4. LOW IMPACT DEVELOPMENT

The following readings provide published information about the benefits and economics of low impact development (LID). LID commonly incorporates nearly all of the BMPs described in this guidance manual as a standard of practice and measurement, achieving not only environmental benefits, but economic benefits for developers and builders, for residents and commercial property owners, and municipal governments as well.

4.1 Seven Benefits of Low Impact Development

Effective. Research has demonstrated LID to be a simple, practical, and universally applicable approach for treating urban runoff. By reproducing predevelopment hydrology, LID effectively reduces runoff and pollutant loads. Researchers have shown the practices to be successful at removing common urban pollutants including nutrients, metals, and sediment. Furthermore, since many LID practices infiltrate runoff into groundwater, they help to maintain lower surface water temperatures. LID improves environmental quality, protects public health, and provides a multitude of benefits to the community.

Economical. Because of its emphasis on natural processes and micro-scale management practices, LID is often less costly than conventional stormwater controls. LID practices can be cheaper to construct and maintain and have a longer life cycle cost than centralized stormwater strategies. The need to build and maintain stormwater ponds and other conventional treatment practices will be reduced and in some cases eliminated. Developers benefit by spending less on pavement, curbs, gutters, piping, and inlet structures. LID creates a desirable product that often sells faster and at a higher price than equivalent conventional developments.

Flexible. Working at a small scale allows volume and water quality control to be tailored to specific site characteristics. Since pollutants vary across land uses and from site to site, the ability to customize stormwater management techniques and degree of treatment is a significant advantage over conventional management methods. Almost every site and every building can apply some level of LID and integrated management practices that contribute to the improvement of urban and suburban water quality.

Adds value to the landscape. It makes efficient use of land for stormwater management and therefore interferes less than conventional techniques with other uses of the site. It promotes less disturbance of the landscape and conservation of natural features, thereby enhancing the aesthetic value of a property and thus its desirability to home buyers, property users, and commercial customers. Developers may even realize greater lot yields when applying LID techniques. Other benefits include habitat enhancement, flood control, improved recreational opportunities, drought impact prevention, and urban heat island effect reduction.

Achieves multiple objectives. Practitioners can integrate LID into other urban infrastructure components and save money. Lot level LID applications and integrated stormwater management practices combine to provide substantial reductions in peak flows and improvements in water quality.

Follows a systems approach. LID integrates numerous strategies, each performing different stormwater management functions, to maximize effectiveness and save money. By emulating natural systems and functions, LID offers a simple and effective approach to watershed sensitive development.

Makes sense. New environmental regulations geared toward protecting water quality and stabilizing our now degraded streams, rivers, lakes, and estuaries are encouraging a broader thinking than centralized stormwater management. Developers and local governments continue to find that LID saves them money, contributes to public relations and marketing benefits, and improves regulatory expediencies. LID connects people, ecological systems, and economic interests in a desirable way.

4.2 Low Impact Development (LID) Practices for Storm Water Management

Water quality concerns have intensified, and storm water management practices have come under scrutiny, as development occurs on an increasing percentage of the available land area in the United States. With more stringent design requirements, costs for traditional collection and conveyance systems have risen sharply. Organizations from community groups, regional watershed authorities, and state and federal agencies have become involved in this issue. Subsequent changes in storm water regulations could strongly impact builders and communities as more new regulations and practices are implemented. Low Impact Development (LID) techniques can offer developers a more cost effective way to address storm water management through site design modifications and "Best Management Practices" (BMPs). These strategies allow land to be developed in an environmentally responsible manner, and create a more "Hydrologically Functional" landscape.

Low Impact Development (LID)

Low Impact Development is an ecologically friendly approach to site development and storm water management that aims to mitigate development impacts to land, water, and air. The approach emphasizes the integration of site design and planning techniques that conserve the natural systems and hydrologic functions of a site.

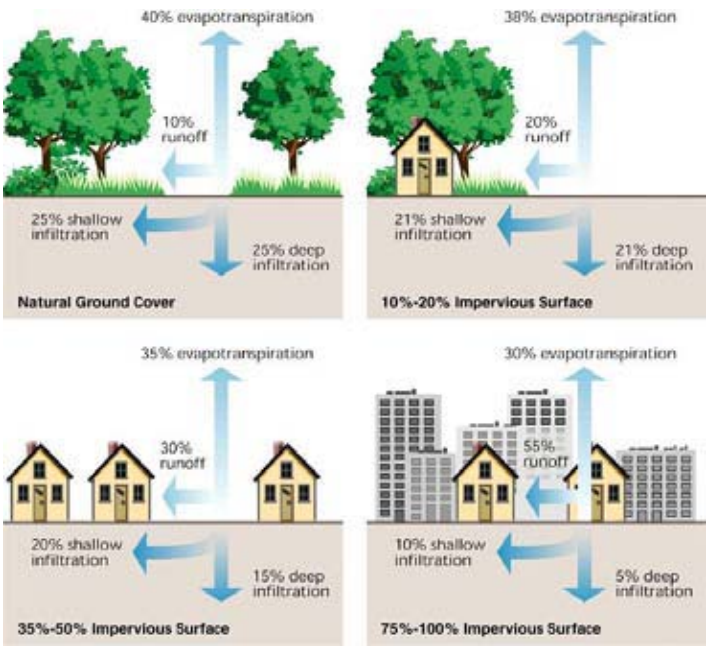
Low Impact Development (LID) strategies strive to allow natural infiltration to occur as close as possible to the original area of rainfall. By engineering terrain, vegetation, and soil features to perform this function, costly conveyance systems can be avoided, and the landscape can retain more of its natural hydrological function. Low Impact Development practices dovetail with "green" building practices that incorporate environmental considerations into all phases of the development process. Builders can often use green building and LID to lower actual development costs. (Although most effective when implemented on a community-wide basis, using LID practices on a smaller scale, i.e., on individual lots, can also have an impact).

Pollution from stormwater runoff can also be a major concern, especially in urban areas. Rainwater washing across streets and sidewalks can pick up spilled oil, detergents, solvents, de-icing salt, pesticides, fertilizer, and bacteria from pet waste. Storm water drains do not typically channel water to treatment facilities, but carry runoff directly into streams, rivers, and lakes. Most surface pollutants are collected during the first one-half inch of rainfall in any "storm event". This is the period when the majority of pathogens, sediment, waste and debris are picked up by flow across lawns and roadways. Carried untreated into streams and waterways, these materials become "non-point source pollutants" which can increase algae content, reduce aquatic life, and require additional costly treatment to make the water potable for downstream water systems. LID design principles can be used as buffers to filter these pollutants before they reach aquifers. For traditional conveyance systems, specially designed catchbasins may be designed to perform a "first flush" filtering function using various technologies for collection of sediment and contaminants. Some units are designed to retrofit existing storm water inlets.

Manufacturers include AquaShield, Stormtreat Systems, Inc, Stormceptor, and Stormwater Management Co.

