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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 Table X). 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.

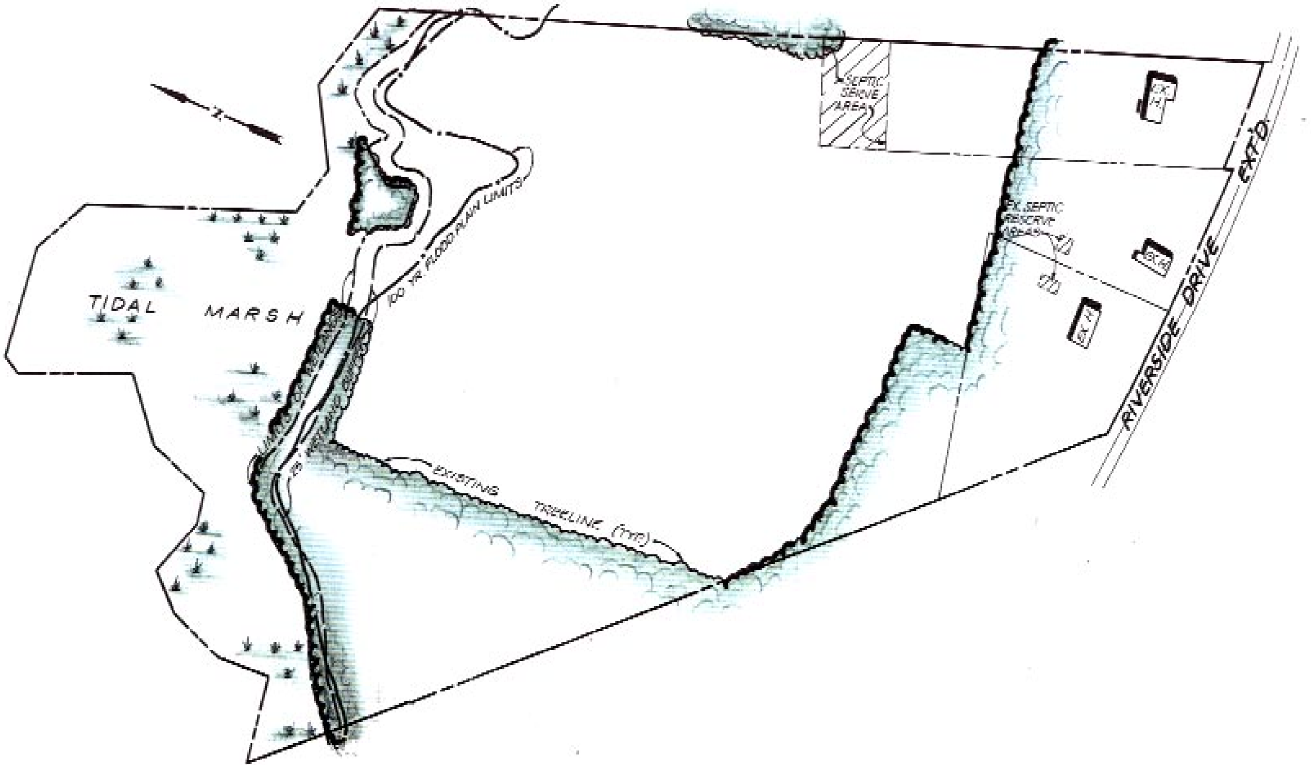

Figure 1: Predevelopment Conditions at the Duck Crossing Site

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 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

