde.state.md.us/ environment/wma/

Summary

For many communities, implementing better site design may require that development rules be changed, and this process is not an easy one. Advocates of better site design are likely to have to answer some difficult questions from fire chiefs, lawyers, traffic engineers, developers, and many others in the community. Will a proposed change make it more difficult to park? Lengthen response times for emergency vehicles? Increase risks to community residents and children? Progress toward better site design will require more local governments to examine their current practices in the context of a broad range of concerns, such as how the changes will affect development costs, local liability, property values, public safety, and a host of other factors.

Subsequent articles in this special issue of *Techniques* supply more background on the benefits of better site design and how it can be implemented in your community. In the next article, *The Benefits of Better Site Design in Residential Subdivisions*, we document how open space subdivisions can reduce runoff, pollutant export and development costs when compared to conventional subdivisions. The third article, *The Benefits of Better Site Design at Commercial Developments*, examines strategies to shrink the parking lots that comprise more than half of the area of new commercial developments and help mitigate the harmful impact parking lots have on the environment. The last article, *Changing Development Rules in Your Community*, describes a process for making better site design happen in your community. Finally, our *Resources* section profiles more than a dozen useful better site design references.

Better site design has considerable potential to reduce the environmental impacts of new development sites, and when adapted properly, of redevelopment sites as well. Better site design is a particularly useful strategy in watersheds where future development is projected to approach or slightly exceed impervious cover thresholds. It should be kept in mind, however, that better site design alone cannot adequately protect most watersheds. It must be combined and integrated with other watershed protection tools, such as watershed planning, land conservation,

Buffer Reforestation	Tree Conservation Area

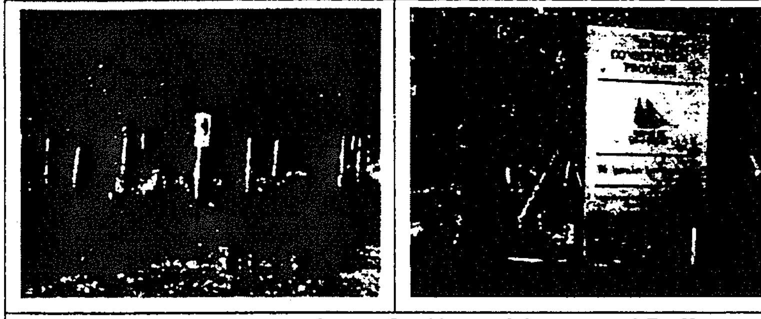

Figure 12: Two Techniques for Natural Areas and Buffers
Buffer reforestation and tree conservation are two important techniques for maintaining natural areas, including buffers. Buffer lines should be clearly marked to protect from clearing and grading both during and after construction.

erosion and sediment control and the rest. These caveats notwithstanding, better site design is the one of the few watershed protection tools that simultaneously provides dividends for watershed advocates, developers and the community as a whole. Consequently, communities are encouraged to invest in the local site planning roundtable process that can make it happen. *–HYK*

Better site design alone cannot adequately protect most watersheds.

Editor's Note: We are currently working on techniques for infill and redevelopment. Beginning later this year, we will begin a national roundtable consensus process focusing on topics, challenges, and concerns. Refer to our website (www.cwp.org) for updates on this project.

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Better Site Design

II. The Benefits of Better Site Design in Residential Subdivisions

Though they may not realize it, site planners have an excellent opportunity to reduce storm water runoff and pollutant export simply by changing the way they lay out new residential subdivisions. Planners that employ open space design techniques can collectively reduce the amount of impervious cover, increase the amount of natural land conserved, and improve the performance of stormwater treatment practices at new residential developments

Simply put, open space designs concentrate density on one portion of a site in order to conserve open space elsewhere by relaxing lot sizes, frontages, road sections, and other subdivision geometry. While site designs that employ these techniques go by many different names, such as clustering or conservation design, they all incorporate some or all of the following better site design techniques:

- Using narrower, shorter streets and rights-of-way
- Applying smaller lots and setbacks and narrow frontages to preserve significant open space
- Reducing the amount of site area devoted to residential lawns
- Spreading stormwater runoff over pervious surfaces
- Using open channels rather than curb and gutter
- Protecting stream buffers
- Enhancing the performance of septic systems, when applicable

In this article, we examine some of the benefits of employing better site design techniques as they apply to residential subdivisions. The analysis utilizes a simple spreadsheet computer model to compare actual residential sites constructed in the 1990s using conventional design techniques with the same sites "redesigned" utilizing better site design techniques. For each development scenario, site characteristics such as total impervious and vegetative cover, infrastructure quantities, and type of stormwater management practice are estimated.

The Simplified Urban Nutrient Output Model (SUNOM) was used to perform a comparative analysis for two subdivisions that span a wide range of residential density (see box on page 645). The first is a large-lot subdivision known as Duck Crossing, and the second is a medium-density subdivision known as Stonehill Estates. In each case, the model was used to simulate five different development scenarios:

- Pre-developed conditions
- Conventional design without stormwater practices
- Conventional design with stormwater practices
- Open space design without stormwater practices
- Open space design with stormwater practices

This article compares the hydrology, nutrient export, and development cost for these sites under both conventional and open space design, and with and without stormwater treatment. The article also summarizes other research on the benefits of open space design and discusses the implications it can have for the watershed manager.

Open space design concentrates density on one portion of a site in order to conserve open space elsewhere.

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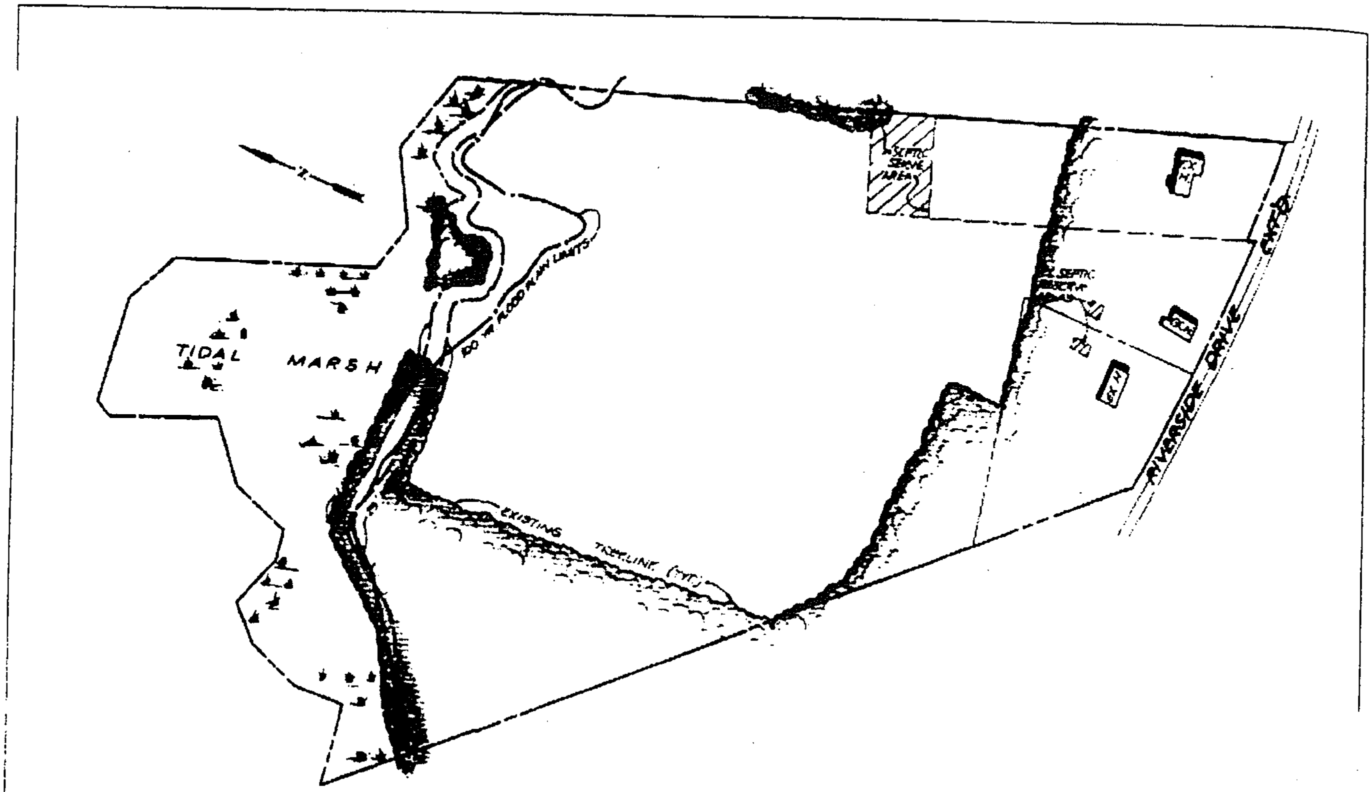

Figure 1: Predevelopment Conditions at the Duck Crossing Site

Duck Crossing - A Low-Density Residential Subdivision

Duck Crossing is a large-lot residential development located in Wicomico County on Maryland's Eastern Shore. Prior to development, the low gradient coastal plain site contained a mix of tidal and non-tidal wetlands, natural forest, and meadow (Figure 1). Its sandy soils were highly permeable (hydrologic soil group A). Three existing homes were located on the parcel, which relied on septic systems for on-site sewage disposal. The existing septic systems discharged a considerable nutrient load to shallow groundwater.

A conventional large-lot subdivision of eight single family homes was constructed on the 24-acre site in the early 1990s. The subdivision is reasonably typical of rural residential development along the Chesapeake Bay waterfront during this era (Figure 2). Each new lot ranged from three to five acres in size, and was set back several hundred feet from an access road. The access road was 30 feet wide and terminated in a large diameter cul-de-sac. Sidewalks were located on both sides of the street. Each lot was served by a conventional septic system with a primary and reserve field of about 10,000 square feet. Stormwater management consisted of curb and gutters that conveyed runoff into a storm drain system that, in turn, discharged to a small dry pond (designed for the water quality volume, only).

The entire site was privately owned, with the exception of the tidal marsh, which was protected under state and federal wetland laws and represented the only common open space on the site. As a result of construction, the existing meadow was entirely converted to lawn, and the impervious cover for the site increased to slightly over 8%.

Open Space Design for Duck Crossing

The critical ingredient of the open space redesign was a reduction in lot size from several acres to about 30,000 square feet. This enabled about 74% of the site to be protected and managed as common open space, which included most of the existing forest, wetlands and meadow (Figure 3). Consequently, only 19% of the site was managed as turf, nearly all of which was located on the private lots.

The open space redesign at Duck Crossing also incorporated a narrower access road (20 feet wide) along with shorter, shared driveways that served six of the eight lots. The road turnaround was designed as a loop rather than a cul-de-sac bulb. Also, a wood chip trail system was provided through the open space

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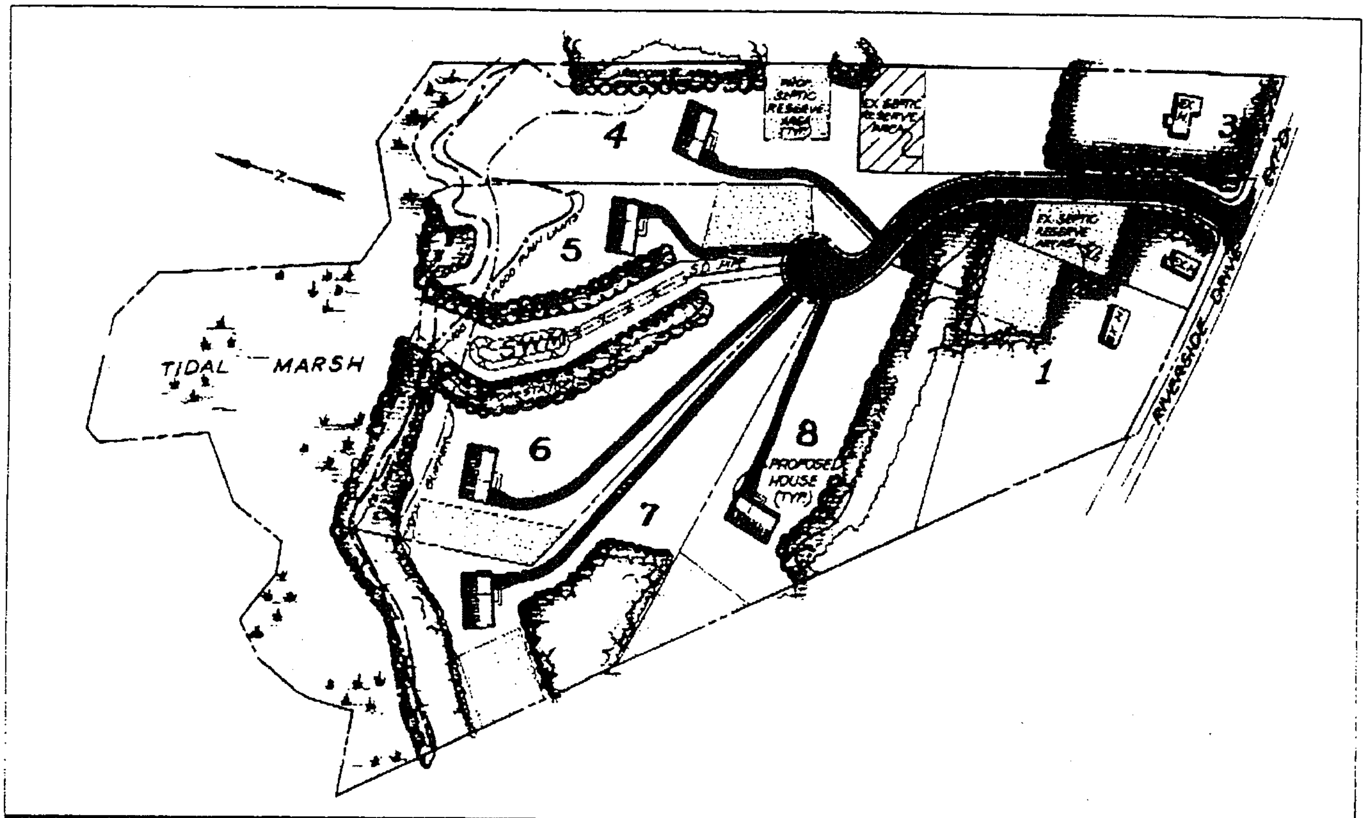