Effects of Runoff

In 1998, a report on Stream Corridor Restoration was produced by the Federal Interagency Stream Restoration Working Group (FISRWG) documenting the impact of human activities on the stream systems forming the backbone of watersheds throughout the United States. This group represents 15 Federal agencies from the Departments of Agriculture, Commerce, Interior, Defense, Housing and Urban Development (HUD), Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), and Tennessee Valley Authority (TVA). The following illustration from the report shows how development affects water infiltration into soils and runoff.



Less developed land areas allow a larger portion of storm water to seep gradually into soils, remove contaminants, replenish soil moisture, and recharge groundwater aquifers. As areas become developed, a much larger percentage of rainwater hits impervious surfaces including roofs, sidewalks, parking lots, driveways, and streets, and must be controlled through storm water management techniques. Traditional approaches have focused on collection and conveyance to prevent property damage. Local building code requirements often require developers to take an "end of pipe" approach, using gutters and piping systems to carry rainwater into ponds or detention basins. As new requirements have attempted to address water quality, erosion, flow volume, and other problems created by common conveyance methods, the cost and complexity of these engineered systems has increased.

History

On September 21-23, 2004 the first national Low Impact Development (LID) Conference, called *Putting the LID on Stormwater Management*, took place in College Park, Maryland. It highlighted innovative LID techniques designed to minimize the effect of development on watersheds. Presenters of over 85 papers provided insight into a variety of Low Impact Development projects conducted nationwide.

During the Conference's closing session, *Future Vision of LID and Storm Water Management*, a panel of experts reflected upon the current state of LID and the direction in

which LID is headed. One common theme was that LID is a concept where residential developers, local public planners, engineers, citizens, and environmental groups all can support the idea of using water as a resource, reducing stream erosion, and pretreating storm water before it enters waterways and recharges groundwater aquifers.

LID should be more than just new storm water technologies for single lots. LID should be about looking at water resources in a holistic, watershed-based manner, and effectively managing such resources. Such an approach involves conserving water inside and outside a house, using decentralized storm water management BMPs for single lots and larger-scale developments, and identifying the best ways to handle wastewater.

Details

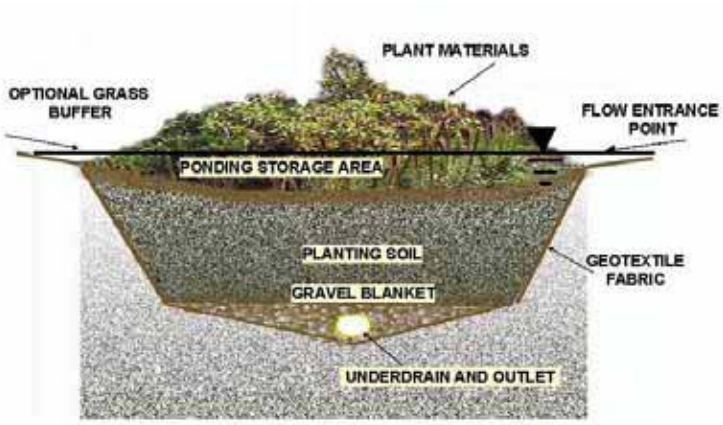
Low Impact Design Strategies:

Strategies fall under the two broad categories of **practices** and **site design**. The most common concepts are summarized below:

Practices:

Basic LID strategy for handling runoff is to: 1) reduce the volume of runoff and 2) decentralize flows. This is usually best accomplished by creating a series of smaller retention/detention areas that allow localized filtration rather than carrying runoff to a remote collection area. For the practices noted below, special attention should be paid to the composition of existing soils, as well as new soils or amended soils used, and underlying topography. For instance, a locale with karst topography may react differently to introduction of LID practices than a site that does not have underground channels. Common methods include:

- **Bio-retention cells** typically consist of grass buffers, sand beds, a ponding area for excess runoff storage, organic layers, planting soil and vegetation. Their purpose is to provide a storage area, away from buildings and roadways, where storm water collects and filters into the soil. Permanent ponds can be incorporated into the cell design as landscaping features. Temporary storage areas without ponds may be called **detention cells**. Bioretention areas have also been called **rain gardens** since they are typically landscaped with native plants and grasses, selected according to their moisture requirements and ability to tolerate pollutants. Annual maintenance of bioretention cells must be planned in order to replace mulching materials, remove accumulated silt, or revitalize soils as required.



- **Grass swales** function as alternatives to curb and gutter systems, usually along residential streets or highways. They use grasses or other vegetation to reduce runoff velocity and allow filtration, while high volume flows are channeled away safely. Features like plantings and checkdams may be incorporated to further reduce water velocity and encourage filtration. Walkways are either separated from roadways by swales, or relocated to other areas. In areas where salts are commonly used for winter de-icing, careful attention must be paid to selecting plant species which are salt tolerant.

- **Filter strips** can be designed as landscape features within parking lots or other areas, to collect flow from large impervious surfaces. They may direct water into vegetated detention areas or special sand filters that capture pollutants and gradually discharge water over a period of time.

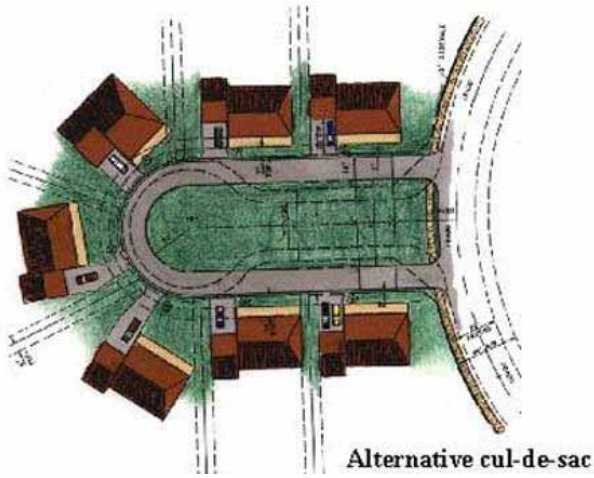
- **Disconnected impervious areas** direct water flows collected from structures, driveways, or street sections, into separate localized detention cells instead of combining it in drainpipes with other runoff. Disconnecting the flow limits the velocity and overall amount of conveyed water that must be handled by end-of-pipe facilities.

- **Cistern collection systems** can be designed to store rainwater for dry-period irrigation rather than channeling it to streams. Smaller tanks that collect residential roof drainage are often called "**rain barrels**" and may be installed by individual homeowners. Some collection systems are designed to be installed directly under permeable pavement areas, allowing maximum water storage capacity while eliminating the need for gravel beds.

Site Design:

Decreasing Impervious Surfaces can be a simple strategy to avoid problems from storm water runoff and water table depletion, by reducing surfaces that prevent natural filtration. Methods may include:

- **Reducing Roadway Surfaces** can retain more permeable land area. In some cases, planners have reduced pavement needs by up to 40% by using longer, undulating roads that create more available lot frontage, instead of wide shorter streets with more intersections. Other options may include shared driveways, "flag" lots with reduced street frontage, landscaped detention islands within cul-de-sacs, or alternate designs for turn-around areas.