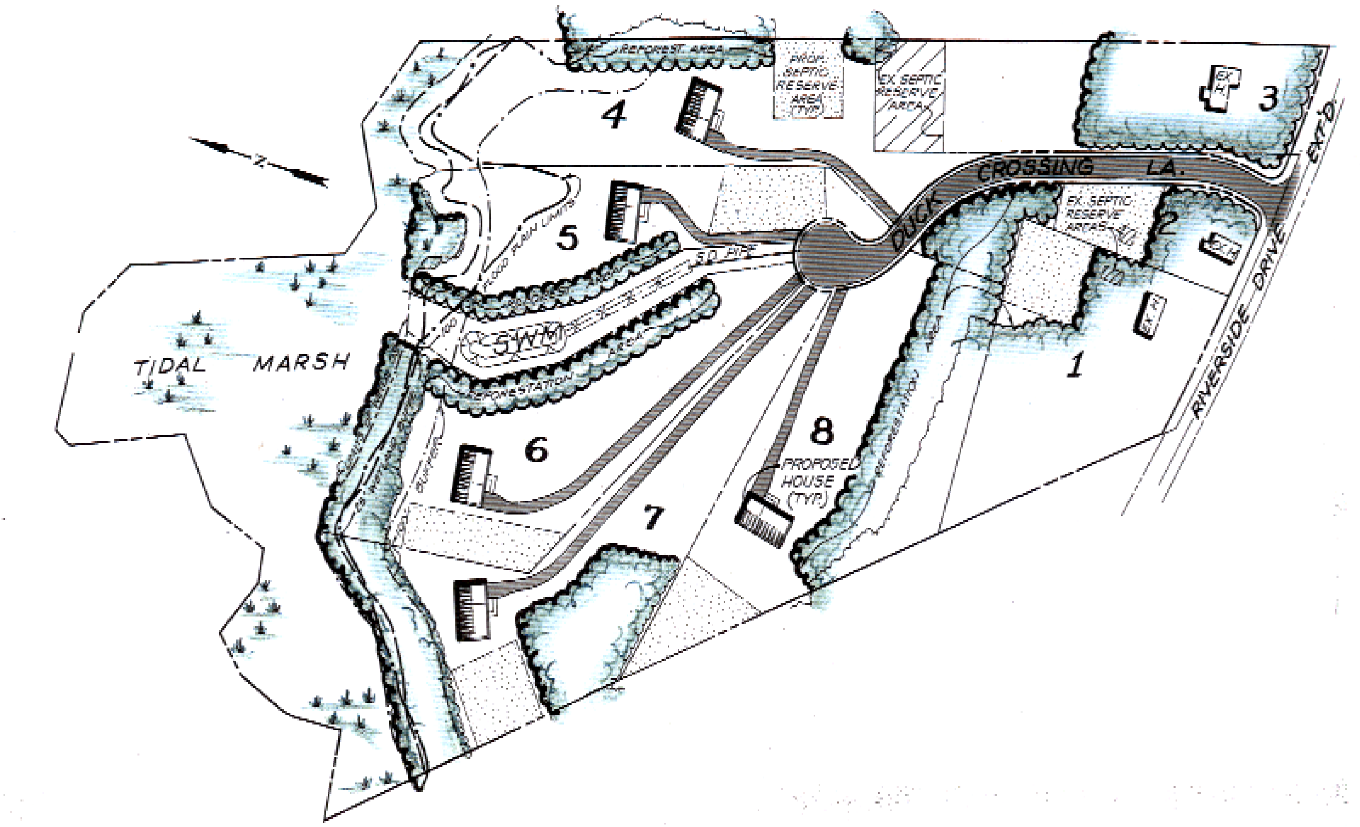

Figure 2: The Low-Density Conventional Subdivision Built at Duck Crossing (eight lots)

