Designing for Water Quality

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(ABSTRACT)

The following document serves as a design guidebook to assist landscape architects, designers, planners, engineers, and architects in the practice of developing land while preserving water quality. This guidebook outlines methods for maximizing permeable surfaces by providing examples of ways to minimize impervious surfaces.
Dedication

I would like to dedicate this thesis to my husband.
Acknowledgements

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I want thank my two biggest fans, my Mom and Dad.

I also want to thank my advisory committee for their support.
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Vita

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Background

“Our ability to perceive quality in nature begins, as in art, with the pretty.”

Not so long ago, very little thought was given to the tension that can exist between increased development and our natural resources. America was thought to possess nearly unlimited resources and vast frontiers. This thinking continued even as America’s cities were being vacated by families seeking to live in suburban communities. Families tolerated the longer commute to the city during the week so that on the weekends they could spend their time in a greener, more rural, “country” setting.

The exodus to the suburbs happened so quickly, however, that today many are complaining that the suburbs now have many of the negative attributes of the cities (i.e., lack of green spaces, congestion), without any of their charm (i.e., quaint shopping, cultural centers, and public spaces).

Today, there is an increased awareness not only on how current development patterns have put a strain and imbalance into existing suburban environments both visually and functionally. There is a growing awareness of how current development patterns are contributing to nature’s ecological imbalance, especially in these previous green, “country” settings. As many are choosing to move farther out to escape the suburbs and live closer to nature, they are left wondering where “nature” has gone.

Designers are faced with the question of how humans can coexist with nature and nature can coexist with humankind in the planning of new residential communities. The natural state of an environment will be altered. The very nature of landscape architecture is to alter the landscape. However, there is a growing recognition that one can make changes to the landscape in a way that will have minimal negative impacts on the environment.

After much research on models and case studies throughout urban development, this guidebook has been assembled to assist landscape architects, land planners, engineers, architects, and designers, on how a symbiotic relationship can be created between development and the environment. The guidebook will demonstrate that proper planning not only can have a positive effect on the environment, it can be aesthetically preferable to past methods of excessive hardscape with little greenscape.

The first step to creating this symbiotic relationship starts with a heightened awareness of water quality, or stormwater management. As a leading academic in this

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area stated, “Every aspect of land use allocation, site planning, and detailed design can be brought to bear on stormwater restoration. An overall measure of success is the amount of impervious surface produced by a given unit of development.”

Ninety-seven percent of the world’s water is mixed with salt in our oceans. Seventy-seven percent is frozen at the earth’s poles. Twenty-two percent is buried within the earth’s soil and .003% is running through our rivers and streams. Only .3% of the earth’s water is fresh and available to humans. In addition, humans are not the only competitor for this freshwater resource. Other competitors are from industry, recreation, navigation, hydroelectric, fish and wildlife.

The natural water cycle is very simple to understand. The following graphic demonstrates the cycle of water in the environment. As the chart shows, water flows on the earth through underground aquifers, rivers and evaporates into the air and forms clouds. This results in precipitation that feeds the aquifers, rivers and streams, or evaporates again to form clouds that will eventually result in further precipitation.


Figure 1.1. Natural Water Cycle

When development occurs, the natural water cycle is disturbed, and in some ways, accelerated. Water is prevented from soaking into the earth and consequently, it is prevented from naturally completing its purification cycle. Stormwater pollution occurs

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as the natural cycle is unable to match the accelerated cycle that is the result of development.

Figure 1.2. When Development Interrupts the Natural Water Cycle

The key to addressing stormwater restoration, then, is to limit impervious surfaces, capture and prevent stormwater runoff, and maximize infiltration.

At one time, biologists debated the value of a single large preserve versus numerous small preserves of equal area. This controversy has been put to rest by leading biologists from opposing sides who finally agrees that ‘bigness’ and ‘multiplicity’ are both essential for regional biodiversity.³

Residential development is occurring rapidly and designers are forced into quick design solutions according to negotiations on density with builders and developers. With

³ Ewing, Reid H., Best Development Practices: doing the right thing and making money at the same time, American Planning Association, Chicago, 1996, p. 98. (“A debate once raged among biologist over the value of a single large preserve versus numerous small preserves of equal area. The controversy was put to rest when leading biologist from opposing sides finally agreed that “bigness” and “multiplicity” are both essential for regional biodiversity.”)
this in mind this guidebook is intended to serve as an easy to use tool to aid designers in making stormwater restorative decisions in their new residential developments.
Chapter 1

The Problem

Alterations to an environmental system will create changes in how the ecosystem handles water and water filtration. Developed land creates stormwater runoff that can cause problems if not addressed properly at the outset.

“Children told us that they see more animals on television and in the movies than they had personally seen in the wild.”

There are three basic water problems that developments typically create. These problems relate to stormwater runoff, heightened water temperature, and increased water pollutants.