Alternative cul-de-sac

- **Permeable Pavement Surfaces** can be constructed from a variety of materials, including traditional asphalt and concrete, gravel or pavers. Permeable roadway or parking areas allow water to flow through, replenishing soil areas directly beneath. However, the sub-base underneath permeable pavements must be engineered to accommodate temporary water storage and filtration. In many cases, permeable surfaces can reduce or eliminate the need for traditional storm water structures.

- **Vegetative Roof Systems** create a lightweight, permeable vegetative surface on an impervious roof area. Moss, grass, herbs, wildflowers, and native plants can be used, creating an aesthetically pleasing roof landscape. The systems start with a high strength rubber membrane placed over the base roof structure. Various layers above the rubber may contain insulation, filter and drainage media, separation fabrics, lightweight growth media, vegetation, and wind erosion fabric. Some systems even incorporate rainbarrel runoff collection, pumping, and irrigation equipment. These systems are more costly than standard roofs, and have not been used on a large scale for residential development in the U.S.

Planning site layout and grading to natural land contours can minimize grading costs and retain a greater percentage of the land's natural hydrology. Contours which function as filtration basins can be retained or enhanced, and incorporated into the landscaping design.

- **Natural Resource Preservation and Xeriscaping** can be used to minimize the need for irrigation systems and enhance property values. Riparian, or stream bank, areas are particularly crucial to water quality, and in most areas, subject to Federal or State regulations. Preserving existing wooded areas, mature trees, and natural terrain, can give new developments a premium "mature landscape" appearance and provide residents with additional recreational amenities. Both of these features can improve marketability. Xeriscaping refers to landscaping with plants native to area climate and soil conditions. These plants thrive naturally, requiring less maintenance and irrigation than most hybrid or imported varieties.

- **Clustering Homes** on slightly smaller lot areas can allow more preserved open space to be used for recreation, visual aesthetics, and wildlife habitat. Clustering can reduce infrastructure costs to the builder, since fewer feet of pipe, cable, and pavement are needed, and maintenance costs are reduced for homeowners. Builders in many areas have been able to charge

a premium price for "view lots" facing undisturbed natural vistas, or pond areas that also function as bioretention cells.

Installation

Low Impact Development requires more precise engineering for soil characteristics, filtration rates, water tables, native vegetation, and other site features. Participation of environmental consultants and planners is critical from the earliest planning phases for residential development.

Benefits

In addition to the practice just making good sense, LID techniques can offer many benefits to a variety of stakeholders.

Developers

- Reduce land clearing and grading costs
- Potentially reduce infrastructure costs (streets, curbs, gutters, sidewalks)
- Reduce storm water management costs
- Potentially reduce impact fees and increase lot yield
- Increase lot and community marketability

Municipalities

- Protect regional flora and fauna
- Balance growth needs with environmental protection
- Reduces municipal infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm sewer)
- Increase collaborative public/private partnerships

Environment

- Preserve integrity of ecological and biological systems
- Protect site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies
- Reduce impacts to local terrestrial and aquatic plants and animals
- Preserve trees and natural vegetation

Costs

Cost benefits to builders and developers utilizing LID strategies can be significant. According to the Center for Watershed Protection, traditional curbs, gutters, storm drain inlets, piping and detention basins can cost two to three times more than engineered grass swales and other techniques to handle roadway runoff. Other LID strategies can have similar impact. Choosing permeable pavement for a parking area may remove the need for a catchbasin and conveyance piping. Small distributed filtration areas on individual lots can reduce site requirements for larger detention ponds that take up valuable land area.

Dissatisfied with a conventional land plan, a developer in central Arkansas contacted Tyne and Associates in North Little Rock AR, who specializes in environmentally sensitive land

development. The resulting design for the Gap Creek community was showcased in the Spring/Summer 2000 issue of Land Development Magazine along with the following cost information:

A Comparison of Two Different Land Plans for Gap Creek Community

PROJECTED RESULTS FROM TOTAL DEVELOPMENT		
Total Site	**Conventional Plan**	**Revised Green Plan**
Lot Yield	358	375
Linear Feet - Street	21,770	21,125
Linear Feet - Collector Street	7,360	0
Linear Feet - Drainage Pipe	10,098	6,733
Drainage Sections (Inlets, Boxes, Headwalls)	103	79
Estimated Total Cost	$4.6 million	$3.9 million

ACTUAL RESULTS FROM PHASE ONE		
Total Site (engineer estimate)	**Conventional Plan**	**Revised Green Plan**
Lot Yield	63	72
Total Cost	$1,028,544	828,523
Cost Per Lot	$16,326	$11,507

BENEFITS FROM LOW-IMPACT DEVELOPMENT	
General Benefit	**Specific Benefit**
Higher Lot Yield	17 additional lots
Higher Lot Value	$3,000 more per lot than competition
Lower Cost per Lot	$4,800 less per lot
Enhanced Marketability	80% of lots sold in the first year
Added Amenities	23.5 acres of green space/parks
Recognition	National, state, and professional group recognition
TOTAL ECONOMIC BENEFIT	More than $2.2 million in savings

This development was also cited in an NAHB Research Center report, published in July 2001, called *Environmentally Green... Economically Green, Tools for a Green Land Development Program.* The report provides a wealth of information and sources on Low-Impact and Sustainable Development practices.

Limitations

Not all sites can effectively utilize LID techniques. Soil permeability, slope, and water table characteristics may limit the potential for local infiltration. Urban areas and locations with existing high contaminant levels may be precluded from using LID filtration techniques.

Many existing local codes, zoning regulations, parking requirements and street standards were developed prior to the emergence of water quality and storm water management concerns, and may prohibit or inhibit implementing LID practices.

Established practices can be difficult to modify, although cost factors may help drive change. Additionally, there may be negative perceptions among homebuyers. Even though many buyers welcome naturalistic features proscribed by LID, others may prefer large flat lots with wide curbed streets. While traffic studies have not borne out the theory, some consumers perceive curbs to be a safety feature for pedestrians. Others fear that the lack of conventional storm water systems will result in basement flooding or structural damage.

Code/Regulatory

Statutes mandating the implementation of storm water management plans include: The Clean Water Act (Wetlands, Section 404; Storm water, Section 402), the National Pollutant Discharge Elimination System (NPDES) regulations, and in some cases, State Pollutant Discharge Elimination Systems (SPDES). State, local, or subdivision codes and zoning requirements may dictate designs or systems which are sometimes not consistent with current LID strategies. Especially in largely developed areas, however, the trend is for land-use or water-basin management authorities to mandate more stringent storm water management planning and practices.

Source: Toolbase Services, NAHB Research Center, 400 Prince George's Boulevard, Upper Marlboro, MD 20774

4.3 Applying an Ecological Systems Approach in Urban Landscapes

URBAN LANDSCAPING

Applying an Ecological Systems Approach in Urban Landscapes

by Steve Apfelbaum and Jack Broughton, Applied Ecological Services, Inc.