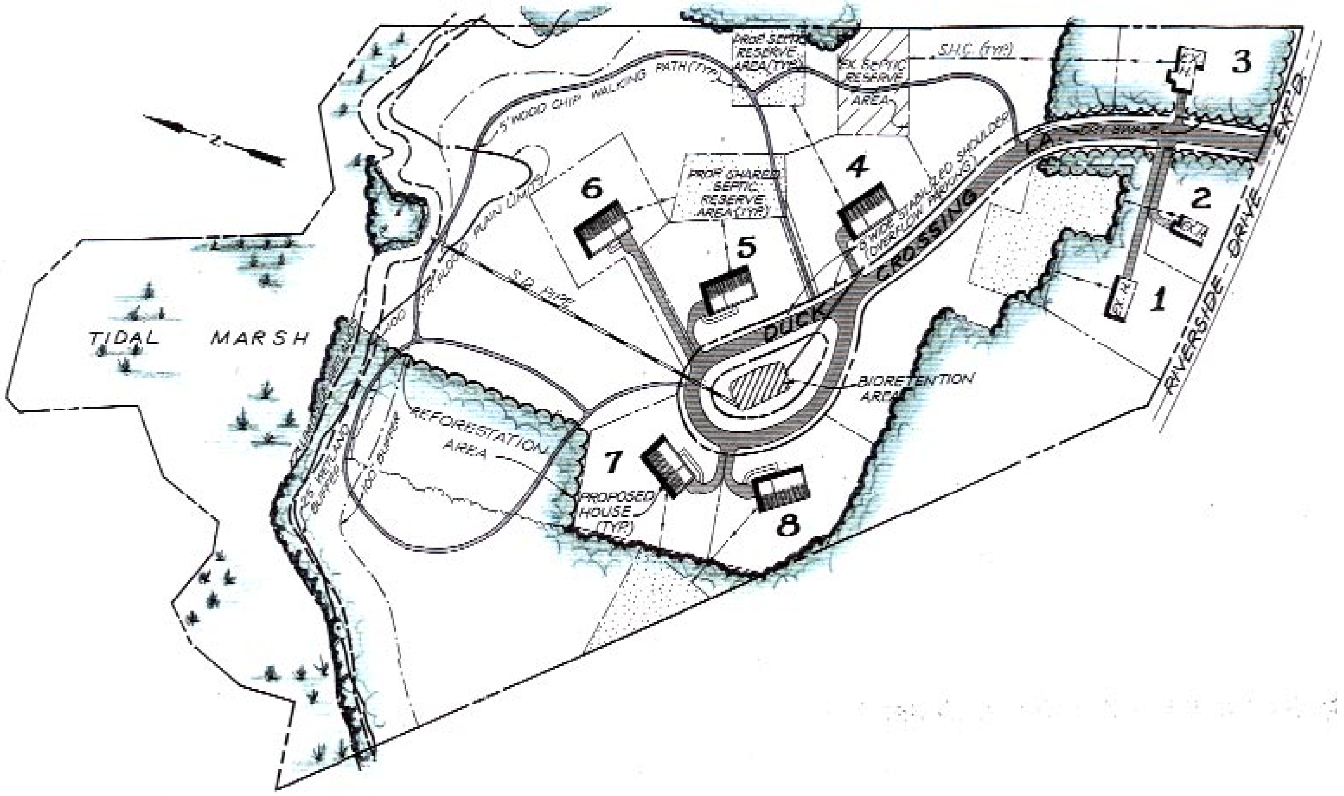

Figure 3: The Open Space Subdivision That Could Have Been Built at Duck Crossing (eight lots)

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).

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).

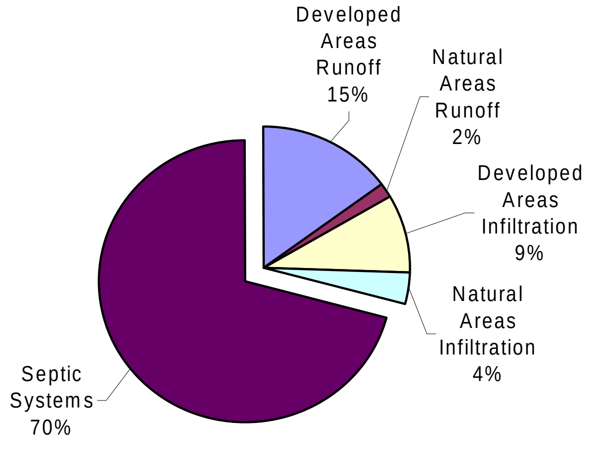

Figure 4: Nitrogen Load Distribution From the Conventional Design of Duck Crossing, Without Stormwater Practices

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.

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

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

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.

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.

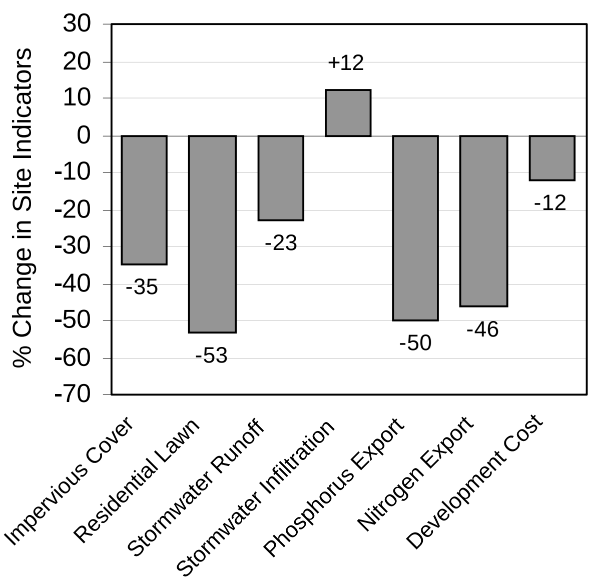

Figure 6: Percentage Change in Key Site Conditions From a Conventional Design to an Open Space Design, Both With Stormwater Practices