Figure 2: The Low-Density Conventional Subdivision Built at Duck Crossing (eight lots)

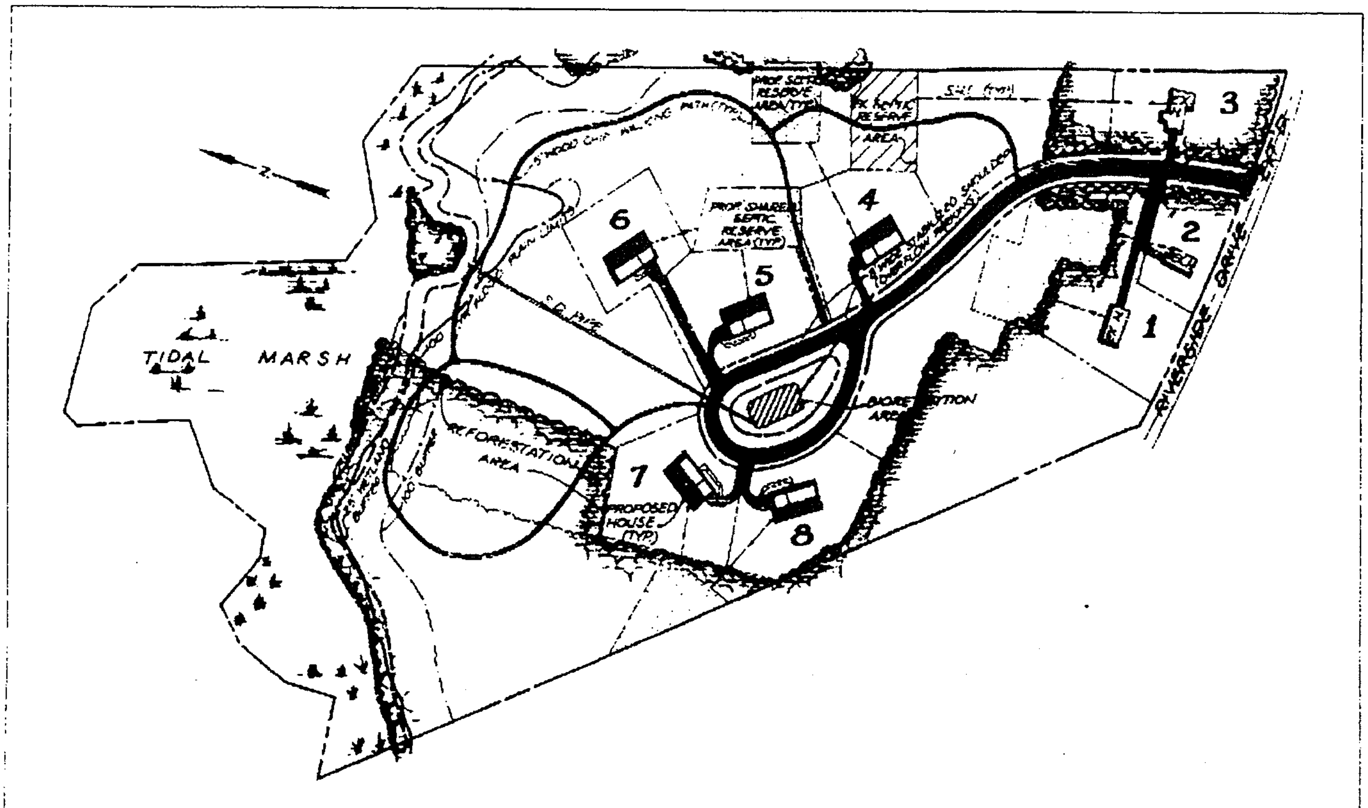

Figure 3: The Open Space Subdivision That Could Have Been Built at Duck Crossing (eight lots)

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instead of sidewalks along the road. Each home site was carefully located away from sensitive natural areas and the 100-year flood plain. Taken together, these better site design techniques reduced impervious cover for the site by about a third compared to the conventional design (from 8% to 5%).

The redesigned stormwater conveyance system utilized dry swales rather than a curb and gutter system, and featured the use of bioretention areas in the roadway loop to treat stormwater quality. This combination of stormwater practices provided greater pollutant removal through filtration and infiltration.

One of the most important objectives in the redesign strategy was to improve the location and performance of the septic systems that dispose of wastewater at the site. Home sites were oriented to be near soils that were most suitable for septic system treatment. In addition, six homes shared three common septic fields located within open space rather than on individual private lots. Lastly, given the permeability of the soils, advanced re-circulating sand filters were installed to provide better nutrient removal than could be achieved by conventional septic systems.

Comparative Hydrology for Duck Crossing

Given its low impervious cover and permeable soils, the water balance at Duck Crossing was dominated by infiltration, even after development. The comparative hydrology under the five development scenarios is presented in Table 1. As might be expected, the conventional design yielded the greatest volume of surface runoff and the least amount of infiltration. The open space design produced about 25% less annual surface runoff and 12% more infiltration than the conventional design, but did not come close to replicating pre-development conditions. The use of stormwater practices did not materially change the water balance under either the conventional or open space design at Duck Crossing (see Table 1).

The open space design sharply reduced nutrient export.

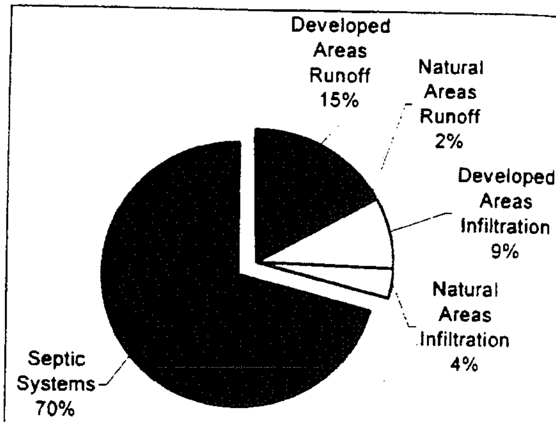

Figure 4: Nitrogen Load Distribution From the Conventional Design of Duck Crossing, Without Stormwater Practices

Comparative Nutrient Output at Duck Crossing

Nutrient export at Duck Crossing was dominated more by subsurface water movement than by surface runoff. Indeed, stormwater runoff seldom comprised more than 15% of the annual nitrogen or phosphorus load from this lightly developed site. The SUNOM model indicated that the major source of nutrients was subsurface discharges from septic systems, which typically accounted for 60 to 80% of the total load in every development scenario (see Figure 4).

The open space design sharply reduced nutrient export, primarily because re-circulating sand filters were used in the shared septic systems and helped to reduce (but not eliminate) subsurface nutrient discharge. The other elements of the open space design (reduced impervious cover, reduced lawn cover, and multiple stormwater practices) also helped to reduce nutrient export, but by a much smaller amount. The comparative nutrient export from each Duck Crossing development scenario is detailed in Figure 5.

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Table 1: Annual Water Budget of Duck Crossing

		Pre-Developed	Conventional Design	Open Space Design
Runoff (inches/year)	no practice	2.3	4.8	3.9
	practices	- -	4.8	3.7
Infiltration (inches/year)	no practice	18.2	15.3	17.0
	practices	- -	15.3	17.2

Comparative Cost of Development

The cost to build infrastructure for the open space design was estimated to be 25% less than the conventional design at Duck Crossing, due primarily to the necessity for less road paving, sidewalks, and curbs and gutters. Even when higher costs were factored in for the more sophisticated stormwater and on-site wastewater treatment used in the open space design, the total cost was still 12% lower than the conventional design. In addition, the open space design had seven fewer acres that needed to be cleared and graded, or served by erosion and sediment controls, compared to the conventional design (these costs are not currently evaluated by the SUNOM model). Overall, the SUNOM model estimated that the conventional design at Duck Crossing had a total infrastructure cost of $143,600, compared to $126,400 for the open space design.

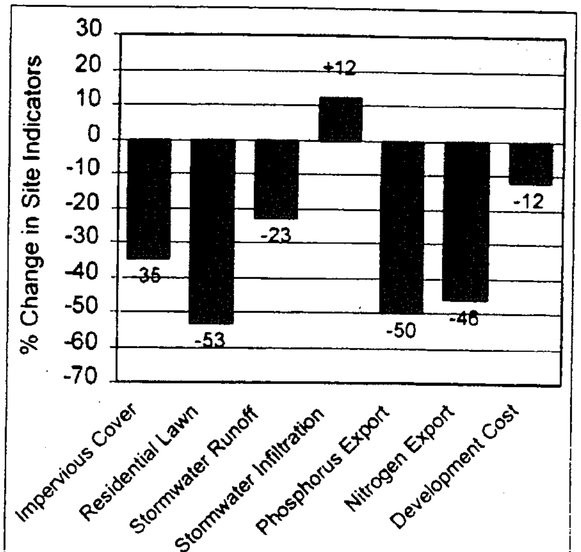
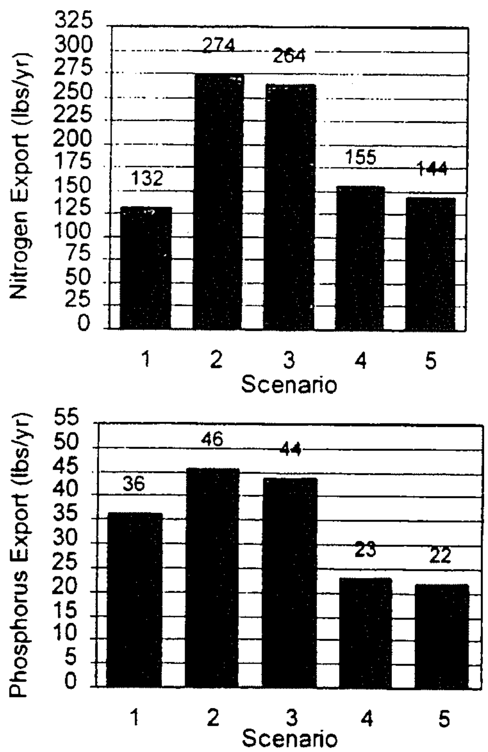


Figure 6: Percentage Change in Key Site Conditions From a Conventional Design to an Open Space Design, Both With Stormwater Practices



1 - Pre-Developed Conditions
2 - Conventional Design (no practices)
3 - Conventional Design (with practices)
4 - Open Space Design (no practices)
5 - Open Space Design (with practices)

Figure 5: Annual Nitrogen and Phosphorus Loads for Each Development Scenario at Duck Crossing

Summary

The comparative results for the Duck Crossing redesign analysis are summarized in Figure 6. The open space design increased natural area conservation and reduced impervious cover, stormwater runoff, nutrient export, and development costs compared to the conventional subdivision design.