"CHICAGO Wilderness", the title of a new, rapidly growing conservation movement in the Chicago metropolitan area, would seem to be an oxymoron. If there is "wilderness" in Chicago, most people have missed it.

But in fact, there once was a vast wilderness in and surrounding the Chicago regions, and in fact, people do miss it! In the northeastern Illinois region, people miss the wild, natural and open spaces so much that the region has become one of our nation's hottest hotbeds for native landscaping and ecological restoration.

They miss it because Chicago presents a typical urbanizing landscape in which the ecological systems we once called wilderness have been replaced by a dominant "ecological system" that can fairly be called a biological desert. We call this dominant system of urban sprawl, lawn.

Tallgrass savanna areas in urban environments.

In the U.S., we've converted 30 million acres into lawns, which are landscapes by German definition "in the absence of trees". We don't usually look at lawns as ecological systems, but if we did, we'd see these systems are dominated by non-native plant and animal species. Kentucky bluegrass is from Europe and Asia. So are the common earthworms. So are dandelions and most other weeds.

We've placed many of these lawn systems in urban landscapes on glacial till clay soils, compacted by earthmovers during development so that we've essentially created millions of acres of low-permeable lawnscape that is hydrologically not unlike that of an impervious asphalt parking lot.

In urbanizing areas, we've surrounded ourselves with these non-native ecological systems which support few species. And to many people — even to people who don't consciously think about it — these lawnscapes are uninspiring. They're especially uninspiring compared to the diverse plant and wildlife species in the many native restorations springing up in the Chicago region.

In contrast to our biologically barren and high maintenance lawns, native ecological systems, such as wetlands, upland prairie or oak savanna are immensely diverse, productive systems. At one time, the marshy Chicago region produced immense flocks of whooping cranes, sand hill cranes, huge flights of ducks and geese, and biological diversity we can only imagine today.

You can get a small sense of this unbelievable productivity by visiting remnants of the wilderness, such as one particularly high, dry hill prairie near Elgin that has survived because its soils were too rocky and dry for agriculture. Historically, when these types of prairies were blended with a mesic prairie featuring deeper, more well developed soil systems, the prairies supported 550 to 650 species of native vascular plants, perhaps thousands of associated insect species, and untold numbers of micro-fauna and micro-flora, bacteria and fungi. A lawn might have 10-15 plant species and far fewer associated organisms.

Complex Native Ecosystems are Highly Integrated

From wetlands to oak savanna, our pre-settlement native systems were seamlessly blended together on gradients of hydrology, topography, soil types and soil nutrition. The blended systems were also impacted by an area's fire history, grazing ungulates, insect infestation and a variety of gradients that intersected on the landscape on an immense scale.

The interrelationships between systems is demonstrated in projects today where disturbances in upland grassland systems create erosion and sedimentation that degrades wet prairie and wetland systems at lower elevations. This can occur when there has been ineffective thinking about the relationship between the developed landscape and natural wetland areas.

What we do on the uplands drastically affects lowland environments. A coffee-colored river flowing into a lake system with algae blooms and large sediment swirls is characteristic of the landscapes we see through most of the upper Midwest today, while historically, our waters ran clear and at a much slower rate.

Hydrology, hydraulics, chemistry, biology and ecology must all be considered if we're to see the true picture of how we impact integrated natural systems at the boundaries where human and natural activities are also integrated.

Conservation Development - Another Oxymoron?

In November, the Wall Street Journal published a survey which showed what home buyers are looking for in today's urbanizing developments. At the top of the list was Natural, Open Space. Second was Walking and Biking Paths. Gardens with Native Plants came in third. Wilderness Areas was fifth, and Interesting Little Parks was eighth. Ninth and tenth were Tennis Courts and Golf Courses.

These rankings show that the need for "Conservation Development" is more compelling now than ever. People feel the need to interact with their natural environment, and conservation developments can help fulfill that internal desire.

Prairie Crossing in Grayslake, IL, is one of the best examples of a Conservation Development, in which an ecological approach to planning considered the needs of the natural areas equal to and integrated with the needs of developed space.

Held up as a national example of conservation development, Prairie Crossings is a 667-acre development that preserves 70% of its acreage as open space and allows only 30% of its land for residential and commercial development.

In the development, 175 acres of prairie and 18 acres of wetland were designed as a basic element for stormwater management, and greenway trails are looped throughout the property. Housing is clustered, and surrounding the clustered housing are prairie swale systems that passively filter water as it flows through 175 acres of prairie and ultimately into 18 acres of wetlands and 27 acres of lake.

By replicating the historic prairie to wetland ecosystem gradient, we've predicted that the majority of contaminants associated with urban land use can be bio-filtered and assimilated within the prairie swales before reaching the wetlands and lake.

Housing is clustered, and surrounding the clustered housing are prairie swale systems that passively filter water as it flows through 175 acres of prairie and ultimately into 18 acres of wetlands and 27 acres of lake.

We wanted a healthy wetland system and healthy lake system and the delivery of high quality water to these systems was an important precursor to that performance-based outcome. In addition, because of the native vegetation and natural swale and wetland design, we've predicted a 60% reduction in peak stormwater discharge from storm events from this system, compared to the previous agricultural land use.

A young ecologist.

Because of the healthy, integrated ecological systems created at Prairie Crossing and the appeal of "living with nature", the walk-in rate at the sales office is substantially higher than conventional developments in the local area. Nature and quality-of-life aspirations are some of the products Prairie Crossings is offering. An in the urban areas, these products are selling.

Traditional Neighborhood Developments Integrated with the Ecological Approach

Because of the growing need to integrate human developments harmoniously with natural systems, Applied Ecological Services, Inc. (AES), Brodhead, WI, and Land Planning Services, Inc., St. Charles, IL, are planning to create a series of model projects that would illustrate how the concepts of conservation development can be integrated with traditional neighborhood development (TND). The model projects will be designed to show how, in urbanizing areas, an ecologically sound TND can fulfill the desires of a growing marketplace, in large part by preserving and restoring the health and integrity of nearby natural areas.

In a Traditional Neighborhood Development, houses are clustered closely together, with wide front porches, sidewalks, large curbside shade trees, narrow streets,

garages built in back, mixed housing types for mixed income levels, lots of public parks and open space, a corner grocery store - in short, a neighborhood as opposed to a suburb.

The TND offers the small-town or neighborhood environment that fits well with the needs of people looking for connections with other people as well s the natural world. The integration of ecological systems with the TND environment is expected to broaden the interest in "conservation development" begun by Prairie Crossing.

A Swamp in the Middle of Town?

Attempts to naturalize urban sites based on ecological function often lead to the creation of wetlands which were far more prevalent historically than they are today. In some areas, this will be a controversial decision, and controversy can sometimes prevent these projects from getting on the ground.