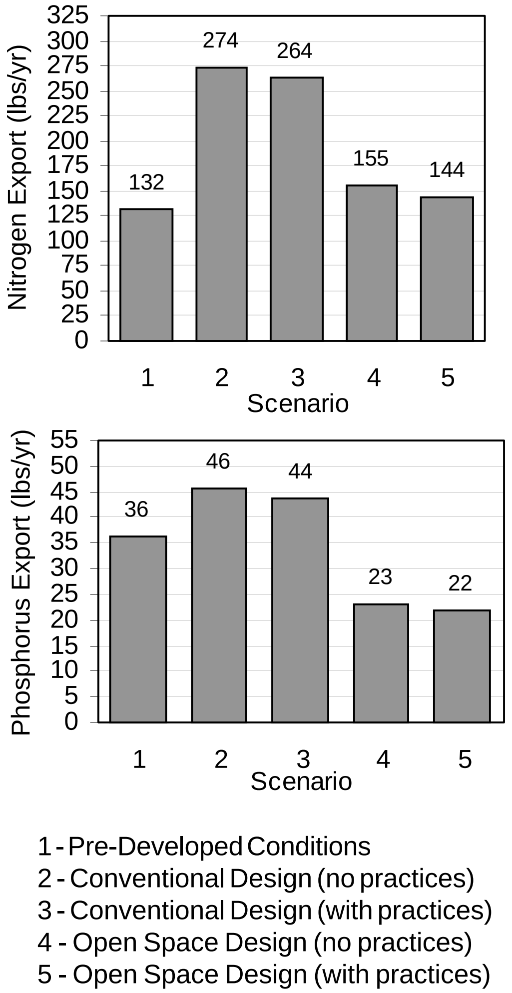

Figure 5: Annual Nitrogen and Phosphorus Loads for Each Development Scenario at Duck Crossing