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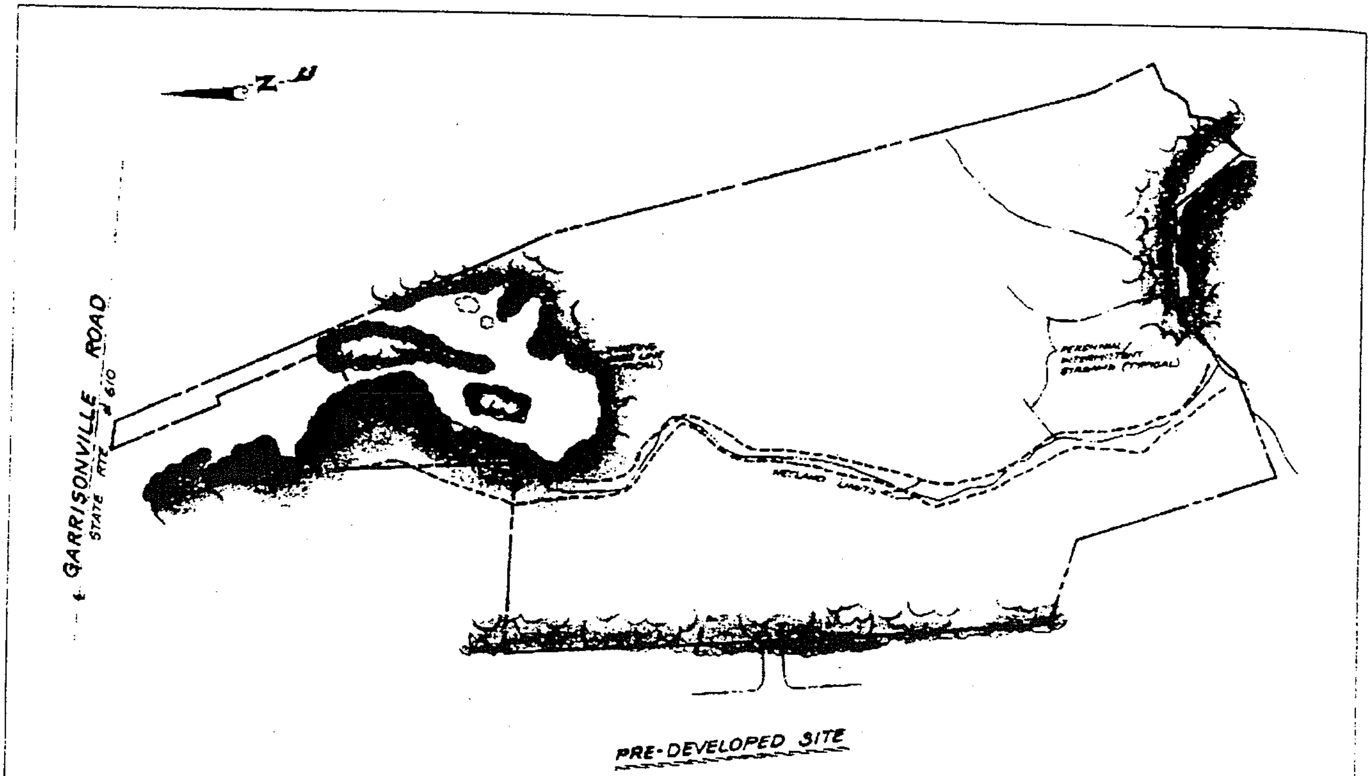

Figure 7: Predevelopment Conditions at the Stonehill Estates Site

Stonehill Estates - A Medium-Density Residential Subdivision

Stonehill Estates, located near Fredericksburg, Virginia, is situated in the rolling terrain of the Piedmont. The undeveloped parcel was 45 acres in size, nearly all of which was mature hardwood forest (Figure 7). An intermittent stream bisected the site, discharging into a perennial stream near the southern edge of the parcel. Roughly 3.6 acres of forested wetlands were found along the stream corridors, and an extensive floodplain was located along the perennial stream. Soils at the site were primarily silt loams and were moderately permeable (hydrologic soil groups C and D).

The site was highly attractive for development, given the excellent access provided by two existing roads, both of which had public water and sewer lines that could be easily tapped to serve the new subdivision. The conventional design was zoned for three dwelling units per acre. After unbuildable lands were excluded, the parcel yielded a total of 108 house lots, each of which was about 9,000 square feet in size (Figure 8). The subdivision design typifies medium-density residential subdivisions developed in the last two decades in the Mid-Atlantic region, where lots sizes were uniform in size and shape and homes were set back a generous and fixed distance from the street. The design utilized a mix of wide and moderate street sections (34 feet and 26 feet), and included six large diameter cul-de-sacs for turnarounds. Sidewalks were generally installed on both sides of the street.

The stormwater management system for the conventional design represents the typical "pipe and pond" approach utilized in many medium-density residential subdivisions. Street runoff was conveyed by curbs and gutters into a storm drain system that discharged into the intermittent stream channel, and then traveled downstream to a dry extended detention pond. The pond was primarily designed to control flooding, but also provided some limited removal of stormwater pollutants.

Interestingly, about 25% of the site was reserved as open space in the conventional design at Stonehill Estates. Nearly all of these lands were unbuildable because of environmental and site constraints (e.g., floodplains, steep slopes, wetlands, and stormwater facilities), and the resulting open space was highly fragmented. Even so, about a fourth of the forested wetlands were impacted by two roads crossing over the intermittent stream. Almost 90% of the original forest cover was cleared as a result of the conventional design, and was replaced by lawns and impervious cover. Overall, about 60% of the site was converted to lawns, and another 27% was converted to impervious cover.

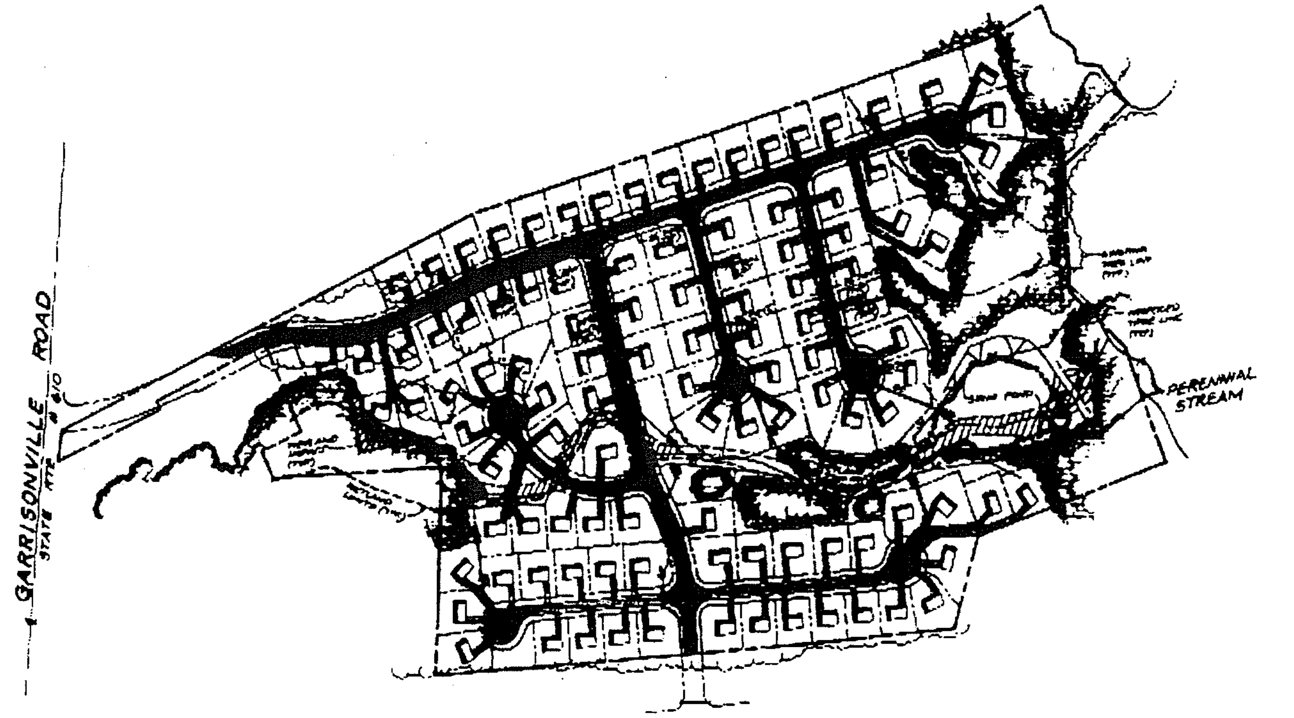

Figure 8: The Conventional Subdivision Design That Was Built at Stonehill Estates (108 lots)

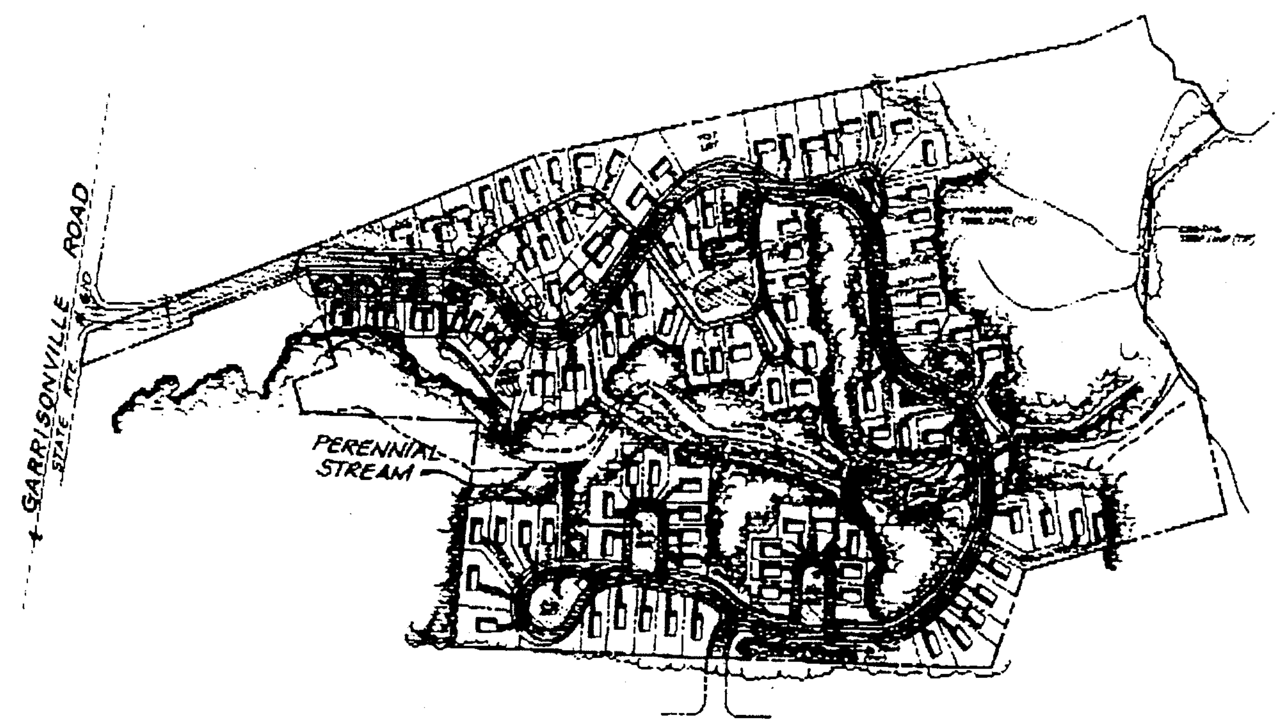

Figure 9: The Open Space Subdivision That Could Have Been Built at Stonehill Estates (108 lots)

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Open Space Design for Stonehill Estates

In the redesign analysis, Stonehill Estates was designed to incorporate many of the open space design techniques advocated by Arendt (1994). The resulting design retained the same number of lots as the conventional design, but had a much different layout (Figure 9). The average lot size declined from about 9,000 square feet in the conventional design to 6,300 square feet in the open space design. This reduced lot size allowed about 44% of the site to be protected as open space, most of which was managed as a single unit that included an extensive natural buffer along the perennial and intermittent stream corridor.

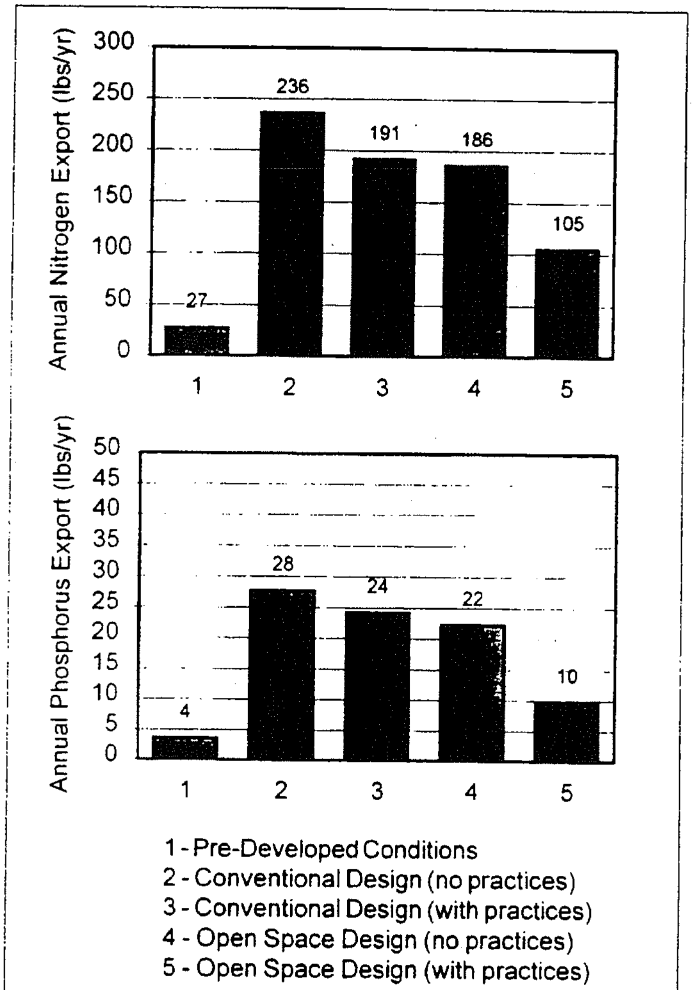

Figure 10: Annual Nitrogen and Phosphorus Loads for Each Stonehill Estates Development Scenario

Table 2: Comparative Hydrology of Stonehill Estates

		Pre-Developed	Conventional Design	Open Space Design
Runoff (inches/year)	no practice	2.1	10.6	8.8
	practices	n/a	10.6	8.0
Infiltration (inches/year)	no practice	4.9	3.1	4.0
	practices	n/a	3.1	4.8

The basic open space layout was augmented by several other better site design practices, including narrower streets, shorter driveways, and fewer sidewalks. Loop roads were used as an alternative to cul-de-sacs. In some portions of the site, irregularly shaped lots and shared driveways were used to reduce overall road length. Each individual lot was located adjacent to open space, so that the more compact open space lots would not feel as crowded. As a result of these techniques, the open space design for Stonehill Estates reduced impervious cover from 27% to 20%. In addition, lawn cover declined from 60% to 30% of the total site area.