For this reason, it is crucial to involve people from all walks of life in the process of urban ecosystems restoration. Not only can local people provide support for a restoration project, but they can also contribute observations about the site, its historic land use, its ecological functions, etc.

In the urban Chicago area, the Otter Creek Wetland Park, developed by Land and Water Resources, Inc. (LWR), Rosemont, IL, stands as the finest example of how to restore a healthy, functioning wetland ecosystem within urban boundaries while gaining appreciation for an improved quality of life from local area residents.

At Otter Creek, LWR developed the first private wetland mitigation bank in the U.S. by restoring a 56-acre farm field to its historic wetlands condition. Since its creation in the early 90s, wetland mitigation credits have been sold to fund the project, and the restored property has contributed to passive recreational uses as a popular public park under ownership of the St. Charles, IL, Park District.

Project team members LWR, Christopher B. Burke Engineering and AES designed the site as a passive recreation park by creating landscapes of prairies, wetlands, and riparian ecological systems. The park and design were keyed to use by school groups for outdoor and environmental education. Consequently, viewing areas, a trail system, and a special bridge to allow access for student projects - including stream water sampling opportunities - were integrated with the project plan.

Today, when student sampling shows the stream water to be clearer and cleaner than when it had been ditched to remove water quickly from the cropland, perhaps a young ecologist will recognize the biofiltration benefits of the upland swales.

And, perhaps, she will make a new discovery — one that will improve our restoration efforts in the future. One that shows us again, with new insight, how integrated our natural ecosystems are, and how connected our human systems can be with functional natural systems. **L&W**

For more information, contact Steve Apfelbaum, Applied Ecological Services, Inc., (608)897-8641, fax (608)897-8486, e-mail: AppliedEco@Brodnet.com

4.4 Impacts of Development Type on Runoff Volume and Infiltration Performance

Kent Brander, Katherine E. Owen, and Kenneth W. Potter[1]

ABSTRACT

Development type has emerged as an important focal point for addressing a wide range of social, cultural, and environmental concerns related to urban growth. Concurrently, infiltration is gaining recognition as an important stormwater mitigation strategy. In this study, four development types (conventional curvilinear, urban cluster, coving, and new urbanism) were modeled both with and without infiltration practices, in order to determine their relative effects on urban runoff. Modeling was performed with an expanded version of the NRCS Curve Number method, which was modified to permit evaluation of infiltration practices. Model results indicate that urban cluster developments produce the smallest volume of runoff due to the large portion of land kept in a natural condition. Additionally, significant reductions in runoff can be achieved in all four development types if infiltration practices treat many impervious surfaces; and as more infiltration practices are implemented, the differences in runoff between development types diminish. With a strategic combination of site layout and infiltration design, any development type can reduce hydrologic impacts, allowing developers to consider other factors, such as convenience, marketability, community needs, and aesthetics.

KEY WORDS: Infiltration, Urban Planning, Hydrologic Modeling, Runoff, Bioretention, Stormwater Management

INTRODUCTION

The introduction of impervious surfaces greatly increases the volume of storm runoff. Traditional stormwater management, which relies heavily on the use of detention ponds, controls the rate of storm runoff, but not the volume. The excess runoff can increase downstream flooding in streams and lakes and cause channel erosion and stream habitat degradation, even when detention practices are used (Lakatos and Krupp, 1982; Ferguson, 1991; Booth and Jackson, 1997). In addition, most of the water that runs off impervious surfaces would have, under natural circumstances, infiltrated into the ground, recharging groundwater. This loss of recharge, especially when coupled with excess groundwater pumping, can deplete groundwater supplies and reduce beneficial groundwater flow to wetlands, streams, and lakes (Simmons and Reynolds, 1982).

Infiltration of stormwater is a proven method for mitigating excess storm runoff. For example, since the 1930's, over 2000 infiltration basins have been constructed on Long Island to restore groundwater conditions; tests of these basins by Aronson and Seaburn (1974) indicated that over 90% of these basins were performing as designed. However, large-scale infiltration basins have serious disadvantages that limit their effectiveness in many locations. One problem is the difficulty of finding sites that have favorable soils and sufficient depths to groundwater. Infiltration basins also have a tendency to clog when fine-grained soils are present in the contributing watershed. For example, Lindsey et al. (1992) found that only 27% of infiltration ponds inspected in Maryland in 1986 and 1990 were working in both years.

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An alternative infiltration strategy is directing of runoff from impervious surfaces to nearby pervious surfaces and depressions, particularly those modified for increased permeability. This approach, which we refer to as on-site infiltration, has several advantages. First, it can be implemented at higher elevations in the watershed where, generally, soils are more permeable and the water table is further below the surface. On-site infiltration practices can also be much smaller than typical infiltration basins, making it easier to find a suitable location. Finally, local practices can be matched to the quality of water draining from a particular site. For example, infiltration of relatively unpolluted roof drainage can be carried out with much less water quality treatment than would be required prior to infiltration of runoff from a parking lot.

In this paper a simple spreadsheet model, based largely on the NRCS curve number runoff equation, is used to evaluate the potential benefits of on-site infiltration practices in the context of four types of development: conventional curvilinear, urban cluster, coving, and new urbanism. (This classification of development types is taken from SEWRPC, 2001).

PREVIOUS RESEARCH

The most common hydrologic models used to compute runoff hydrographs and to design stormwater control structures were not originally developed to model infiltration practices. Investigators of such practices have therefore either modified existing models or developed new ones suitable to the task.

Moglen (2000) modified the NRCS runoff method to account for the effects of directing runoff from impervious surfaces to pervious surfaces. Holman-Dodds, et al., (2003) used Moglen's approach to compare runoff from a hypothetical area under natural conditions with runoff from the same area under developed conditions, considering both conventional and infiltration-based stormwater management practices. They found that infiltration practices are most beneficial in relatively permeable soils and for small, common rain events. Sample, et al., (2001) modified NRCS runoff curve numbers to account for infiltration practices. Using a rainfall-runoff model developed for research purposes and based on the NRCS runoff method, they found the optimal mix of management practices for a hypothetical development.

Huber (2001) modified the Stormwater Management Model (SWMM) to account for runoff that is directed from one surface to another. This enables evaluation of vegetative buffer areas and spreading from an impervious surface to a pervious surface.

CH2M Hill (2001) used HSPF and the Santa Barbara Urban Hydrograph (SBUH) to evaluate the potential benefits of various practices including bioretention, soil amendments, reduced building footprints, and grass swales, in the context of two proposed developments in Pierce County, Washington. They found that low impact developments could produce a post-development hydrologic regime much closer to the natural regime than conventional developments.

Kronvater, et al., (2001) developed a new continuous hydrologic model for evaluating stormwater conditions in developed areas. This model includes options for modeling the performance of infiltration trenches and the disposition of runoff routed from impervious surfaces to pervious ones. In an application of the model to a development in Israel, they found that infiltration practices could

increase annual infiltration by 5-50%, depending on soil conditions, annual rainfall, and size of the practices.