When land is developed, stormwater that once seeped into the ground or nourished vegetation now confronts rooftops, roads, paved parking lots, and other impervious surfaces. These surfaces deflect the water and create a runoff. A large volume of runoff results in a loss of natural groundwater recharge and purification. It also can result in other problems such as flooding. “By one recent estimate, conversion of woodlands to high-density residential and commercial uses causes an eleven-to-nineteen fold increase in direct storm runoff, with a corresponding 11-100 percent loss of natural groundwater recharge.”

Impervious surfaces also add pollution to the stormwater. Because this stormwater often is not able to seep in to the ground, the polluted water runs into streams, rivers, and other sources without ever being filtered. “Sources of stormwater pollution from urban areas include materials washed off paved areas, including de-icing salts.”

The United States Environmental Protection Agency concluded: “As rain falls, it picks up pollutants from the air. Then as it becomes runoff it collects more impurities while passing over rooftops, streets,

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parking lots, landscaping, and gutters. This runoff typically enters a storm drain system that rapidly conveys it, untreated, to a lake, creek, river, bay or ocean. With the progress made in the past twenty-five years in controlling pollution from factories and other industrial point sources, this concentration of pollutants from various dispersed sources—nonpoint source pollution—is today responsible for over half of the water quality problems in waters of the United States.”

Obviously, increased pollutants in the stormwater runoff creates environmental problems. As Reid Ewing states, “Pollutant loads in urban runoff kill aquatic life, detract from aesthetics of receiving waters, and may contaminate drinking water supplies.”

Runoff not only adds pollutants to larger water supplies, it contains sediments that one may not normally associate with pollution that nonetheless adversely impact an ecological environment. Toby Toubier states, “Sediments destroy spawning grounds for fish and alter the species composition of the fish population. Sediments also reduce light penetration and thereby alter the ecological balance of the stream.”

In addition, as Mr. Toubier points out, impervious surfaces can affect the temperature of stormwater. He states, “Increases in the temperature of runoff from hot pavements is also a form of runoff pollution. ... A study of Long Island found that stormwater runoff may increase stream temperatures by 10-15 degrees Fahrenheit.”

Irresponsible development needs our attention for the safety and security of a high quality of life for humans and the environment. Water is the essential indicator of this quality. Becoming aware of water quality is the first step toward its restoration.

The Solutions

The first step toward solving the problem of stormwater pollution is recognizing that the problem exists. The next step is to do something to address the problem. It may

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feel as if an individual effort is small and insignificant. However, each small step toward helping restore water quality adds to create a larger impact.

Recent studies, including the Nationwide Urban Runoff Program, indicate that planning and designing for the minimization of pollutants in stormwater discharge is the most cost effective approach to stormwater management.\textsuperscript{11} Moreover, as Mr. Tourbier points out:

\begin{quote}
“Traditional engineering practices have failed to solve many of the problems which result from urban development and this failure has prompted alternative approaches to protecting water resources in urbanizing areas.”\textsuperscript{12}
\end{quote}

The Goal, therefore, is to “minimize overall impervious land coverage and maximize infiltration.”\textsuperscript{13}

The first step in tackling stormwater management is to address infiltration. As Mr. Ewing points out, “Infiltration is the first line of defense in stormwater management. Ideally, at least the ‘first flush’ (first inch) of stormwater will be retained and recharged. This alone will largely solve the stormwater pollution and water balance problems created by land development.”\textsuperscript{14}

When creating an infiltration system, one key is to create as “natural” a drainage system as possible. The more “natural” the system, the more valuable it will be for wildlife and water quality. In both of these regards, heavily vegetated swales are superior to grassy swales, wet ponds superior to dry ponds, and a combination of march and open water are superior to open water alone.\textsuperscript{15}

\begin{flushleft}\textsuperscript{11} Tom Richman & Associates, Camp Dresser & McKee, Ferguson, Bruce, Design Artefact, \textit{Start at the Source}, Forbes, New York, 1999, P. 3.\end{flushleft}

\begin{flushleft}\textsuperscript{12} Tourbier, J. Toby, \textit{Water resources protection technology: a handbook of measures to protect resources in land development}, Urban Land Institute, Washington, D.C., 1981, p. 4.\end{flushleft}

\begin{flushleft}\textsuperscript{13} Tom Richman & Associates, Camp Dresser & McKee, Ferguson, Bruce, Design Artefact, \textit{Start at the Source}, Forbes, New York, 1999, p. 6.\end{flushleft}

\begin{flushleft}\textsuperscript{14} Ewing, Reid H., \textit{Best Development Practices: doing the right thing and making money at the same time}, American Planning Association, Chicago, 1996, p. 110.\end{flushleft}

\begin{flushleft}\textsuperscript{15} Ewing, Reid H., \textit{Best Development Practices: doing the right thing and making money at the same time}, American Planning Association, Chicago, 1996, p. 111.\end{flushleft}
Mr. Ewing points out that a natural, open drainage system has advantages that go beyond its ability to filter the water. He states, “If designed properly, open drainage can provide valuable habitat. It can save money relative to storm sewer systems—hundreds of dollars per dwelling unit. And wet ponds, and perhaps wetlands, have amenity value that can be captured in the price of bordering lands.”