The innovative stormwater collection system utilized dry swales rather than storm drains in gently sloping portions of the site. The dry swales and several bioretention areas located in loop turnarounds were used to initially treat stormwater quality. Each of these practices then discharged to a small micro-pool detention pond, whose embankment was created by the single road crossing over the intermittent stream.

Comparative Hydrology

Prior to its development, the highly wooded site produced very little surface runoff, but because of relatively tight soils, generated only a modest amount of infiltration. However, after the site was converted into the conventional subdivision, surface runoff increased by a factor of five, and infiltration was reduced by about 40% (Table 2). In contrast, the open space design worked to reduce stormwater runoff and increase stormwater infiltration compared to the conventional design, although it did not come close to replicating the original hydrology of the forested site (Table 2).

Comparative Nutrient Output

As might be expected, the conversion of the forest into a conventional subdivision greatly increased nutrient export from the site; the model indicated that annual phosphorus and nitrogen export would increase by a factor of seven and nine, respectively, after development (see Figure 10). Unlike Duck Crossing, nutrient export at Stonehill Estates was dominated by stormwater runoff after development. The SUNOM model indicated that stormwater runoff contributed about 94% of the annual nutrient export from the site,

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Table 3: Redesign Analyses Comparing Impervious Cover and Stormwater Runoff from Conventional and Open Space Subdivisions

Residential Subdivision	Original Zoning for Subdivision	Impervious Cover at the Site			Reduction in Stormwater Runoff (%)
		Conventional Design	Open Space Design	Net Change	
Remik Hall [1]	5 acre lots	5.4 %	3.7%	-31%	20%
Tharpe Knoll [2]	1 acre lots	13%	7%	-46%	44%
Chapel Run [2]	½ acre lots	29%	17%	-41%	31%
Pleasant Hill [2]	½ acre lots	26%	11%	-58%	54%
Prairie Crossing [3]	½ to 1/3 acre lots	20%	18%	- 20%	66%
Buckingham Greene [2]	1/8 acre lots	23%	21%	- 7%	8%
Belle-Hall [4]	High Density	35%	20%	- 43%	31%

Sources: [1] Maurer, 1996; [2] DE DNREC, 1997; [3] Dreher, 1994; and [4] SCCCL, 1995.

with subsurface water movement adding only 6% to the total export. Nutrient loads were not greatly reduced by the dry extended detention pond installed at the conventional subdivision; the model indicated that nutrient export from the conventional design would still be six to seven times greater than the predevelopment condition even with this stormwater treatment practice.

In contrast, the open space design resulted in greater nutrient reduction (Figure 10). For example, the open space design scenario *without* stormwater practices produced a lower nutrient load than the conventional design scenario *with* stormwater practices. This was primarily due to lower impervious cover associated with the open space design. When the open space design was combined with more sophisticated stormwater practices (i.e., bioretention, dry swales and wet ponds), nutrient export was half that of the conventional design. It is interesting to note, however, that even when the most innovative site design and stormwater techniques were applied to the site, nutrient export was still three to four times greater than that produced by the forest prior to development.

Infrastructure Costs

The total cost to build infrastructure at Stonehill Estates was about 20% less for the open space design than for the conventional design. Considerable savings were realized in the form of less road paving and shorter lengths of sidewalks, water and sewer lines and curbs and gutters. The cost difference between the open space and conventional designs would have been greater were it not for the fact that higher costs were incurred for the more sophisticated stormwater practices used in the open space design. It was estimated that the infrastructure cost for the conventional design was $1.54 million, compared to $1.24 million for the open space design.

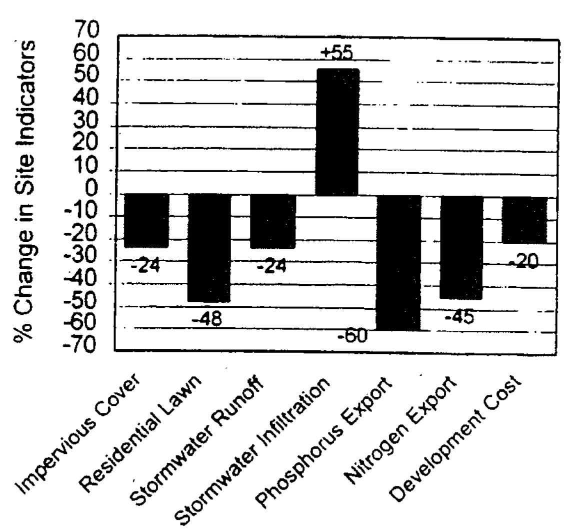

Figure 11: Change in Site From a Conventional Design to an Open Space Design, Both With Stormwater Practices

Table 4: Projected Construction Cost Savings for Open Space Designs from Redesign Analyses

Residential Development	Construction Savings	Notes
Remlik Hall[1]	52%	Includes costs for engineering, road construction, and obtaining water and sewer permits
Tharpe Knoll[2]	56%	Includes roads and stormwater management
Chapel Run[2]	64%	Includes roads, stormwater management and reforestation
Pleasant Hill[2]	43%	Includes roads, stormwater management and reforestation
Buckingham Greene[2]	63%	Includes roads and stormwater management

Sources:[1] Maurer, 1996; [2] DE DNREC, 1997

Summary

The comparative results for the Stonehill Estates redesign analysis are summarized in Figure 11. The open space design reduced impervious cover, natural area conversion, stormwater runoff, nutrient export and development costs compared to the conventional subdivision design.

Other Redesign Research

Several other researchers have employed redesign comparisons to demonstrate the benefits of open space subdivisions, over a wide range of base lot sizes. The results are shown in Table 3. It should be recognized that each study used slightly different models and assumptions, and as such, strict comparisons should be avoided. The redesign comparisons clearly show that open space designs can sharply reduce impervious cover and stormwater runoff while accommodating the same number of dwelling units, at least to base lot sizes of an eighth of an acre. The reductions in impervious cover and runoff range from 7 to 65%. The ability of open space design to reduce impervious cover starts to diminish for residential zones that exceed densities of four dwelling units per acre.

> Other studies reinforce the conclusion that open space designs are less expensive to build than conventional subdivisions.

These studies reinforce the conclusion that open space designs are usually less expensive to build than conventional subdivisions. The projected construction cost savings associated with open space designs ranged from 40 to 66% (Table 4). Most of the cost savings were due to reduced need for road building and stormwater conveyance. In another study, Liptan and Brown (1996) reported that open space design produced infrastructure construction costs savings of $800 per home in a California subdivision.

Numerous economic studies have shown that well-designed and marketed open space designs are very desirable to home buyers and very profitable for developers. Strong evidence indicates that open space subdivisions sell faster, produce better cashflow, yield a higher return on investment and appreciate faster than their traditional counterparts (Arendt *et al.*, 1994, Ewing, 1996, NAHB, 1997, ULI, 1988. CWP, 1998a, and Porter, 1988). While open space designs are often perceived as applying only to upscale and affluent consumers, several successful open space subdivisions have been built for moderate to lower income buyers. Both ULI (1988) and Ewing (1996) report that open space designs can be an effective tool to promote affordable housing within local communities.

The relatively high demand for open space designs reflects two important economic trends. The first trend is that the tastes and preferences of many new home buyers are gradually changing. Recent market surveys indicate that home buyers increasingly desire natural areas, smaller lawns, better pedestrian access, wildlife habitat and open space in the communities they choose to live in. The second trend is that open space developments that can provide these amenities seldom comprise more than 5% of the new housing offered in most communities. Consequently, there appears to be a large and relatively untapped potential demand for more open space developments. Other compelling benefits of open space design are detailed in CWP (1998a) and Schueler (1995).

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Table 5: Sample Evaluation Criteria for the Quantity and Quality of Open Space Development (Adapted from Conservation Fund, 1999)

Points Achieved by the Development	Percent of Open Space Achieved for Different Residential Zones				
	More than 4 units per acre	From 2 to 4 units per acre	From 1 to 2 units per acre	From 0.5 to 1 unit per acre	less than ½ unit per acre
-2	0 to 9%	less than 15%	15 to 24%	25 to 34%	less than 40%
-1	10 to 14%	15 to 24%	25 to 34%	35 to 49%	less than 50%
0	15 to 24%	25 to 34%	35 to 49%	50 to 59%	less than 60%
+1	25 to 30%	35 to 40%	50 to 55%	60 to 70%	less than 70%
+2	more than 30%	more than 40%	more than 55%	more than 70%	more than 80%

The total open space achieved by the site is computed using the following formula:

$$\frac{A(0.2) + B(0.2) + C(0.5) + D}{E} \times 100$$

A = open space acres in managed landscape
B = open space acres in annual crops
C = open space acres in perennial crops
D = open space acres in native vegetation
E = total undeveloped acres in open space

Evaluating the Quality of Individual Open Space Developments

In the real world, site designers must satisfy a wide range of economic objectives, and water quality or resource protection is usually not on the top of the list. It is certainly possible to design a lousy open space design, and communities should expect a wide range in the quality of open space designs they review. How can a community objectively evaluate the quality of individual open space design proposals, and differentiate poor or mediocre projects from the good and outstanding ones?

Nerenberg and Freil (1999) have recently developed a simple rating system to evaluate the quality of individual open space design proposals. The rating system, known as the Conservation Development Evaluation System (CeDES), was developed in consultation with a host of planning agencies and organizations. The CeDES employs 10 core criteria to test how well a proposed open space design reduces impervious cover, minimizes grading, prevents soil loss, reduces and treats stormwater, manages open space, protects sensitive areas, and conserves trees or native vegetation. Each of the 10 core criteria has a quantitative benchmark for comparison. An example of one benchmark that rates the quantity and quality of open space is provided in Table 5. A full description of the CeDES rating can be found in Conservation Fund (1999).

Based on the total score achieved under the 10 core criteria, an open space design project can earn anywhere from zero "oak leaves" up to four "oak leaves." The more oak leaves earned, the better the quality of the proposed project. Based on initial testing, the CeDES seems to do a good job of sorting the poor projects from the outstanding ones. While the CeDES is intended for use as a tool for local development review, it can also be used as a marketing tool to let home buyers know how green their new subdivision actually is.

Implications for the Watershed Manager

The redesign comparisons have several implications for the watershed manager. First, they offer compelling quantitative evidence that open space design can sharply reduce stormwater and nutrient export from new development, and as such, can serve as an effective tool for watershed protection. It is interesting to note that open space design, by itself, produced nutrient reductions roughly equivalent to those achieved by structural stormwater practices. In other words, nutrient export from open space designs *without* stormwater treatment was comparable to the conventional designs *with* stormwater treatment. When open space design were combined with effective stormwater treatment, nutrient loads were sharply reduced, but were still greater than pre-development conditions.

> Despite its economic and environmental benefits, open space design is not a development option in many communities.

A second, more troubling implication is that it may well be impossible to achieve a strict goal of no increase in nutrient load for new development, even when the best site design and most sophisticated stormwater practices are applied. A handful of communities have adopted stormwater criteria that mandate that no

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net increase in phosphorus load occur as a result of development, but as the redesign comparisons in this article show, such criteria are not likely to be actually achieved. Thus, if nutrient loads are capped in a watershed, managers may need to remove pollutants at existing developments with stormwater retrofits in order to offset increases in nutrient loads produced by new development.

The redesign research also has some implications for watershed-based zoning. Quite simply, a shift from conventional to open space design can reduce the impervious cover of many residential zoning categories by as much as 30 to 40%. In some watersheds, an aggressive shift to open space design in new residential zones is an essential strategy to meet an impervious cover cap for protecting sensitive or impacted streams.

Another notable finding is that large lot subdivisions have the potential to generate the same unit area nutrient export as higher density subdivisions. The high nutrient loading from large lot developments in un-sewered areas is attributed to subsurface discharges from septic systems. From a nutrient management standpoint, it may be more cost effective to regulate septic system performance than stormwater performance in very low density residential subdivisions located on permeable soils.

Lastly, watershed managers have only a few tools at their disposal that offer developers a real chance to save money. The economic evidence clearly suggests that open space design is such a tool, and has potential to either reduce the cost of development, or at least offset the cost of other watershed protection measures. However, despite its economic and environmental benefits, open space design is not a development option in many communities, nor is it widely used by most developers even when available. Many communities will need to fundamentally change their local development rules in order to make open space design an attractive development option.

Site planning roundtables that involve the local players that shape new residential development, described later in this issue, are an effective way to bring this change about. The ultimate goal is to make open space design a "by-right" form of development, so that its design, review and approval are just as easy and certain as a conventional subdivision. Who knows, the day may come when a special exception or permit is needed to build a conventional subdivision. *- JAZ*

Editor's Note: Some useful model ordinances for open space design can be found at www.cwp.org. Also, check the Resources section in this issue for some great references on how to make open space design work in your community.

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Description of the Simplified Urban Nutrient Output Model

The basic tool used in the redesign analysis was a spreadsheet model known as the Simplified Urban Nutrient Output Model (SUNOM). The SUNOM model computes the annual hydrologic budget, nutrient export and infrastructure cost for individual development sites, using simple input variables that can be easily derived or measured from any site engineering plan.