DESCRIPTION OF THE MODEL, IP

Modification of widely used models to permit evaluation of infiltration practices is an important tool for low-impact stormwater design. Infiltration Patch (IP), a spreadsheet-based model developed for this study, utilizes and expands upon the curve number method outlined in NRCS Technical Report 55 (TR-55) by adding the capability to model infiltration practices. IP has the same capability as TR-55 to compute event runoff volumes, peak flows, and hydrographs from given precipitation events for small, urbanizing watersheds with known soil type, antecedent moisture conditions, and land use characteristics. Additionally, IP calculates the average annual runoff volume for the site, based on a geographically specific rainfall record. IP is not a continuous model, as it does not simulate ongoing changes in soil moisture conditions, and it also fails to account for the seasonal variations of frozen ground and snowmelt. In order to calculate average annual runoff volumes, the long-term precipitation record from thawed seasons is split into discrete, independent 24-hour events. All results from this study apply to Madison, Wisconsin, where the model was created, for the April 15th to October 15th time period. The average annual runoff from a site is important as an indicator of how much water is added to or taken away from the regional surface water or groundwater systems.

Two calculation procedures are included in IP that characterize general strategies for increasing the amount of infiltration at a site: spreading runoff from an impervious or less pervious surface over a more pervious surface, and using lot-scale infiltration basins (e.g., raingardens) to collect and infiltrate stormwater. Model characterization of these infiltration-enhancing processes may be used to represent a variety of specific structures that exist in the field.

In IP, the user divides the area under consideration into several land cover categories commonly found in residential neighborhoods (rooftop, driveway, street, lawn, raingarden, and high-permeability enhanced or undisturbed areas). The amount of runoff from each of these surfaces is computed separately, using the equations from TR-55, and the runoff can then be treated by one of the infiltration strategies described above. Looking at the entire site, the user determines the total amount of each type of land cover with runoff treated by either strategy. The original results from TR-55 are then modified to reflect the effects of the infiltration treatments.

Spreading Methodology

The user may choose to direct runoff from less-pervious to more-pervious surfaces. For example, the user can dictate that runoff from 30% of the total rooftop area will spread over 15% of the lawn area, or that runoff from 50% of the driveway area will spread over 40% of the enhanced area. Using the procedure Moglen (2000) created, the volume of runoff from the shedding surface is determined, and then added to the precipitation for the receiving surface. The runoff from the receiving surface is then computed using the adjusted precipitation value.

Raingarden Methodology

The user can also include raingarden area as part of any run of the IP model. A raingarden in IP is modeled as a depression with vertical sides, the bottom of which is a high-permeability engineered soil layer overlying the natural subsoil. The user enters the total raingarden area, raingarden

depression depth, engineered soil layer thickness, engineered soil infiltration rate, engineered soil porosity, engineered soil field capacity, and natural subsoil infiltration rate.

Inflow to the raingarden is represented by a runoff hydrograph computed using the SCS type II rainfall distribution and NRCS runoff calculation equations. This hydrograph (divided into 1-minute time steps) is routed through the raingarden basin, where during each interval water may infiltrate, overflow, remain in the raingarden depression, or be stored as soil moisture in the engineered soil layer. Infiltration rates into the two soil layers are controlled by the minimum of the available water and the corresponding constant infiltration rate. If water remains in the depression 48 hours after the beginning of the event, IP will return a warning message indicating that standing water could oversaturate and kill raingarden plants.

ANALYSIS OF DEVELOPMENT TYPES AND INFILTRATION PRACTICES

Four development types were considered: conventional curvilinear, urban cluster, coving, and new urbanism. Development characteristics were taken from the Land Division Control Guide, Planning Guide Number 1, (SEWRPC, 2001) as reproduced in Table 1. These characteristics were augmented by data collected from a conventional curvilinear development and new urbanism development located in Middleton, Wisconsin to obtain specific geometric elements.

Figure 1 illustrates the four development types. Conventional curvilinear, the most common development type in the United States, is easily identifiable by the cul-de-sacs, large lots, and minimal open space. Urban cluster developments are designed to protect environmentally sensitive areas by maximizing undisturbed open space and by creating small lots. Coving developments offer an estate-like feel by providing large lots, setbacks, and minimal streets. New urbanism developments typically consist of a large public common area and smaller lots. In an effort to encourage neighbor interaction and walking, garages are moved to alleys and therefore total street area is higher than in other development types.

Several factors affect runoff variations among different development types. First, if no infiltration practices are in place, the development layout, land cover distribution, and soil type determine the runoff volume. For example, development types such as urban cluster and new urbanism that emphasize communal open space rather than larger individual lot sizes produce less runoff, because open space has a lower curve number than lawns (In our analysis we assume that communal green space left open is not subject to grading, which allows the area to retain close-to-natural infiltration characteristics.) If local infiltration practices are used, other factors become important. Primarily, soil type and texture control infiltration rates and runoff curve numbers. In addition, it is important from a practical standpoint to consider how much space is conveniently available on each lot for infiltration practices. People who have already sacrificed a larger lot for additional open space may not be willing to give up what little yard space they do have in order to install a raingarden, and by this measure, the small lots associated with urban cluster and new urbanism developments leave less opportunity for lot-scale infiltration.

Infiltration Practices

Numerous combinations of infiltration practices were modeled within the context of the four development types under consideration. Individual practices are described in Table 2, and the constituent practices of the ten most representative and significant development scenarios

evaluated in this study are identified in Table 3. Neither of these tables is an exhaustive list of the practices or scenarios that may be modeled with IP.

The hydrologic effects of variations in soil type and precipitation were evaluated along with the effects of infiltration strategies, again within the context of the four development types. As indicated in Table 4, the three hydrologic soil types and textures modeled were group A (loamy sand), B (silt loam), and C (silty clay loam). The three precipitation scenarios modeled were the 1-year 24-hour event, the 100-year 24-hour event, and a long-term (many-event) analysis from which average annual hydrologic budget components were computed. These precipitation scenarios were selected for their applicability to key stormwater management issues. First, the 1-year 24-hour storm (2.4" for Madison, Wisconsin) is an important storm with respect to water quality. Second, many communities calculate detention storage from the 100-year 24-hour (6") storm. For this or other large storms, IP can be used to determine the reduction in detention requirements effected by the use of infiltration practices. Finally, the long-term analysis (19.88" of precipitation for April 15 to October 15) and subsequent computation of average annual runoff allows for comparison of the overall water budgets resulting from different scenarios. Most rain events in a year are small enough that infiltration practices can reduce their associated runoff to zero; the long-term calculations account for the cumulative effect of reducing or eliminating runoff from these many small events, an effect that is not detected when analysis is limited to infrequent large events.

RESULTS

Figures 2a to 2i presents the runoff depth for each infiltration practice scenario, precipitation scenario, and soil type, in context of the four development types under consideration. Several conclusions can be drawn from the model results presented in the above figures. The following remarks highlight key observations.