The natural areas created for open drainage can be attractive areas for residents as well as wildlife. Many people would love to walk or bike to work if given the opportunity. Unfortunately, many of our communities were built exclusively around the automobile.

**Lifestyle Change**

No one disputes the automobile’s usefulness in society. It is remarkable, however, to contemplate the effect the automobile has had on creating conditions that have been contrary to good stormwater management principles.

For example, the leading expert in stormwater management, Bruce Ferguson, points out the amount of impervious surface area needed to accommodate an automobile. He states:

> “In contemporary American development, cars are the principal generators of impervious surfaces. Whenever a car goes, it leaves a parking space of 300 to 350 square feet, travels in a lane occupying 2,000 square feet or more, and arrives at a second parking space of still another 300-350 square feet. Automotive pavements occupy more than half the impervious surface in residential developments; in commercial developments they occupy 80% of all the land.”

Consequently, encouraging walking and biking by creating paths for these purposes is a simple but effective way of decreasing stormwater runoff. By increasing these activities, there is a decrease in the automobile usage and a correlative elimination on the demand for paved surfaces. Walking and biking require much more narrow paved surfaces than cars, and in some cases, these paths do not need to be paved at all. Typically, a bike lane is only half as wide as a car lane. In addition, 15 bikes can be parked in the space required for one car.

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In today’s fitness-conscious environment, walking and biking trails are much appreciated by perspective residents. Such trails can enhance the aesthetics of a community and increase property values. In addition, these activities reduce traffic congestion and reduce noise. As Mr. Ferguson points out, such results are “distinctively compatible with the quietness and safety of residential neighborhoods. Walking and biking help to eliminate runoff and pollution by never generating them in the first place.”

In addition, these paths enhance the quality of living:

“Site planning is more than a practical art, however complex its technical apparatus. Its aim is moral and esthetic: to make places which enhance everyday life- which liberate their inhabitants and give them a sense of the world they live in.”

The balance of this guidebook is broken into the following five sections:

- Overall Design Considerations
- Permeable Pavement
- Streets
- Parking Lots
- Driveways
- Using the Landscape to Control Runoff

Within each section are visual representations and models that show designers how small, seemingly insignificant design decisions can make the difference between irresponsible and responsible development.

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Chapter 2

Overall Design Considerations

Before a site is designed, before roadways, driveways, and pathways are laid out the following goals and intentions must be visited.

First we want to make sure that we will be maximizing infiltration of rainwater back into the ground and that we are minimizing impervious surfaces. Note alternative materials suggested within the permeable surfaces chapter for examples. Second we want to recognize significant vegetated areas and existing water paths and collection areas. Providing buffers around these key locations will allow the site’s existing filtration system to continue adding it’s benefits to the purification of the water by slowing the water down as it moves across the site as well as prevent erosion. Third, we want to channel any impervious rainwater flow into various planned impervious areas throughout the site.

In addition to using impervious surfaces for relief from strictly impervious paved areas we also can use the landscape as a resource for channeling water away from unavoidable impervious zones. Keeping excess water from gathering in those impervious areas is a matter of redirecting flow to alternate impervious areas.

Finally we need to remember that seemingly insignificant changes that we provide for in the beginning will add up across a site resulting in a significant difference collectively.

In urbanizing a landscape, effort should be made to preserve patches as large as possible. Not only does this provide greater filtration surface area, but it also allows more species to habitat those patches.  

If a preserve is large enough, a wide range of species can be assembled by government through land acquisition and mitigation banking programs. A matrix of smaller preserves may be suitable with other species with less need for space. Generally, land developers can facilitate the population of smaller preserves by a variety of species.  

In cases where land is limited, preserves should be as nearly circular as possible to minimize edge effects. Edges invite competition from generalist species, predation, and human disturbance. Edge widths vary from 50 to 200 meters.  

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When working with significant wetlands, impacts on the wetlands should be limited to road crossing points—and then only if no alternative route exists. When road crossings over wetlands are unavoidable, they should be placed at a place of minimal impact, which is usually the narrowest point in the wetlands.\textsuperscript{24}

When working around a wetlands area, check with your state’s requirements relating to buffer zones between developed areas and a wetlands. Many states require buffers of 50 feet or more next to wetlands, lakes or streams. Experts generally agree that a buffer zone of this width is necessary.\textsuperscript{25}

Upland buffers should be used to protect a wetlands area. Upland buffers protect wetlands and natural water bodies from erosion, nutrient overload, and loss of many species that require more than one habitat to meet their feeding, nesting and shelter needs. In addition, upland buffers contribute woody debris, control water temperatures, provide food, and provide cover for fish in adjacent waters.\textsuperscript{26}

\textsuperscript{24} Ewing, Reid H., \textit{Best Development Practices: doing the right thing and making money at the same time}, American Planning Association, Chicago, 1996, p. 101.
\textsuperscript{25} Ewing, Reid H., \textit{Best Development Practices: doing the right thing and making money at the same time}, American Planning Association, Chicago, 1996, p. 103.
\textsuperscript{26} Ewing, Reid H., \textit{Best Development Practices: doing the right thing and making money at the same time}, American Planning Association, Chicago, 1996, p. 103.
Chapter 3

Permeable Surfaces

“Permeable pavements have tremendous (and largely untapped) potential for stormwater management. They eliminate runoff at the source and therefore require no extra land. With a 20 percent void structure, they can pass three to five gallons per minute for each square foot (assuming a gravel recharge bed underneath). This is a higher infiltration rate than attainable with natural groundcovers.”