The first step in applying the SUNOM model is to measure the fraction of the site in each of six categories of surface cover: impervious surfaces, lawns, forests/wetlands, meadow, open water, and stormwater treatment areas. In the next step, the user measures key infrastructure variables from the site plan including the length of roads, sidewalks, water and sewer utilities, curb and gutter, and storm drain pipes (in some cases, widths or diameters are needed as well). Basic soil type data is then collected, in order to classify soils according to the hydrologic soil group(s) present on the pervious surfaces of the site. Lastly, basic data is assembled on the size and type of stormwater practices and septic systems, when present. Depending on the size and complexity of the plan, it typically takes about a day to derive all the necessary inputs to operate the model.

Estimating Hydrology for the Site

SUNOM operates based on a simplified water balance. Rainfall can take several different pathways once it reaches the ground surface. A fraction of the rainfall leaves the site directly as stormwater runoff, while the remainder infiltrates into the subsurface soils (storage in surface depressions or interception by the tree canopy interception is ignored in the model, since they are a small and often temporary component of the annual water balance). Once water infiltrates into the soil, much of it returns to the atmosphere through evapotranspiration. The remainder moves to shallow ground water, is transported as interflow, or recharges deeper groundwater. The SUNOM model does not differentiate between these three final destinations, but simply computes the total volume of subsurface infiltration. The water budget can be adjusted further if lawn irrigation or septic system effluent is expected to contribute "outside" water to the development site.

Surface runoff from all surfaces is calculated using a volumetric runoff coefficient that is closely related to impervious cover. Resulting runoff quantities are normalized to runoff inches over the entire site (Schueler, 1987). Surface runoff from natural cover and turf are computed assuming that these areas are one percent impervious (NVPDC, 1980), but these values can be changed to reflect the prevailing soil type or soil compaction (see Technical Note 107).

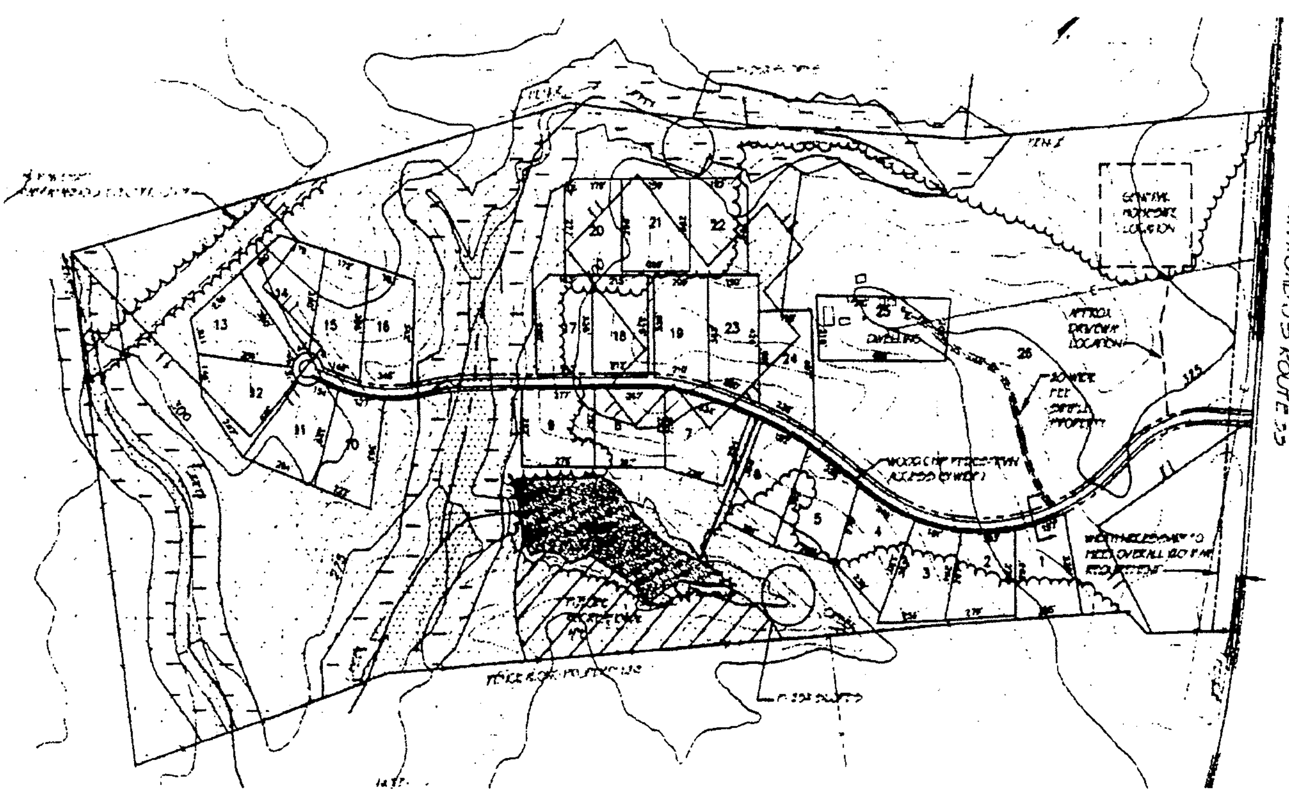

Figure 1: The SUNOM Model Operates Using Basic Site Variables That Can Be Easily Derived From Most Site Plan Submittals

Estimating infiltration is a somewhat trickier affair. For the purposes of the model, total infiltration is defined as the sum of subsurface infiltration plus septic infiltration. Subsurface infiltration is estimated based on annual infiltration volume for the prevailing hydrologic soil group of the pervious area, which can be adjusted for soil compaction. The annual volume of subsurface infiltration is calculated without estimating its final destination (i.e., quick interflow, deep recharge, shallow groundwater). Once annual stormwater runoff and subsurface infiltration volumes are calculated, they can be checked against an annual evapotranspiration volume to ensure that the overall water balance is reasonable.

Annual septic system infiltration is calculated under the assumption that entire wastewater flow into a septic system infiltrates to the subsurface. The volume of this wastewater flow, in site-inches, is derived as a function of the number of individuals using each septic system multiplied by their per capita annual water use. Some stormwater practices can take surface runoff and convert it into subsurface infiltration. The model accounts for this by deducting the fraction of treated runoff volume that is infiltrated back into the soil from the annual stormwater runoff volume and adding it to the infiltration volume.

Calculation of Nutrient Loads

This module computes nutrient loads for each of the types of surface cover present at a site by multiplying its computed stormwater runoff and subsurface infiltration volume by a median nutrient concentration. For stormwater flows, the mean concentrations are derived based on national stormwater monitoring data or single land use or source area marketing data. Subsurface nutrient concentrations for natural areas are estimated based on measured baseflow concentrations from adjacent undeveloped receiving waters. Median nutrient concentrations from published sources were used to characterize the subsurface concentrations from turf areas. In the case of septic systems, typical per capita septic loads, along with septic efficiencies, were used to characterize this nutrient loading source.

The total annual nutrient load for a development site is then computed as the sum of the stormwater runoff load, and the subsurface infiltration load from natural areas, turf, and septic systems. Surface stormwater loads are adjusted to reflect pollutant reduction by stormwater practices if they are present. The spreadsheet contains typical nutrient removal rates for many common stormwater practices (see Technical Note 95). Subsurface infiltration loads can also be adjusted to reflect the use of innovative septic system technology with higher nutrient removal capability. Default data are provided in the SUNOM model for all nutrient concentration and removal parameters, but the user can also supply their own estimates if better local or regional data are available.

Development Cost

The SUNOM modules computes the cost of building the infrastructure to serve a new development. The module calculates these costs based on the dimensions of the infrastructure that are specified in the development plan, and supplied as model input (e.g., length and area of roads, length and diameter of pipe). These units of infrastructure are then multiplied by unit costs that were derived for the mid-Atlantic region. The SUNOM model can estimate the following component costs: paving for roads or parking lots, curb and gutter, sidewalks, stormwater conveyance, utilities, landscaping, reforestation, septic systems and other necessary elements for site construction. Stormwater treatment costs are calculated as a function of the volume of stormwater runoff treated by the practice using predictive equations developed by the Center (see Technical Note 90). At this time, the SUNOM model does not estimate engineering or permitting costs, nor does it itemize costs related to clearing, grading and erosion and sediment control, but these enhancements can be added by the user.

Appropriate Use of the SUNOM Model

The SUNOM model is basically a simple accounting tool to track the annual runoff, nutrient loads, and total infrastructure costs from four kinds of surface cover in a development plan. The model is most appropriately used as a tool to compare how these factors change in response to different development scenarios. These "redesign" scenarios help demonstrate the costs and benefits of better site design. As with any empirical model, it is very important to make sure that parameter values are sensible and regionally appropriate. The user should always check whether default infiltration rates, nutrient concentrations, removal rates and unit costs make sense given local conditions. The SUNOM model is intended to serve as a planning model rather than an engineering model. More detailed simulation models or monitoring may be required to give the precise and accurate predictions needed for actual engineering design at a given development site. More extensive documentation on the model is contained in Appendix A of CWP, 1998. We are continually improving the SUNOM model, and the most recent version, which utilizes a Microsoft Excel spreadsheet, is available through the Center at a nominal charge.

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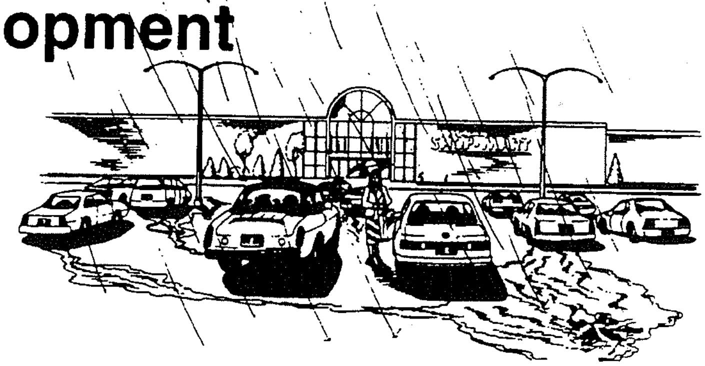
Better Site Design

III. The Benefits of Better Site Design in Commercial Development



Modern commercial development is dominated by the parking lot. Indeed, as much as half of the entire surface area of a typical office park or shopping center is devoted to parking. No one has ever stepped up to claim that they invented the parking lot, and their reluctance is understandable: the parking lot is a prime habitat for the car and not much else.

From an environmental standpoint, parking lots rank among the most harmful land uses in any watershed. Parking lots not only collect pollutants that are deposited from the atmosphere, but also accumulate pollutants that leak, drip or wear off cars. Researchers have found that parking lot runoff can have extremely high concentrations of nutrients, trace metals and hydrocarbons (see Technical Notes 15 and 105). Parking lots also influence the local air and stream temperatures. In the summer months, pavement temperatures can exceed 120 degrees Fahrenheit, which in turn increases local air temperatures five to 10 degrees compared to a shaded forest. Parking lots can also exacerbate smog problems, as parked cars emit greater levels of smog precursors under extreme heat island conditions (Scott *et al.*, 1999).

Perhaps the greatest environmental impact of parking lots is hydrological in nature. Simply put, there is no other kind of surface in a watershed that produces more runoff and delivers it faster than a parking lot. When this runoff is discharged into a headwater stream, its great erosive power steadily degrades the quality of downstream habitats, unless exceptionally sophisticated stormwater practices are installed.

Is it possible to design a better parking lot? At first glance, there seems to be little opportunity to incorporate better site design into parking lots. However, the better site design techniques described earlier in this issue suggest a key design strategy: *work to incrementally shrink the surface area of the parking lots and then use the space saved to integrate functional landscaping and better stormwater treatment within the parking lot.* Through a series of relatively minor design adjustments, it is possible to reduce the surface area of parking lots by 5-20%. These design adjustments include curbing excess parking, incrementally reducing parking demand ratios, providing credits for mass transit, shrinking stall sizes, narrowing drive aisles, and using grid pavers for spillover parking areas.

In this article, we examine some of the benefits of employing better site design as they apply to commercial development. As with the residential redesign, this analysis also uses the Simplified Urban Nutrient Output Model (SUNOM) to compare actual commercial development sites constructed in the 1990s with the same sites redesigned utilizing better site design techniques. The two commercial developments analyzed include a retail shopping center and a commercial office park.

Our fairly conservative approach to parking lot redesign is intended to reflect realistic opportunities in a suburban setting. For example, we did not utilize shared parking, porous pavement, or structured parking in any of the redesigns, although each of these techniques is very effective. Nor did we reduce the basic footprint or size of the buildings in either scenario, although smaller "boxes" may well have been more appropriate for the zoning. Instead, our basic approach was to make a series of relatively modest changes in parking lot design to shrink parking lot area, and then implement better landscaping and stormwater treatment measures within the saved space.

> From an environmental standpoint, parking lots rank among the most harmful land uses in any watershed.

This article reports on the potential benefits of parking lot redesign in terms of reduced runoff, pollutant export and development costs. It also reviews the initial experience of communities that are experimenting with new and innovative parking lot designs, and concludes with some implications for both the engineer and watershed manager.