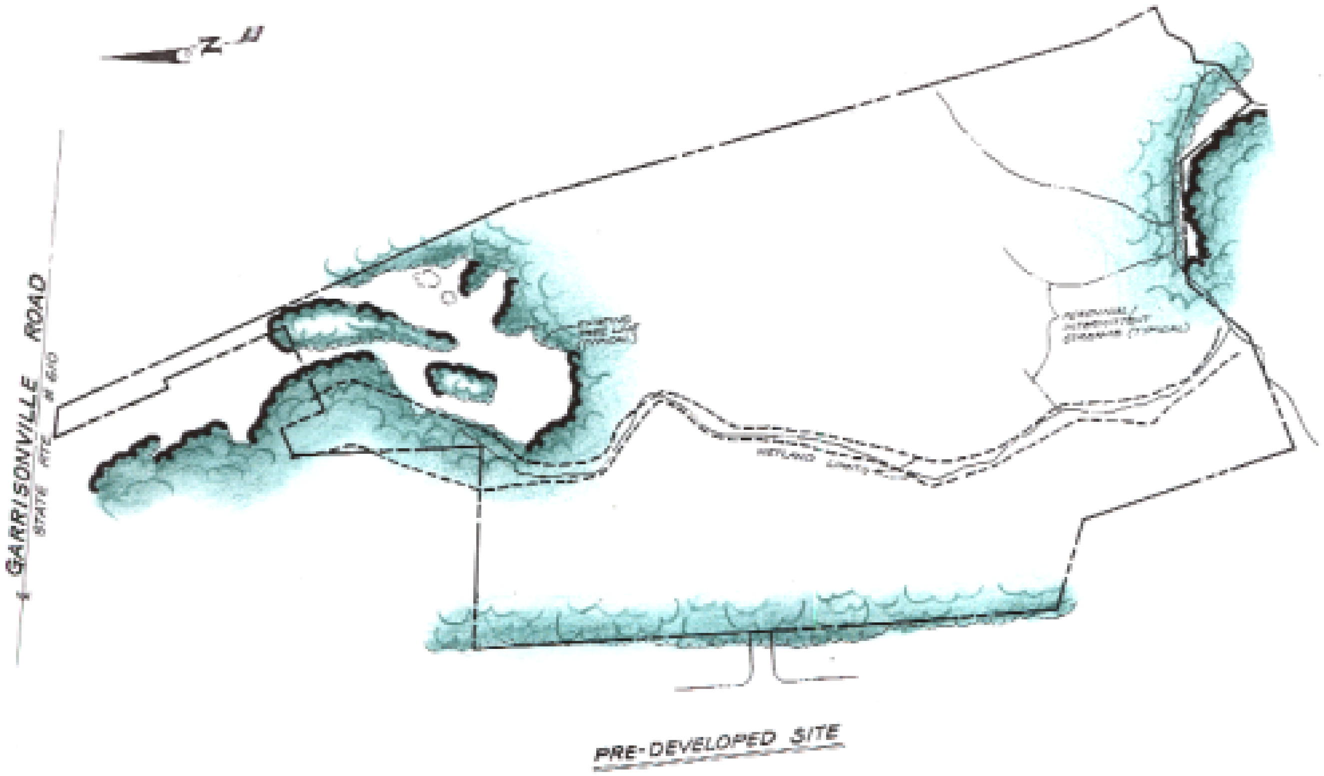

Figure 7: Predevelopment Conditions at the Stonehill Estates Site

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.