The following chart shows how typical concrete and asphalt result in 100% runoff, whereas other choices such as gravel, clay, or turf yields a significantly lesser percentage of runoff. These other methods offer a more purified system for water quality as well as a more aesthetic alternative to our typical uses of asphalt and clay.

![Coefficients of Runoff](image)

(Source: Tom Richman & Associates, Camp Dresser & McKee, Ferguson, Bruce, Design Artefact, Start at the Source, Forbes, New York, 1999, p. 49.)

Figure 3.1. Coefficients of Runoff

From an environmental perspective, there is no question that permeable pavements are beneficial. What about economic considerations? Generally, porous pavements cost about 10% more than conventional pavements. Open-celled pavements

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are more expensive still. When porous pavements are part of an overall stormwater system, however, their ability to substitute for storm drains can make them 12-38 percent less expensive than conventional paved surfaces.\(^{28}\)

Porous asphalt and porous concrete are strong enough for use in walkways, parking lots and low-volume roads. Porous materials are used on high-volume roads as well, however, in those cases they typically are used only in the surface layer for skid resistance or the base for rapid water removal and extended pavement life.\(^{29}\)

One of the reasons that porous surfaces have not been widely used to date is a fear that the porous pavement eventually will become clogged. The concern is that the porous spaces will become filled with finer particles that will build-up and prevent stormwater from penetrating. This is the most cited reason engineers give when declining to use porous pavement. According to Reid Ewing, however, researchers have found that proper design, installation and maintenance can prevent any loss of porosity over time.\(^{30}\)

The next two charts illustrate configurations with porous asphalt and porous concrete, respectively. Figure 3.2 demonstrates how a porous asphalt system is designed. It follows the basic description outlined above.


Figure 3.2. Porous Asphalt

Figure 8 demonstrates how a porous concrete system would be set up. As illustrated, the first layer is comprised of the pervious concrete. The pervious concrete acts as a filter and eliminates the need for a first layer of filter course. The second layer is a crushed, aggregate base, which is necessary only if the subgrade is not well-drained. The last layer is the subgrade, which is minimally compacted to promote porosity.


Figure 3.3. Porous Asphalt

Compare Figures 3.2 and 3.3 with the following Figure 3.4, which illustrates how typical impervious paving causes water to find other permeable surfaces—the primary cause of stormwater runoff.

By eliminating impervious surfaces whenever it is practicable the result is less stormwater runoff. Even breaking up the impervious surfaces where possible will increase filtration and decrease stormwater runoff.

Figure 3.4. Impervious surface


Figure 3.5. Pervious Surface

Turf block is another way to replace an impervious surface with one that allows for filtration. Turf block is not realistic on a high volume, high speed avenue. However, it works well on less traveled, tertiary avenues, driveways, overflow parking areas, and emergency access areas. Moreover, turf block is an aesthetically pleasing alternative.

Turf blocks are approximately ½” thick. The turf block contains a porous material such as sand, and the block is usually placed on a 1” layer of sand. The next layer, which can vary from a few inches to almost a foot, is an open graded, crushed aggregate base. Again, the final layer is a minimally compacted subgrade. Figure 3.6 illustrates a cross section of turf block.
Figure 3.6. Turf Block

Open-celled pavers are a variation of turf blocks. Figure 3.7 illustrates two common examples. However, there are a nearly endless variety of designs in this category. The common theme is that they allow for substantial filtration by increasing the amount of permeable surface area. Figure 12 illustrates two examples of open-celled pavers—lattice and castellated.

Figure 3.7. Open Celled Pavers

Figure 3.8 illustrates, grass block is a basic concept that can be easily incorporated into a design plan. It has aesthetic value and also greatly reduces runoff by allowing for direct filtration. Again, this option is not suited for high volume avenues. It is an ideal option for driveways, low volume avenues, overflow parking areas, and emergency access areas.
Figure 3.8. Grass Block

Brick, natural stone and unit pavers allow water to flow around the individual impervious surfaces. On walkways, the brick and stone can be placed on a bed of sand, which lays upon the soil. On driveways, low volume roads, and overflow parking areas, the materials should be placed on at least 6” of crushed aggregate to add filtration.

These materials also present a myriad of aesthetic possibilities since they come in a variety of materials and colors. Figures 3.9 through 3.12 illustrate how these materials work.

Figure 3.9. Brick Paving on Sand

Figure 3.10. Brick Paver

Figure 3.11. Natural Stone Paver
Figure 3.12. Unit Pavers on Sand Base

Gravel and crushed aggregate decrease runoff and filter incoming water. Figures 3.13 and 3.14 illustrate how these materials work. Gravel and crushed aggregate are good choices for driveways, overflow parking areas, and emergency access roads. When using these materials, hard, impervious edges should be used to keep the gravel or crushed aggregate in place.