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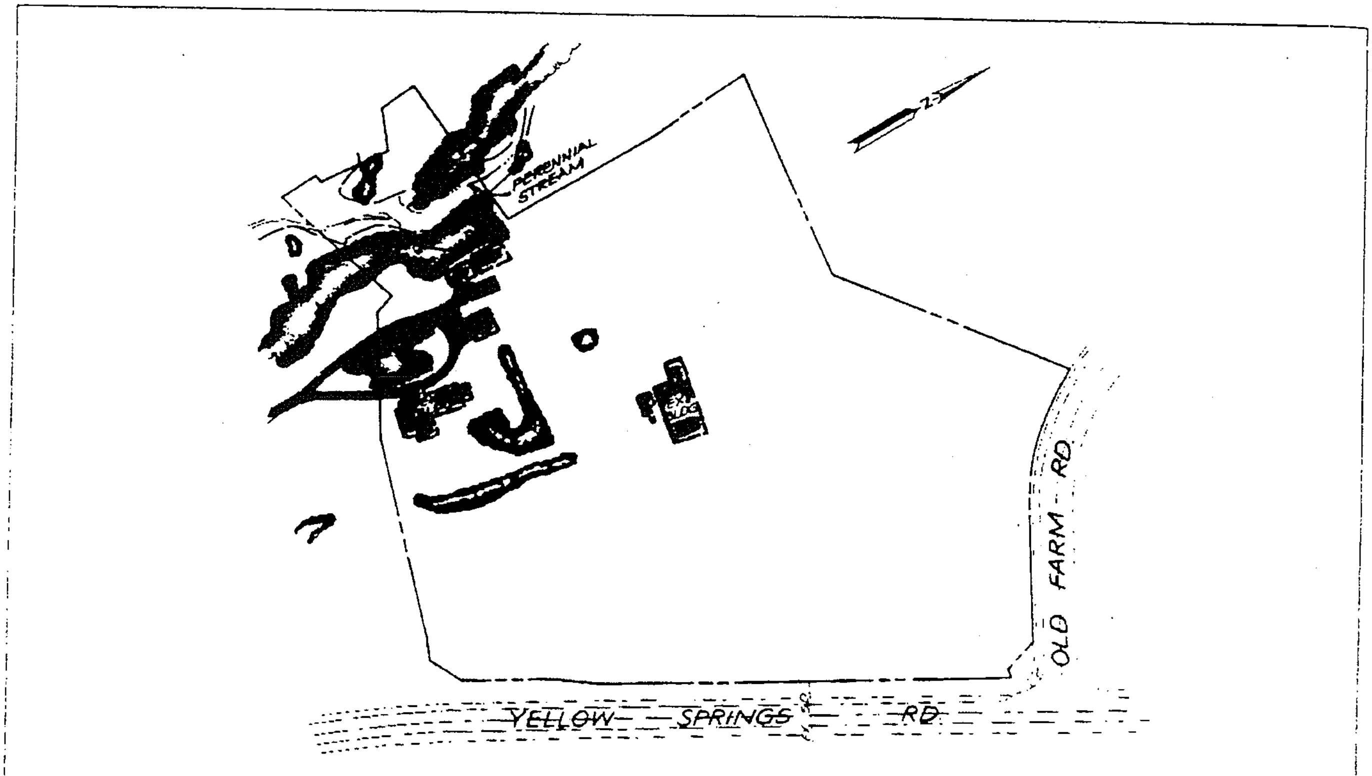

Figure 1: Predevelopment Conditions at the Old Farm Shopping Center Site

Redesign of the Old Farm Shopping Center

The undeveloped Old Farm shopping center, located in the City of Frederick, Maryland, was primarily meadow, with some shrubby forest and a few farm buildings. Bordered by two major arterial roads and served by existing public water and sewer, the site was a prime candidate for commercial development.

Construction of the shopping center site parcel commenced in 1992. The 9.3 acre site is a typical suburban "strip" shopping center with two large retail stores, other retail space, a gas station and a drive-in bank (Figure 2). In terms of surface cover, the shopping center devoted 50% of its total area for parking, as compared to 16% for the actual footprint of the retail buildings. Another 24% of the surface area was devoted to landscaping or stormwater treatment. Less than 10% natural cover was retained on the site, and part of the project encroached on the 100-year floodplain and the stream buffer. The entire site was mass graded during construction. The basic layout was designed to accommodate the car, with generous parking located in front of the stores. The parking lot design provided 5.2 full-size stalls per 1,000 square feet (sf) of retail space, which exceeded the already generous local parking requirement of five spaces per 1,000 sf. According to the most recent national parking research, only 4.0 to 4.5 spaces are needed to serve shopping centers (ULI, 1999).

The stormwater treatment system at Old Farm consisted of an infiltration basin located near the rear of the shopping center that captured runoff from about a third of the site, and three oil grit separators that provide some treatment for the remaining two-thirds of the site. After discharging from the oil/grit separators, runoff traveled through a series of storm drains that extended along the road and eventually discharged to the stream (albeit without detention of any kind). It should be noted that recent performance monitoring has shown that oil grit separators have little or no pollutant removal capability (see Technical Notes 101 and 104).

The Redesigned Old Farm Shopping Center

The Old Farm shopping center was redesigned using a "U-shaped" layout that maintained the same amount of gross floor area, but sharply reduced the site area devoted to parking (Figure 3). The new design reduced walking distances, encouraged pedestrian use, and created a more intimate shopping experience. Parking dropped from 50% of the total site area to 38%, primarily because the parking demand ratio was reduced from 5.2 spaces to 4.4 spaces per 1,000 sf of retail area.

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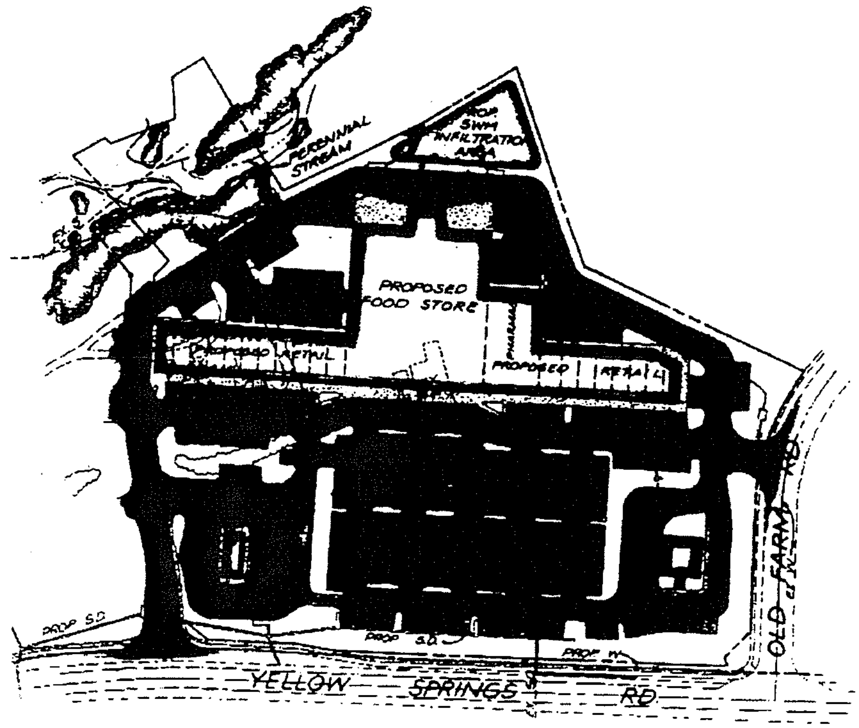

Figure 2: The Conventional Design of the Old Farm Shopping Center

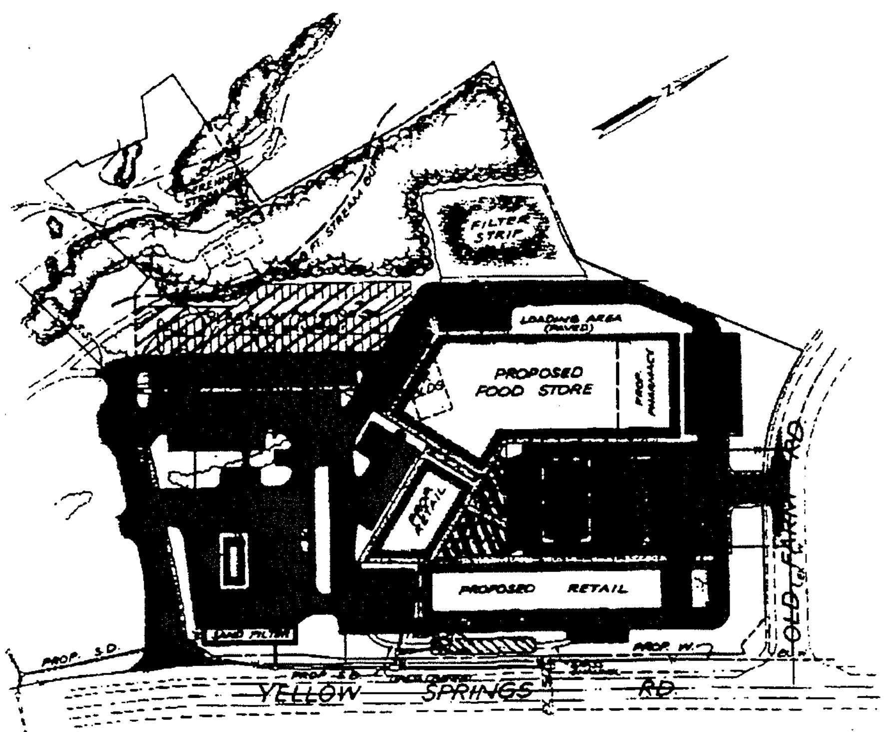

Figure 3: The Innovative Design of the Old Farm Shopping Center

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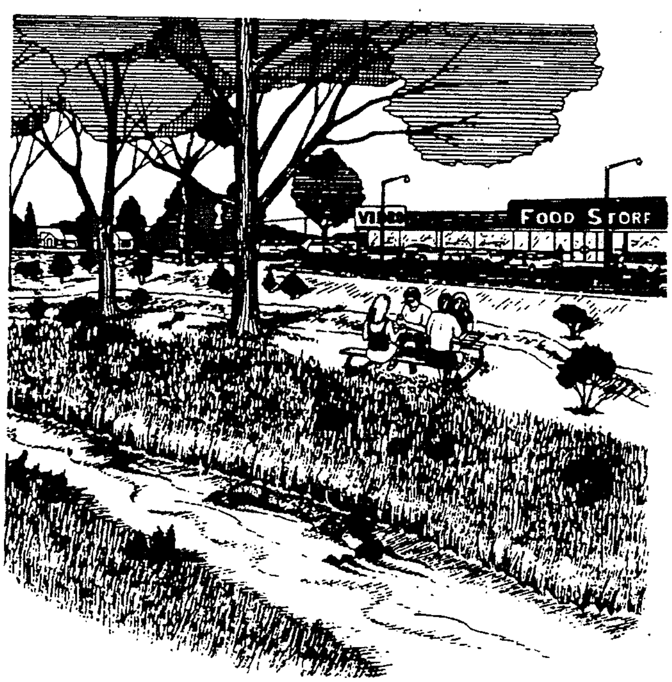
Table 1: Hydrology of the Old Farm Shopping Center Case Study				
		Pre-Developed	Conventional Parking Lot	Innovative Parking Lot
Runoff (inches/yr)	no practice	2.6	24.5	20.6
	practices		18.1	15.1
Infiltration (inches/yr)	no practice	11.8	2.7	3.4
	Practices		9.1	8.9

The rationale for the lower parking demand was justified in two ways. First, no extra parking spaces were allowed beyond those required by the locality. Second, the existing parking demand ratio was reduced by about 15% to reflect actual parking demand more accurately. As a result, the total number of parking spaces dropped from 343 to 291. In addition, 17% of the parking stalls were designed for compact cars, which require slightly smaller stalls than standard full-sized spaces. Taken together, these changes eliminated slightly more than one acre of parking area, which provided enough space to design a more effective landscaping and stormwater treatment system.

Several parking lot islands were increased in size and converted into bioretention areas to treat stormwater. Other elements of the stormwater treatment system included a sand filter, an infiltration trench, and a filter strip. Furthermore, 25% of the entire parking area was designated for "spillover parking," and grid pavers were used rather than normal paving materials. The grid pavers helped store the first few tenths of an inch of rainfall that would have otherwise run off the parking lot (ICPI, 2000). Lastly, the redesign enabled reforestation and greater protection of the buffer along the stream that runs along the edge of the property. As a result, the proportion of natural cover at the site climbed from 7% to 19% as a result of the parking lot redesign.



Comparative Hydrology at the Old Farm Shopping Center

As expected, the construction of the original shopping center dramatically changed the hydrology of the site (Table 1). The increase in impervious cover from 1% to more than 70% increased annual runoff volume by a factor of nine. The infiltration basin used in the original design helped put some runoff back into the ground, but even so, annual runoff was seven times greater than the pre-development condition. The redesigned parking lot, by virtue of its lower impervious cover and improved stormwater practices, produced about 20% less runoff than the original design. Nevertheless, the stormwater practices at the redesigned parking lot were not able to match the pre-development hydrology.

Comparative Nutrient Output from the Old Farm Shopping Center

The conversion of the meadow into a shopping center greatly increased nutrient export from the site; the SUNOM model indicated that annual phosphorus and nitrogen export would increase tenfold as a result of the development (see Figure 4). Nutrient export from the shopping center was dominated by stormwater runoff, as the model indicated that stormwater runoff contributed about 95% of the annual nutrient export from the site. Nutrient loads were not greatly reduced by the infiltration basin or oil/grit separators that were installed at the conventional parking lot. Nutrient export was still projected to be eight to ten times higher than pre-development conditions, even after these stormwater treatment practices were installed.