- *Infiltration practices can significantly reduce runoff in any development type*

Although runoff is not reduced to predevelopment levels in any of the development types (Scenario 10), infiltration practices can significantly reduce runoff in all of them. With the most aggressive infiltration combination used in this study, runoff from the 100-year 24-hour storm in a conventional curvilinear development atop A soils is reduced by 60% (Scenario 9) as compared to the development with no infiltration practices (Scenario 1).

- *Hydrologic Group A soils are most sensitive to infiltration practices*

Hydrologic Group A soils are the most sensitive to infiltration practices and achieve the highest percent runoff reduction of all soil groups from infiltration practices. For example, all developments atop A soils achieve a minimum runoff reduction of 47% for the 100-year 24-hour storm from the case when many infiltration practices are used (Scenario 9), as compared to the case in which no infiltration practices are used (Scenario 1). Comparatively, the corresponding reduction in the case of C soils is at most 21%.

- *It is better to do numerous infiltration practices, rather than a few "very good" practices*

Results from IP suggest that it is more effective to treat more impervious areas than to treat fewer areas to a higher level. For example, if a developer were to install only very well constructed

raingardens to treat rooftop water and did no other infiltration practices, runoff would still be significantly higher than the scenario with multiple practices. This is apparent in the difference in runoff between Scenario 3 and Scenario 9.

- *Raingardens boost recharge more than spreading onto lawns*

In all cases, raingardens are more effective in reducing runoff than spreading runoff onto lawns (Scenario 2 vs. Scenario 3). Additionally, Dussaillant (2002) showed that raingardens concentrate water and maximize recharge, due in part the resulting reduction in evapotranspiration.

- *Infiltration practices are most effective for small storms*

These results confirm the conclusion made by Holman-Dodds, et al. (2003) that infiltration practices are most effective for small storms. Because an average year is mainly comprised of very small precipitation events, runoff from most daily events can be eliminated via infiltration. Runoff for all developments atop B soils is reduced by at least 85% for an average year when many infiltration practices are used (Scenario 9), as compared to the case in which no infiltration practices are used (Scenario 1). By way of contrast, the analogous reduction in the case of the 100-year 24-hour storm is at most 32%.

- *Spreading runoff over a compacted lawn is not very effective*

The effectiveness of the runoff-spreading strategy depends to a large extent on how a given pervious area has been treated. In particular, lawns compacted during construction are significantly less effective infiltration areas than uncompacted lawns (Scenario 5 vs. Scenario 6 and Scenario 7 vs. Scenario 8). In order to maximize infiltration on lawns, compaction must be either avoided during construction, or reversed following construction by deep tilling with compost or other accepted methods.

- *The urban cluster development type produces the least runoff due to the large area left in its natural condition*

Urban cluster produces the least runoff of all the development types under consideration, because much of the site is left in its natural state. Consequently, even if a developer decides not to implement any infiltration practices, benefits could still be attained by including significant undisturbed open area in the site design.

- *Differences in runoff between development types diminish as more infiltration practices are implemented*

For example, if no infiltration practices are implemented (Scenario 1), the difference between conventional curvilinear and urban cluster for the average year for Hydrologic Group B soils is nearly 0.9”, whereas the difference between these two development types for the most aggressive infiltration combination (Scenario 9) is only 0.1”.

CONCLUSION

Concern about the consequences of land development with regard to surface water and groundwater volume has motivated studies on the hydrologic effects of site design and on-site

infiltration practices. In this study, a model based on an expanded version of the NRCS curve number method was developed and used to assess how infiltration practices and development type affect the amount of runoff from a site. Four prevalent development types (conventional curvilinear, urban cluster, coving, and new urbanism), with and without various infiltration practices, were analyzed within multiple hydrologic soil group and precipitation contexts. While infiltration practices reduce runoff, they are not a substitute for conveyance and detention and should be used in combination with these traditional techniques. The urban cluster development type produced the least amount of runoff due to the large percentage of total land area left uncompacted. Model results indicated that significant reductions in runoff can be achieved in any development if infiltration practices treat many impervious surfaces; and that as more infiltration practices are implemented, the differences in runoff between development types diminish. With a strategic combination of site layout and infiltration design, any development type can reduce hydrologic impacts, allowing developers to consider other factors, such as convenience, marketability, community needs, and aesthetics.

ACKNOWLEDGMENTS

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Table 1: Comparative Analysis of Subdivision Designs

	Subdivision Type			
	Conventional Curvilinear	Urban Cluster	Coving	New Urbanism
Lot Information				
Number of Lots	160	160	160	160
Average Lot Size (sq. ft.)	17002	6028	16517	7325
Average Lot Width (ft.)	95	60	81	62
Average Lot Depth (ft.)	179	101	204	118
Average Rooftop Area (sq. ft.)*	2200	2200	2200	2200
Average Front Yard Setback from Right-of-way (ft.)*	30	17	50	17
Average Driveway Width (ft.)*	20	20	20	20
Average Driveway Length if Connected to Street (ft.)*	43	30	63	30
Average Driveway Length if Connected to Alley (ft.)*	N/A	N/A	N/A	12
Percent of Site Area within Lots	77.0	27.3	74.8	33.2
Street Information				
Total Street Length (ft.)	10363	10730	9865	17154
Street Right-of-Way Width (ft.)*	66	66	66	66
Street Width (ft.)*	40	40	40	40
Alley Width (ft.)*	N/A	N/A	N/A	14
Sidewalk Width (ft.)	4	4	4	4
Percent of Site Area within Street Right-of-Way	18.1	15.8	15.3	20.7
Open Space Information				
Percent of Site Area within Open Space	4.9	57.2	9.9	46.1

*These assumptions were based on Northlake Development, a conventional curvilinear development, and Middleton Hills, a new urbanism development, both located in Middleton, Wisconsin. All other data directly from Land Division Control Guide (Southeast Wisconsin Regional Planning Commission, 2001).

Table 2: Infiltration Practices Used in Modeling

Practice	Comments
Spreading rooftop runoff over lawns	Downspouts are set to drain onto pervious lawn area rather than to impervious surfaces connected to the drainage network. 100% of rooftop area is treated in this manner.
Improving the infiltration capacity of lawns	Minimizing damage through careful construction or reversing effects of soil compaction by tilling in compost can increase the curve number and infiltration of lawns. The curve number of the lawn improves to 49 for A group soils, 69 for B group soils, and 79 for C group soils.
Directing rooftop runoff into raingardens	Due to limited lawns in urban cluster and new urbanism developments, raingarden sizes are kept at 10% of the rooftop area. Raingarden sizes are set at 30% of the rooftop area for the conventional curvilinear and coving developments, which contain larger average lot sizes.
Spreading driveway and sidewalk runoff over lawns	Driveways and sidewalks are designed to shed runoff onto adjacent pervious area.
Reducing street width	Street width for all developments is reduced to 32'.
Directing street runoff into grass swales	Curb-and-gutter networks are either eliminated or slotted to permit drainage into pervious, vegetated drainage swales.
Directing street runoff into raingardens	A series of raingardens are placed between the street and sidewalks to collect runoff from the streets. These raingardens are sized at 10% of the street area.