Figure 3.13. Gravel as Impervious Surface
Cobbles. Cobbles are an attractive alternative for low volume areas such as driveways and parking areas. Cobbles are usually between 4” and 6” in diameter. A cobbled area should be bordered by a hard, impervious edge to keep the cobbles in place. The cobbled stones are placed on a bed of sand. The sand may be placed on top of crushed aggregate or directly on the subgrade.
Chapter 4

Controls for Street Runoff

Impervious streets will create stormwater runoff. There are ways, however, to minimize runoff and increase filtration. Generally, these strategies involve integrating local swales, green spaces, and natural drainage features to capture stormwater, rather than have all of the runoff directed into a sewer.

Conventional cul-de-sacs are paved across their entire diameter. This large impervious surface area increases stormwater runoff and creates a ‘heat island’ at the front of adjacent land uses. This problem can be overcome easily by creating a landscaped area in the center of the cul-de-sac. A landscaped center can reduce impervious surfaces by as much as 40 percent, while still allowing for the required turning radius.\(^{31}\) In addition, a landscaped island in the center of a cul-de-sac is aesthetically preferable to traditional, paved cul-de-sacs.

It also should be noted that these cul-de-sacs need to follow codes relating to turnaround radiiuses. These codes usually require a turnaround area large enough to accommodate large trucks, such as moving vans and emergency access vehicles (e.g., fire departments often require 60 feet or greater diameter turnarounds).\(^{32}\)

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Figure 4.1. Cul de sacs

Concave medians provide a simple, effective means to capture first-flush runoff. Unlike flat medians or convex medians, which direct water across the street to a drainage system, a concave median catches water and filters it.

Concave medians can be designed as a landscaped swale or turf-lined biofilter to treat first-flush runoff—which carries a high concentration of oils and other pollutants off the street.\(^3\)

There are two basic issues to be addressed when planning a concave median. First, the median must be sized to accommodate the anticipated water quality volume. And second, the vegetation and planting must be able to withstand periodic inundation.\(^4\) Figures 4.2 and 4.3 illustrate how they work.


Figure 4.2. Concave Median


Rural swales provide an efficient means of dealing with stormwater. Because these swales are linear, runoff from the street is not concentrated but dispersed along its entire length. Consequently, pollutants in the soil are minimized. In addition, the swale can be designed to provide for parking, or if parking is not wanted, trees, bollards or other groundcovers can be added.\textsuperscript{35}

When using rural swales, the street should be crowned so that runoff will be directed to either side. If drainage will only be provided on one side, then the street should be sloped to direct water to that side.\textsuperscript{36}

Surface swales also provide for easy and convenient maintenance. Drainage problems are easy to monitor and clear because they will be visible. Contrast this to an underground drainage system where problems are more difficult to monitor and maintenance often requires a street excavation.\textsuperscript{37} Figure 4.4 illustrates a typical swale system.

When designing rural standard streets, use a more narrow width street and increase filtration through the use of gravel or pea shoulders. This also eliminates the need for an underground drainage system.

Not only is the model more environmentally sensitive, it has added aesthetic value. “Properties on narrower streets with tree-lined landscaped parkways typically command higher values than those on wider treeless streets.”

Figure 4.5 provides an overhead view of this system.
Urban neo-traditional standard access streets typically have a pavement width of 20’ to 30’ for vehicular movement and parking, as compared to conventional local streets that typically require 36’ to 40’ of pavement.

Urban neotraditional streets will have a parkway on one or both sides, which can be used for planting as well as surface drainage. These streets will reduce impervious land coverage by up to 50 percent.

An urban neotraditional street generally utilizes curbs and gutters. However, the gutter may be tied to a biofilter or swale rather than an underground storm drain.

These streets reduce sediment, oil and grease, and hydrocarbons when combined with biofilters and swales.
Where appropriate: Urban neotraditional streets are appropriate for areas where traffic volumes are at or below 500-750 ADT and speeds between 15 and 25 miles per hour. Figures 4.6 and 4.7 illustrate this system.


Figure 4.6. Neo-Traditional Standard

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A dual drainage system consists of two catch basins at each inlet point. The first is sized to direct the water quality volume into a landscaped infiltration area. The second collects overflow of larger storms and directs it to the storm drain system.

Dual drainage systems can be used in residential or commercial developments. The swale that acts as an infiltration area can be located on the shoulder or in concave median. Figure 4.8 demonstrates how this system would work.

In an urban curb/swale system, runoff travels along the gutter, but instead of being emptied directly into catch basins and underground pipes, it flows into surface swales.

Stormwater can be directed into swales either through conventional catch basins with outfall to the swale or notches into the curb with flowline leading to the swale.
Obviously, multiple curb openings closely spaced are better than fewer openings widely spaced because it allows for greater dissipation of flow and pollutants.\textsuperscript{41}

Figures 4.9 through 4.13 demonstrate that there are a number of ways to set up this system. A number of different curbs can be used, including notched curbs, dragon tooth curbs, or rolled curbs.