In contrast, the redesigned parking lot sharply reduced nutrient export (Figure 4). In fact, the redesigned parking lot *without* stormwater practices produced about the same nutrient load as the conventional parking lot *with* stormwater practices. This reduction was a direct result of the lower impervious cover associated with the redesigned parking lot. When the redesigned parking lot was combined with more sophisticated stormwater practices (i.e., bioretention, sand filter, infiltration trench and filter strip), the total nutrient export was half that of the conventional parking lot with stormwater practices. It is interesting to note, however, that this load was still about five times higher than that produced by the meadow prior to development.

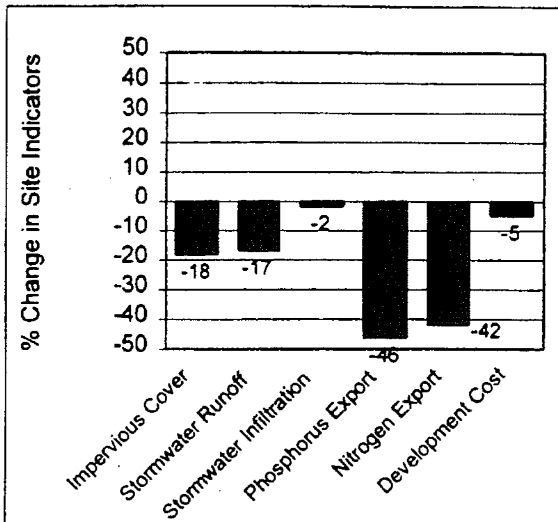


Figure 5: Percentage Change in Key Site Indicators From a Conventional Design of the Old Farm Shopping Center to an Innovative Design, Both With Stormwater Practices

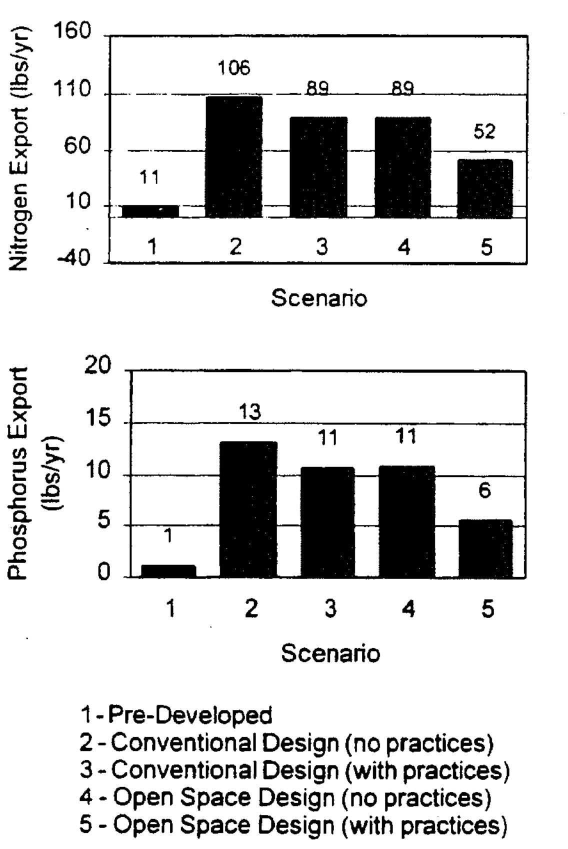


Figure 4: Annual Nitrogen and Phosphorus Export in Each Old Farm Shopping Center Development Scenario

Comparative Cost to Develop the Old Farm Shopping Center

The cost to develop the redesigned parking lot was marginally lower than the cost for the conventional parking lot — about 5%. Considerable cost savings were realized due to less paving, shorter sidewalks, and fewer curbs and gutters, but these savings were largely offset by added costs for improved stormwater practices, landscaping and grid pavers. Overall, the estimated cost to build the conventional parking lot was $782,500, compared to $746,270 for the redesigned parking lot. The extent of potential cost savings depends heavily on the level of sophistication of the original stormwater treatment system. In this case, the unsophisticated stormwater practices used in the conventional parking design were fairly inexpensive, but were also not effective in removing nutrients.

Summary

Figure 5 summarizes the redesign analysis of the Old Farm Shopping Center. The redesigned parking lot resulted in less impervious cover, stormwater runoff, and nutrient export for a slightly lower development cost than the conventional design.

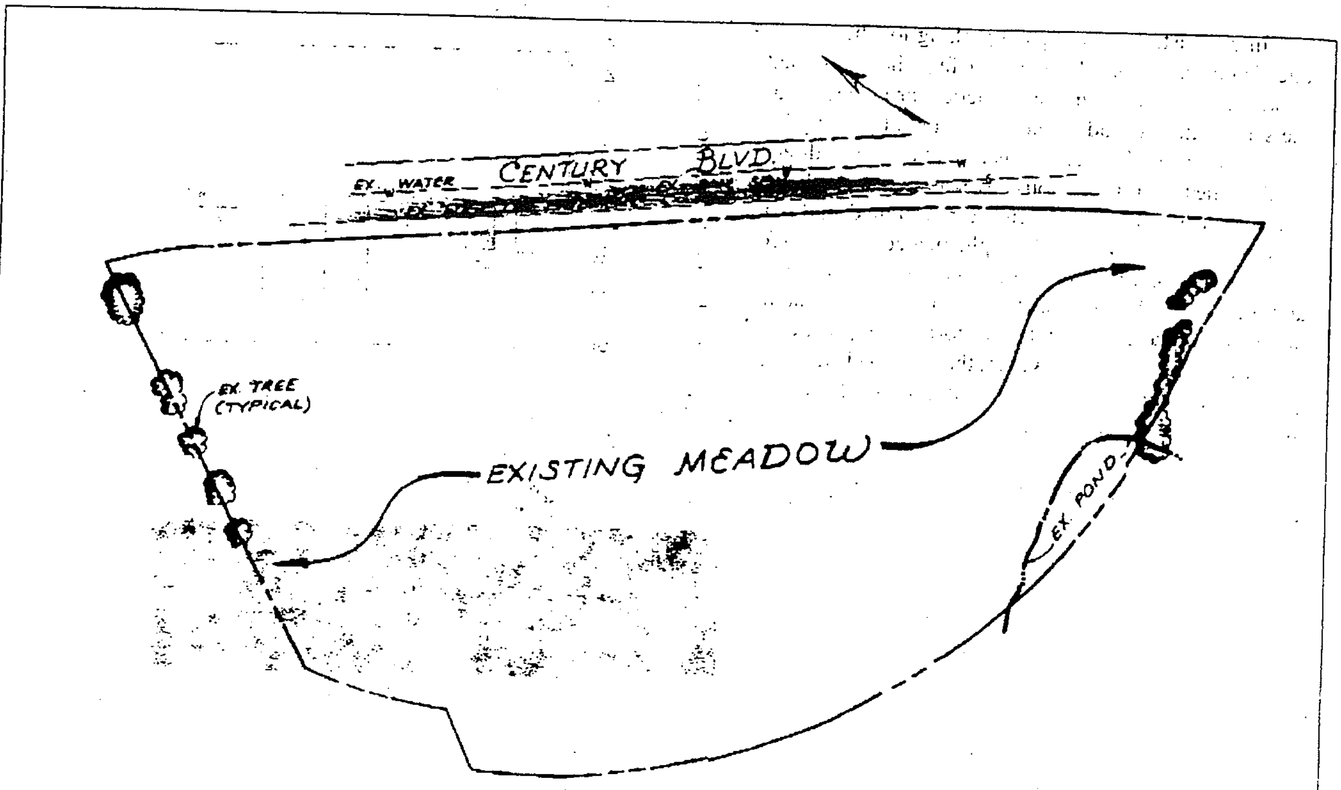


Figure 6: Predevelopment Conditions at the 270 Corporate Office Park Site

Redesigning the 270 Corporate Office Park

The second case study involved the redesign of a typical suburban office park. The 12.8 acre parcel is located in Germantown, Maryland in the mildly sloping terrain of the Piedmont (Figure 6). The existing cover at the site was almost entirely meadow, except for a few trees and an old farm pond that bisected the property boundary. No wetlands or other sensitive natural features were evident on the site. The site was zoned for office development, and existing infrastructure made it an attractive candidate for development. An existing network of public water and sewer, electric, gas, and other utilities ran along the frontage of a large arterial road.

The layout of the conventional suburban office park design is depicted in Figure 7. The project included a pair of five-story office buildings, surrounded by a sea of parking. Over half (52%) of the surface cover at the office park was devoted to parking, as compared to only 11% for actual footprint of the office building. Most of the remainder of the site was utilized for landscaping, stormwater treatment or turf. Only 2% of the natural cover was retained on the site, and nearly all of the parcel was mass graded during construction.

As with many suburban office parks, the location of the building and parking were primarily oriented toward the car. The parking lot was sized using a parking demand ratio of 3.1 spaces per 1,000 sf of building, which slightly exceeded the minimum parking requirements of the locality. As a result, the parking lot created room for 745 standard stalls, along with 33 larger stalls for vans and disabled access. The parking bays also featured roomy aisles between the stalls (24 feet wide). The design was intended to provide some amenities for the office workers, including a short path system between buildings, an ornamental stormwater pond, and some landscaping in required setbacks and parking islands.

The conventional design featured the classic "pipe and pond" approach to stormwater management. Parking lot runoff was initially collected by a curb and gutter system that sent runoff into underground storm drain pipes that, in turn, discharged into two very small wet ponds. Each pond served roughly half of the site and was expected to have a reasonably good capability to remove nutrients (see Technical Note 95).

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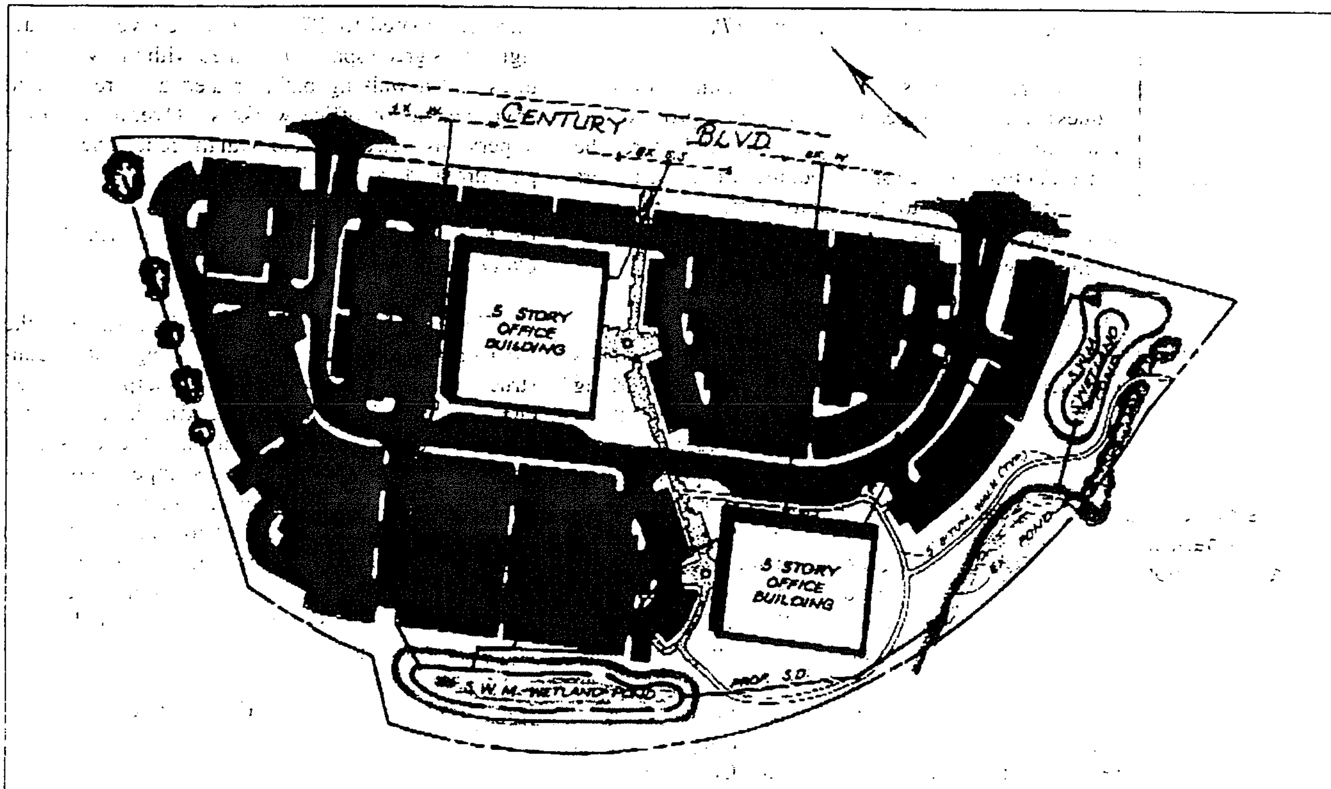