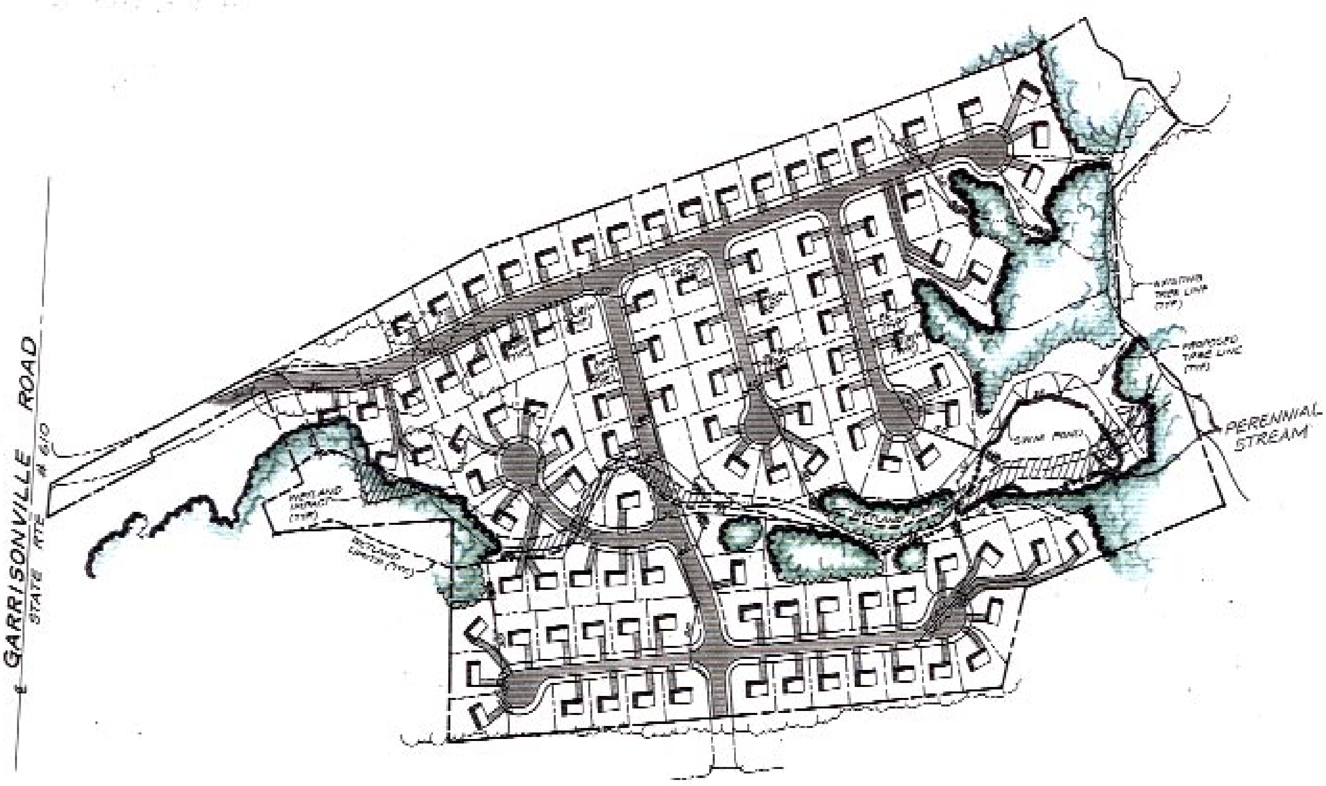

Figure 8: The Conventional Subdivision Design That Was Built at Stonehill Estates (108 lots)

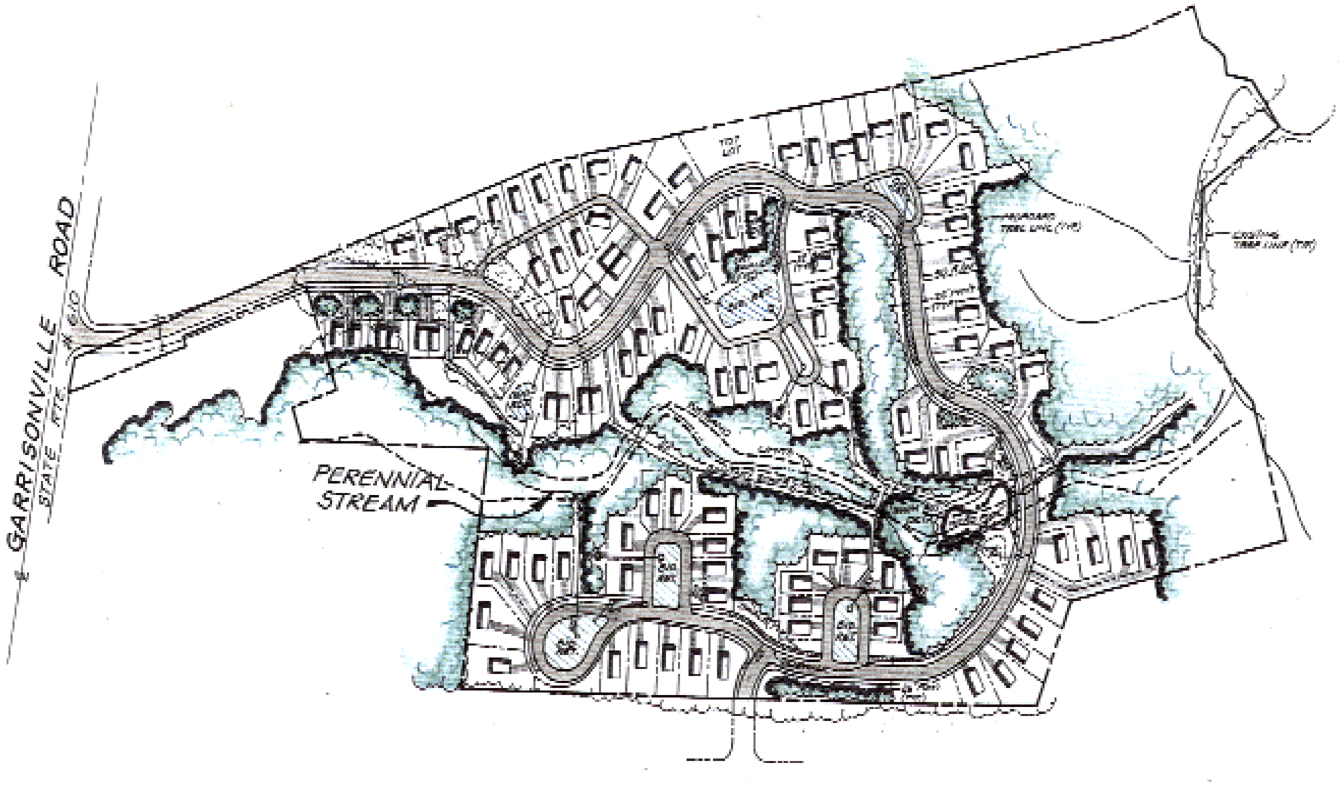

Figure 9: The Open Space Subdivision That Could Have Been Built at Stonehill Estates (108 lots)

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).