\textbf{Figure 4.9. Urban curb/Swale System}

Figure 4.10. Curb Cut


Figure 4.11. Dual Drainage System

Figure 4.12. Curb Cuts Allowing Flow Into Turf Area
Chapter 5

Parking Lots

Parking lots often are large impervious surfaces that create high volume of stormwater runoff. Because parking lots typically yield a lot of automobile pollutants and other contaminants such as road salt, the runoff created by parking lots is also disproportionately polluted. Consequently, parking lots can be the environment’s worst enemy.

Fortunately, parking lots can be designed to increase permeable surfaces, slow water down, and redirect water to swales.

There are four basic goals in designing an environmentally sensitive parking lot:
1. Disconnect large impervious surfaces
2. Slow water down
3. Redirect water into vegetated areas
4. Introduce permeable pavements where appropriate

Porous pavement recharge beds underneath parking lots are gravel beds that receive and store filtration.42


Figure 5.1. Porous Pavement Recharge Bed

As Figure 5.2 demonstrates, a lot can be designed where the travel lanes are made of more resilient, impervious surfaces. While the actual parking spaces are made of permeable material to allow for infiltration.


Figure 5.2

Hybrid lots can reduce the overall impervious surface coverage of a typical double-loaded parking lot by 60 percent. In addition, they can avoid the need for underground drainage systems.

Differentiation between aisles and stalls can mitigate the overall visual impact of the parking lot.

When designing hybrid parking lots, keep permeable pavement areas relatively flat (slope less than 5 percent).

Stall markings can be indicated with wood headers laid in a field of permeable pavement, change in unit paver color, concrete bands or pavement marker (“botts dots”) depending on the material used.\(^\text{43}\)

Hybrid parking lots are also aesthetically more interesting than typical parking lots. Figure 5.3 illustrates how a hybrid parking lot works. Notice that the impervious surface is sloped to allow the water to drain to the permeable surfaces.

Figure 5.3. Hybrid Parking Lot

In many cases, regular parking demand accounts for approximately two-thirds of the total area, with one-third accommodated as overflow. Instead of blocking off the entire area with impervious surfaces, it makes sense to design the overflow area with a permeable material.

Overflow areas can be pervious materials such as turf block, crushed stone, unit pavers on sand, grass blocks, and permeable concrete. Visually, they are beneficial because they can be designed to break up an expanse of continuous parking lot.

Irrigation may be necessary if overflow parking is turf block. Figure 5.4 illustrates how the overflow parking would connect to the impervious-surfaced parking area.

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A parking grove not only shades parked cars, but it presents an attractive open space when cars are absent. They are utilized best in situations where vehicles park for long periods of time, such as hotels, housing, and offices.

Parking groves are not recommended for lots with a high turnover, such as restaurants and commercial areas because of additional care needed to navigate around trees.

In parking groves, the stalls must be oversized to accommodate thickness of bollards and trees. A grid of trees/bollards spaced approximately 19 feet apart allows two vehicles to park between each row of the grid (9.5 foot space per stall, compared to the standard 8.5 to 9 foot space per stall). A grid of 28 to 30 feet allows for three cars between each pair of trees.

Trees/bollards should be set at least three feet in from the end of the stall to allow for turning movements into and out of stall.

Trees should be protected during the establishment period with double staking of 3” diameter wood stakes. Align stakes along implied stall line.

Bollards may be omitted if proper tree stacking is provided during establishment period.
Obviously, trees will require necessary irrigation.\textsuperscript{45}

Figure 5.5 demonstrates how a parking grove would work. Notice that the impervious area is sloped to drain water toward the permeable surfaces.


\textbf{Figure 5.5}
As Figure 5.6 illustrates, a parking grove concept does not necessarily have to incorporate parking spaces on permeable surfaces. Figure 5.6 illustrates a creative way to position a parking lot within a grove. The impervious surfaces would be sloped to drain water to the permeable surfaces surrounding the lot. The aesthetic qualities of the configuration in Figure 5.6 are obvious.


Figure 5.6. Parking Grove Preserving Existing Trees
Chapter 6

Driveways

In designing driveways that will have minimum negative effect on stormwater runoff, it is important to keep in mind that every effort to help lessen the effects of runoff pollutants is important. Positive design changes, no matter how small, can add up across any given development.

A residential development of 800 homes provides an opportunity for 800 driveways to adopt a new, positive form such as one of the following.

A temporary parking space is an easy way to decrease impervious surface area. It uses the overflow parking concept on a smaller scale. As Figure 6.1 illustrates, a temporary parking area may be incorporated with a conventional asphalt driveway. In Figure 6.1, the temporary parking area is located to the side of the driveway and is used only occasionally. A temporary parking area can be made of gravel, grass block, open-celled pavers, brick, or stone.


* An additional design solution for this detail is to direct flow toward the designated impervious area

Figure 6.1. Temporary Parking
As Figure 6.1 illustrates, the temporary parking space can appear as green space or a patio for the majority of time when not used for parking.⁴⁶

As Figure 7.2 illustrates, a flared driveway is a narrow strip of impervious surface that leads from the street toward the garage. However, prior to reaching the garage, the driveway flares to accommodate maneuvering by automobiles that will be using the garage.