Figure 7: The Conventional Design of the 270 Corporate Office Park

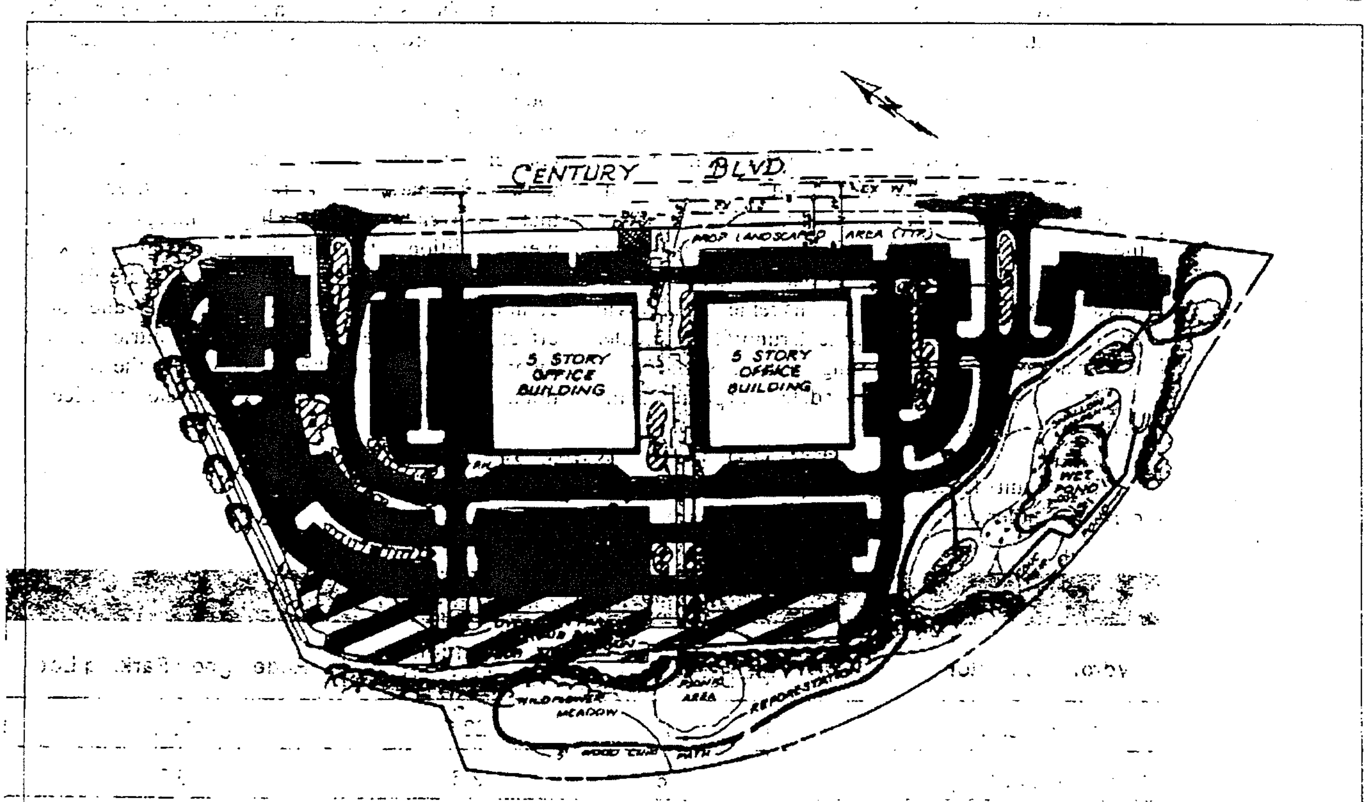

Figure 8: The Innovative Design of the 270 Corporate Office Park

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The Redesigned 270 Corporate Office Park

The redesigned site employed a number of techniques to minimize impervious cover and improve stormwater treatment (Figure 8). The office park featured the same amount of office space, but the two office towers were situated closer to the road to shorten utility extensions, and pedestrian access to a bus stop was provided to encourage the use of public transportation.

The key strategy employed in the redesign was to incrementally reduce the size of the parking lot, and this was achieved in five ways. First, no excess parking spaces were allowed over those required by the local parking demand ratio. Second, the local parking demand ratio was reduced by 8% to reflect actual parking demand. Third, the parking demand ratio was reduced by another 10% to reflect the proximity to the bus stop. Fourth, the size of approximately 20% of all parking stalls was downsized to accommodate compact cars. Lastly, drive aisles in many parking bays were reduced from 24 feet in width to 20 feet. Combined, these measures reduced the total parking lot area by nearly 30%, or about two acres. Once again, the savings in paving gave the designer more room to integrate landscaping with more effective stormwater treatment.

Construction of the conventional office park sharply increased annual runoff and decreased infiltration.

For example, larger landscaping islands were installed in the parking lot to plant shade trees, and some of these areas were also converted into bioretention areas to treat stormwater. A dry swale was used to treat stormwater within a landscaped setback area in another part of the site. About 15% of the lot was designated for spillover parking, and grid pavers were used to attenuate runoff in this area. The basic stormwater management goal was to attenuate, treat, or recharge as much runoff from smaller storms as possible in the parking lot itself. Runoff from larger storms was treated in a wet detention pond near the outlet of the property.

As a result of the redesign, roughly 14% of the office park was either retained in natural land cover or reforested (compared to 2% under the conventional design). This green space, combined with the water features and a walking path, created a more tranquil environment for office workers. Overall, the total impervious area associated with the redesigned office park dropped from 68% to 53%.

Comparative Hydrology for the 270 Corporate Center Office Park

The hydrological story was much the same for the 270 Corporate Center as for the shopping center. Construction of the conventional design sharply increased annual runoff volumes and decreased infiltration (Table 2). Runoff did not increase as much in the redesigned parking lot, primarily because its impervious cover was much lower. Annual runoff volumes were 21% lower in the redesigned parking lot compared to the conventional design, and infiltration volumes were 42% higher. Despite these improvements, the redesigned parking lot was unable to mimic the hydrologic conditions prior to development.

Nutrient Output at the 270 Corporate Center Office Park

As expected, the conversion of the meadow into an office park greatly increased nutrient export. Annual phosphorus and nitrogen export increased roughly ten-fold, according to the SUNOM model (Figure 9). As with the shopping center, stormwater runoff was found to generate about 95% of the annual nutrient export from the site. The two wet ponds were reasonably effective in removing nutrients at the conventional office park, but still resulted in nutrient export that was seven to eight times higher than pre-development conditions. In contrast, the redesigned parking lot sharply reduced nutrient export (Figure 9). The combination of lower impervious cover and more effective stormwater practices reduced nutrient export by about 40 to 50%, when compared to the conventional parking lot design *with* stormwater practices.

Table 2: Hydrology of the 270 Corporate Office Park Case Study

Hydrologic Factor	Pre-Developed	Conventional Parking Lot	Redesigned Parking Lot
Runoff (inches/yr)	2.7	23.9	18.9
Infiltration (inches/yr)	11.8	2.6	3.7

Note: no change in the annual volume of runoff or infiltration was calculated as a result of the [illegible] practices installed at either the conventional or redesigned parking lot [illegible]

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Comparative Cost to Develop the 270 Corporate Office Park

The cost to develop the redesigned office park was approximately the same as the cost to develop the conventional office park, although the component costs were somewhat different. Less was spent on paving, sidewalks and utility pipes, but these savings were largely offset by higher costs for improved stormwater treatment practices, landscaping, grid pavers and curiously, curbs and gutters (the higher cost for this last item was due to the wider parking islands used for bioretention areas). Overall, the estimated cost to build the conventional parking lot was $948,900, compared to $921,200 for the redesigned parking lot.

Summary

The redesigned parking lot at the 270 Corporate Office Park resulted in less impervious cover, stormwater runoff, and nutrient export for about the same development cost as the conventional design. The results are summarized in Figure 10.

The Limits and Potential of Parking Lot Redesign

To our knowledge, no one has yet tried to quantify the potential economic and environmental benefits of better parking lot design at new commercial developments. This initial analysis provides compelling evidence that better site design is an important, if not indispensable, tool for managing the quantity and quality of stormwater runoff from parking lots.

In each of the case studies, the redesigned parking lot resulted in less impervious cover, stormwater runoff, and nutrient export for about the same or even slightly lower cost than the conventional design. Taken together, better site design techniques reduced impervious cover by at least 15% in each case. While this is an impressive reduction, about half of each site remained impervious after the redesign. Perhaps the most critical benefit of each redesign was that it created more room to locate more effective stormwater treatment practices. When smaller parking lots were combined with better stormwater practices, the resulting nutrient export was almost half that of a conventional parking lot.

In each case study, the critical ingredient was an incremental reduction in the local parking demand ratio. Without this capability to shrink the surface area devoted to parking, designers have little ability to devise the more sophisticated stormwater treatment and landscaping systems that can

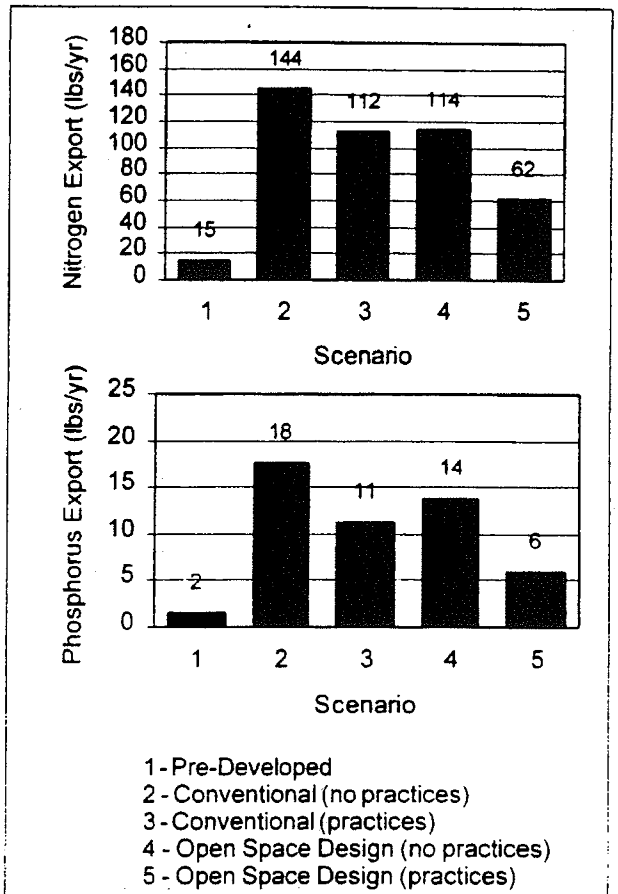

Figure 9: Annual Nitrogen and Phosphorus Load in Each 270 Corporate Office Park Development Scenario

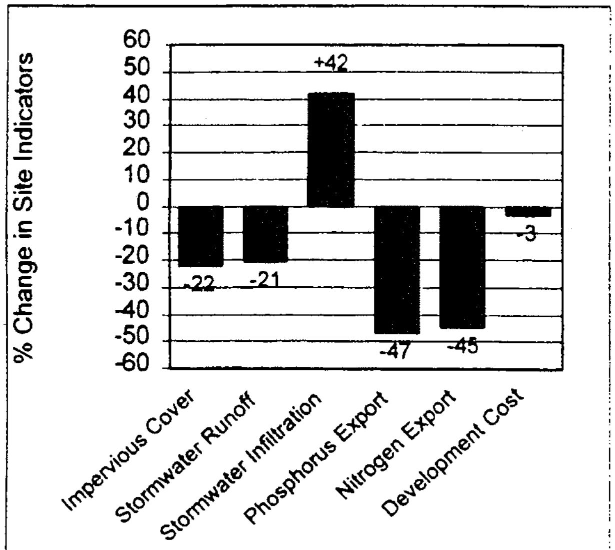

Figure 10: Percentage Change in Key Site Conditions from a Conventional Design to a Redesigned Parking lot at the 270 Corporate Office Park, Both With Stormwater Practices

help mitigate the impact of the parking lot. Therefore, the first and most important step in implementing better site design for commercial developments *is to reduce local parking demand ratios, even if only by five or ten percent.* For many communities, however, this modest step may seem like a terrifying leap, possibly off a cliff.

Developers, bankers, retailers and drivers all have a shared interest in abundant and convenient parking, and it is hard to convince them that any attempt to downsize parking lots, however modest, will not work against this goal. This kind of thinking is quite understandable. Most people can easily recall the rare situation where parking was hard to find, but the more common situation where parking is plentiful generally escapes our everyday notice.

Small wonder, then, that so many communities are prone to inertia when it comes to changing parking codes. Perhaps the only way watershed advocates can overcome this inertia is to document the existence of excess parking capacity in each community. Indeed, it is a rather simple step for volunteers to count cars and photograph empty stalls during peak times at similar commercial land uses to demonstrate how generous local parking requirements actually are.

> The most important step to implement better site design for commercial developments is to reduce local parking demand ratios.

A small but growing list of communities are now experimenting with their parking standards and parking lot designs, including cities like Scarborough, Ontario; Oakland, CA; Olympia, WA; Sacramento, CA; Bellevue, WA; Davis, CA and Prince George's County, MD. Each community has worked in different ways to redesign their parking lots, and many of their successful experiences are recounted in *Better Site Design: A Handbook for Changing Development Rules in Your Community* (CWP 1998a).

Given the prevalence of parking lots in our urban landscape and the environmental harm they cause, we need to fundamentally change the way that parking lots are sized and designed. The modest ideas presented in this article are merely an initial step in this direction. A wide range of professions collectively influence the form and function of parking lots, including engineers, hydrologists, landscape architects, urban foresters, soil scientists, developers, leasing agents, plan reviewers, transportation researchers and many, many others. Working together, these groups can move us closer toward the goal of a truly sustainable parking lot, i.e., one that not only provides car habitat, but also prevents damage to other habitats, as well. **- *JAZ***

Editor's Note: Some useful benchmarks for testing how good your local parking codes can be found in the Codes and Ordinances Worksheet (see accompanying article).

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