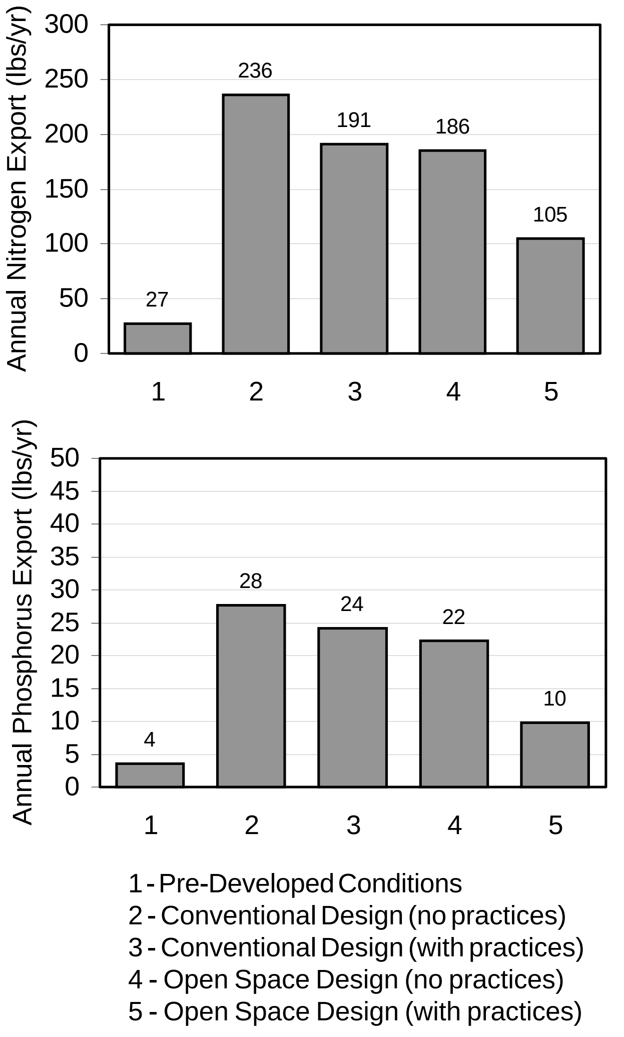

Figure 10: Annual Nitrogen and Phosphorus Loads for Each Stonehill Estates Development Scenario

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 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.

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, 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

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	
Remlik Hall [1]	5 acre lots	5.4 %	3.7%	- 31%	20%
Tharpe Knoll [2]	1 acre lots	13%	7%	- 46%	44%
Chapel Run [2]	‰ acre lots	29%	17%	- 41%	31%
Pleasant Hill [2]	‰ acre lots	26%	11%	- 58%	54%
Prairie Crossing [3]	‰ 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.

export from the conventional design would still be six to seven times greater than the pre-development 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.

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.

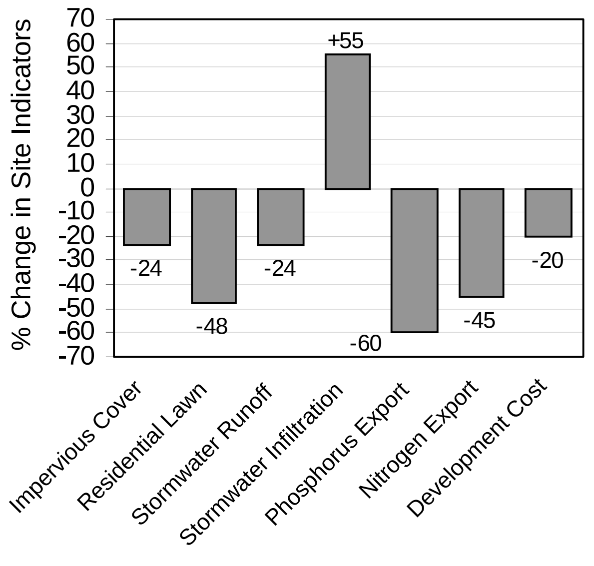

Figure 11: Change in Site From a Conventional Design to an Open Space Design, Both With Stormwater Practices

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		

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.

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).

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?

Table 5: Sample Evaluation Criteria for the Quantity and Quality of Open Space Development (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 ‰ 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

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.