A flared driveway design reduces impermeable surface area compared to a two lane, or even multi-lane, driveway extending the entire length from the garage to the street.⁴⁷


Figure 6.2. Flared Driveway


Crushed aggregate driveways can be formal or rural depending on the design and materials. These driveways have a distinctive “crunchy” sound that is appealing. Because of the material used, these driveways should be used on flat sites with a slope of less than or equal to 5 percent. These driveways are also economical. They cost less than paved driveways.

Open-graded crushed aggregate (such as 3/8” to 3/4” granite) should be used rather than rounded stones such as pea gravel. Angles of the crushed stone form a matrix that holds the granular material in place, able to bear the load of traffic without substantial displacement.

In addition, as Figure 6.3 illustrates, open-graded, crushed aggregate driveways should have a rigid edge such as a wood header, concrete, metal or brick band to keep the aggregate in place. These driveways should have a non-granular apron at the intersection of the driveway with the street to accommodate turning movements. And, there should be a concrete band or wood timber between the apron and the crushed aggregate to absorb the impact of repeated wheel crossings.48


Figure 6.3. Crushed Aggregate Driveway

The general principle behind this driveway is to direct stormwater pollutants toward an adjacent green area, which filters the water. This is accomplished by sloping the driveway (i.e., cross slope) side to side rather than front to back.

The key to this design is that the cross slope must be greater than the front to back slope. In addition, the edge of the driveway must be approximately three inches above the adjacent lawn area, so that the turf or vegetation does not impede the stormwater runoff from the driveway to the soil.49

This design often is used in California. This design creates an impervious surface of concrete or paved asphalt only under the wheel tracks. This design can reduce impervious surface area by up to 70 percent over a traditionally paved driveway.

This design works best with straight driveways. It is not recommended for curved driveways.

The wheel tracks must be wide enough to accommodate a variety of tire widths and variabilities in driving. The wheel tracks must be strong enough to support vehicle loads. They are normally made from concrete or mortar-set pavers such as stone or brick.

In soil areas with low infiltration rates, a drain line may be buried between the wheel tracks to collect and direct runoff.

If ground cover or grass is used between the wheel tracks, an irrigation system must be available, and parked cars must be moved periodically so that a single spot is not continuously in the shade.50

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Figure 6.4. Paving Only Under Wheels
Chapter 7

Using the Landscape to Control Runoff

The following landscape section contains general landscape design considerations and information, as well as some additional site planning tools to take into consideration at the beginning of each new site to be developed.

One goal should be to employ design strategies that help to conserve water in the landscape. Fast moving dry winds across a vast bare surface of moist soil will pull water out of the soil and decrease filtration. One way to tackle this problem is to place low growing shrubs and small trees mixed with taller, mature trees in the path of the wind. The trees will slow down the wind and provide shade to the soil.

In addition to planting trees to serve as windbreaks, a development should try to incorporate native grasses instead of turf. Mulch should be used instead of grass when appropriate. And berming should always direct water back on the site.

Compare the design differences between Figures 7.1 and 7.2. Figure 7.1 does not employ a wind strategy, while Figure 7.2 is designed to reduce water evaporation and direct the wind to make it as unobtrusive as possible.


Figure 7.1. Wind Taking Moisture From Vegetation
Figure 7.2. Trapping Moisture by Design

A vegetated area will slow the velocity of stormwater runoff and act as a filter to catch sediment. Small soil particles or stones that are too tightly packed do not allow water to penetrate and force it to run off. In addition, large soil particles such as sand allow water to percolate and evaporate too quickly.

Mulch is an ideal ground cover. It allows water into the soil and tends to keep it in. It limits reflectivity of heat into the surrounding area, providing for a cooler surface area, which limits evaporation. It helps to prevent weeds, and reduces maintenance by reducing irrigation. In addition, it improves the appearance of an area.

Especially in sloped area, saucers around the bases of trees and shrubs catch more of the water falling on a site and put it directly around plants, rather than letting it run off to be replaced later with irrigation water.

Planters are a good way to break up plazas and massive hardscaped areas and allow for infiltration.

Grading always should be done to either retain water on the site or direct it to where it is needed. Grading should always be gently sloped. A planner should avoid using drastic slopes. In addition, plants with high water requirements should be placed
at the top of the slope. Conversely, plants with low water requirements should be placed on low, wild, naturalistic areas.

And, water can be reused by placing plants on a slope, which will direct the water downhill to be used and reused by the plants on the slope.

A diversion should be used to keep water off of parking areas at the bottom of a slope. See figure 7.3 for an example of a diversion.


Figure 7.3

Grading should always be designed to accept water on the landscaped areas, and to prevent water from being directed to paved streets.
Extended dry ponds store water during storms for a short period of time (from a few hours to a few days), and discharge water to adjacent surface waters. They are dry between storms and do not have a permanent pool of water.
Extended dry ponds have potential for multiple uses, including flood control basins, parks, playing fields, tennis courts, open space, and overflow parking lots.

Inside basin slopes should not be greater than 3:1 (horizontal:vertical), to minimize erosion and allow heavy equipment access for periodic cleanout.

Fencing or vegetation placed around the perimeter of the basin will increase safety.\textsuperscript{51}

Wet ponds are permanent pools of water that detain and treat stormwater runoff. They can be enhanced by designing a forebay to trap incoming debris and sediment, and by establishing a fringe wetland at the pond edge to increase pollutant removal and enhance the aesthetic, economic, and habitat value of the pond.

Pollutants are removed by settling suspended solids, uptake by wetland plants and algae, and bacterial decomposition.

Wet ponds are appropriate for stormwater drainage in a development or project with a drainage area greater than approximately 2 acres, but are more cost effective for drainage areas greater than 10 acres.

Wet ponds can be an attractive and useful addition to a development with opportunities for use as a recreational site. For example, wet ponds can be used for birdwatching, fishing or boating. In addition, a pedestrian or bicycle trail can be added that circles the pond.

For risk management, basin areas often are fenced. A more aesthetic alternative would be to place vegetation around the basin.

Surface area must equal 1 percent of the drainage area for high pollutant removal. For example, 100 acre drainage area would require a 1 acre wet pond.\textsuperscript{51}

Grass/Vegetated Swales. An alternative to lined channels and pipes are grass and vegetated swales. These are vegetated earthen channels that convey and infiltrate water and remove pollutants.

When swales are not holding water, they appear as a typical landscaped area.

A single grassy swale can drain approximately 4 acres of land. Multiple swales would be required to drain a larger site.

\textsuperscript{51} Tom Richman & Associates, Camp Dresser & McKee, Ferguson, Bruce, Design Artefact, Start at the Source, Forbes, New York, 1999, P. 142.

\textsuperscript{52} Tom Richman & Associates, Camp Dresser & McKee, Ferguson, Bruce, Design Artefact, Start at the Source, Forbes, New York, 1999, P. 144.
Grass swales move water more quickly than vegetated swales. A grass swale is planted with turf grass. A vegetated swale is planted with bunch grasses, shrubs or trees. 53

When using grass swales, careful attention should be used to select plant species that can survive through both periods of inundation and periods of drought. A variety of grass species, including native and non-native, can together produce a swale turf that is adapted to a variety of environmental conditions.

Trees and shrubs can be located adjacent to swales, and on the banks of larger swales.

Side slope should be 3:1 (horizontal:vertical) or shallower, to limit erosion and to improve maintainability.

Grass swales are more economical than underground pipe. Compare grass swale construction cost per linear foot $4.50-$8.50 (from seed) to $15-$20 (from sod), to $2 per inch of diameter underground pipe.


Figure 1. Reinhold Company, New York, 1984.
Chapter 8

Land Plan

The attached residential land plan contains 48 duplex units and 124 single family units. In addition, it has a large, natural wetlands area. There are a variety of slopes on the site that range from steep to moderate. This particular site developer was looking for a high density of single family and duplex products. Due to the site’s constraints, the land plan utilized cul de sacs stemming from a major road to avoid excessive grading and save forested areas.

In designing the land plan, the strategy was to minimize overall impervious land coverage and maximize infiltration. To this end, the plan incorporates a running and bike path not only to increase the aesthetics of the site, but to encourage residents to decrease their reliance on the automobile.

Where possible, the plan utilizes permeable surfaces to increase filtration. As one can see, the plan incorporates cobbles and crushed aggregate on secondary roads.

Because impervious surfaces could not be completely dispensed with, the plan incorporates strategies to minimize stormwater runoff and direct water toward local filtration opportunities such as the three major parks. In addition, there are thirteen cul de sacs on the plan, which incorporate grassy swales in the center. The plan also maintains a large portion of forested property, especially around the wetlands areas. There is a natural spring, which is a focal point of the amenity area. It lays in the heart of the community and reminds people of the importance of water and water quality.

The original trees have been preserved to the greatest extent possible, especially on slopes surrounding the wetlands in order to minimize soil erosion and serve as wind buffers, which will minimize water evaporation throughout the site. Shorter trees and shrubs will be added to complement the older trees and provide wind barriers for the homes.

There is one major road that runs through the site. It is only 24 feet wide in order to reduce impervious surface area. This road is sloped to allow runoff to the adjacent natural areas.

As stated earlier, parking lots can be a major cause of stormwater runoff. In this plan, there are gravel and turf block hybrid lots disbursed throughout the property to handle guest parking. Since there are no commercial spaces in this development, this is not a major issue.

All of the driveways on this plan are made up of crushed aggregate and cobble to allow for infiltration.
Obviously, the land plan cannot incorporate all of the ideas in this guidebook. The key for developers, however, is to think about stormwater management at the very start of a project. As the land plan demonstrates, stormwater management techniques can be utilized in a way that benefits the environment and adds aesthetic value. In addition, these techniques often are more economical than traditional methods of handling stormwater.
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