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 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 unsewered 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***

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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 article 36).

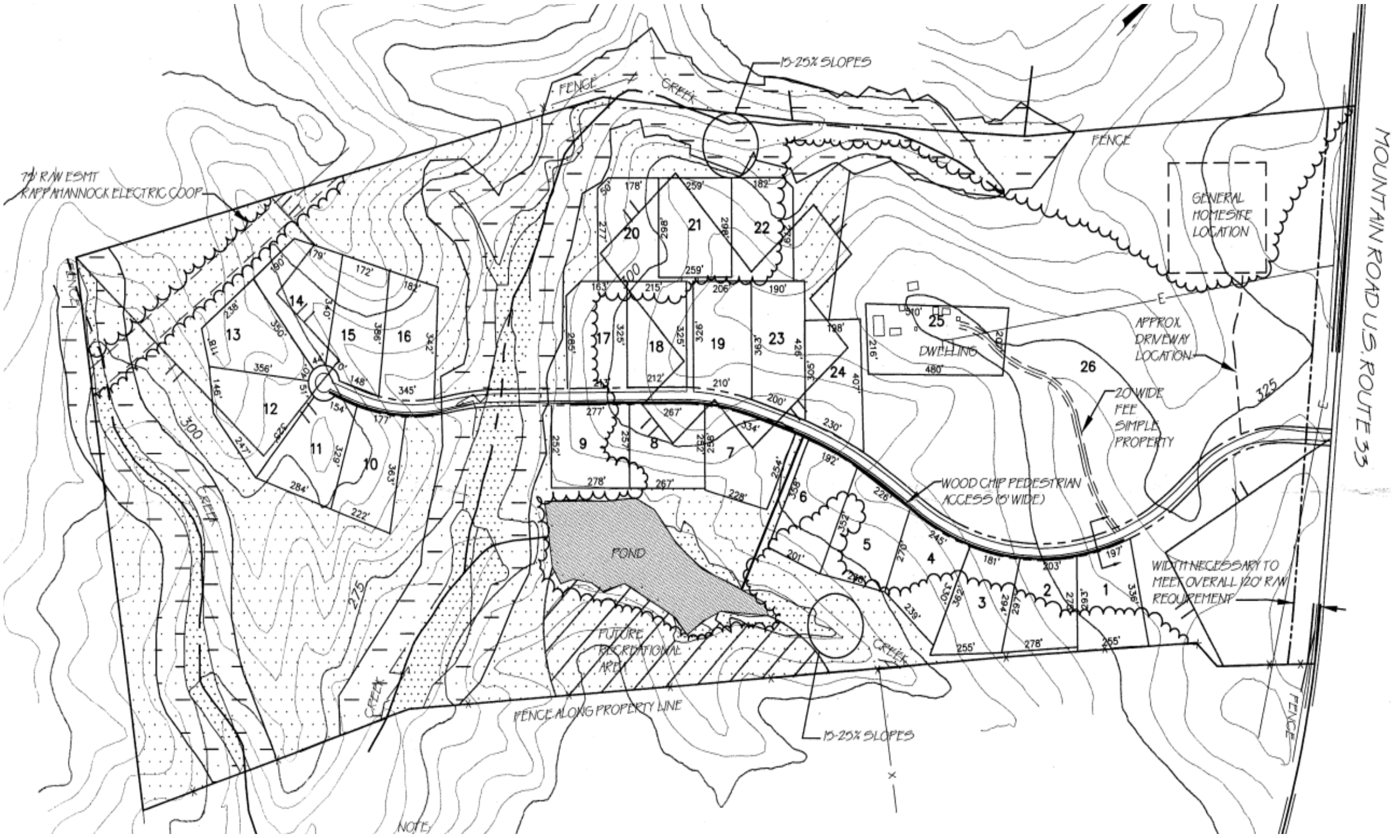

Figure 1: The SUNOM Model Operates Using Basic Site Variables That Can Be Easily Derived From Most Site Plan Submittals

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 (seearticle 64). 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 article 68). 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.

References

Center for Watershed Protection (CWP). 1998. *Nutrient Loading From Conventional and Innovative Site Development*. Ellicott City, MD.

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Schueler, T. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*. Metropolitan Washington Council of Governments. Washington, DC.