Table 3: Evaluated Combinations of Infiltration Practices

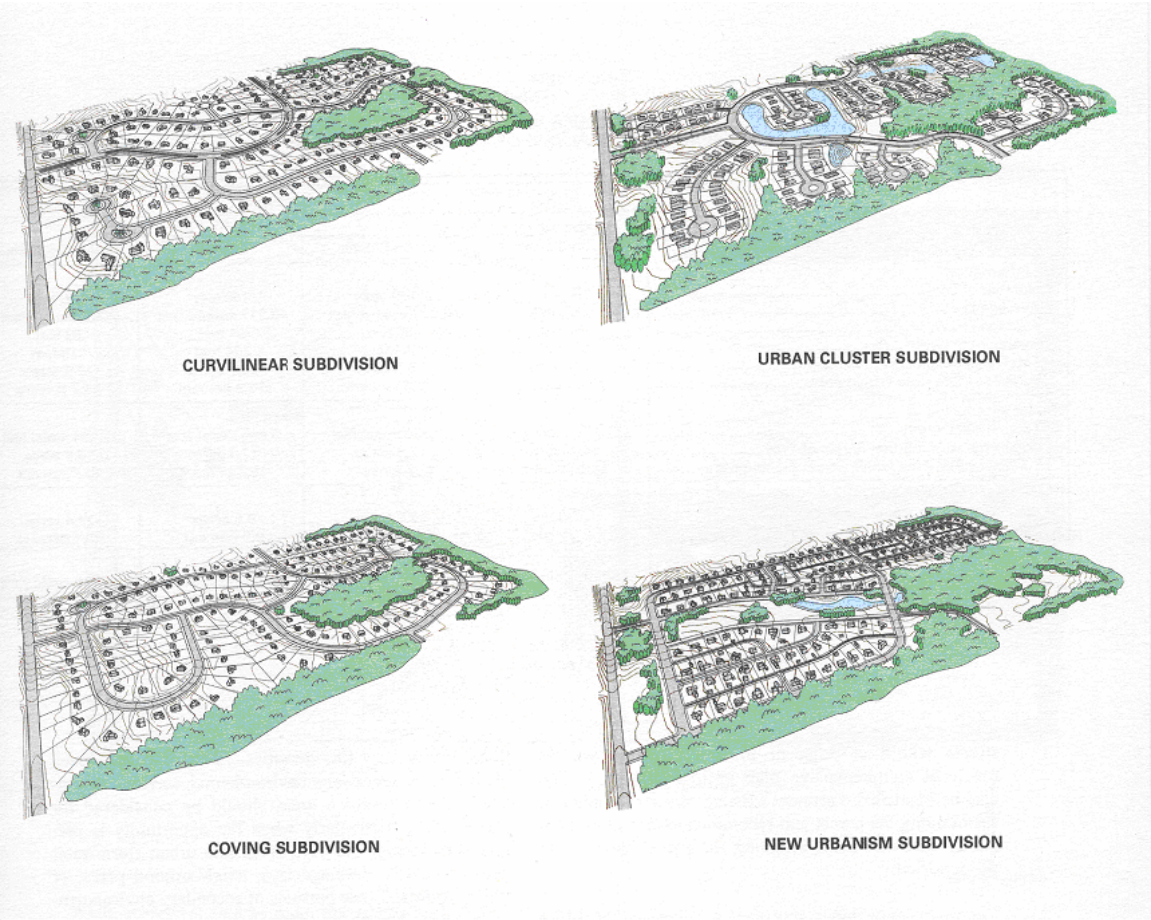
Infiltration Practices	**Scenarios**									
	1	2	3	4	5	6	7	8	9	10
No Infiltration	X									
Spread Roof to Lawn		X		X	X	X				
Improve Lawn				X	X		X		X	
Raingarden (10% or 30% of roof)			X				X	X	X	
Spread Driveway to Lawn					X	X	X	X	X	
Reduce Street Width					X	X	X	X	X	
Grass Swales					X	X	X	X		
Raingarden (10% of street)									X	
Predevelopment										X

Table 4: Comparative Analysis of Soil Groups

	Hydrologic Soil Group		
	A	B	C
Undisturbed Enhanced Open Area Curve Number	30	58	71
Compacted Lawn in Poor Condition Curve Number	68	79	86
Rooftop Curve Number	98	98	98
Driveway Curve Number	98	98	98
Street Curve Number	98	98	98
Soil Texture	Loamy Sand	Silt Loam	Silty Clay Loam
Natural Subsoil Infiltration Rate (in/hr)**	1.2	0.26	0.04

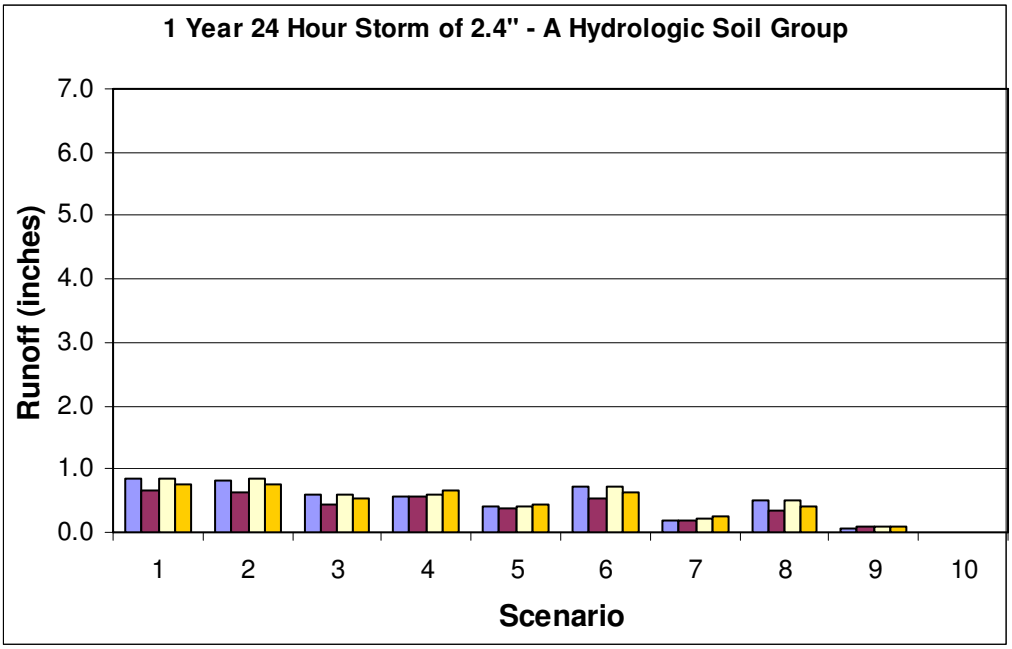
**From Rawls, Brakenseik & Miller (1987)

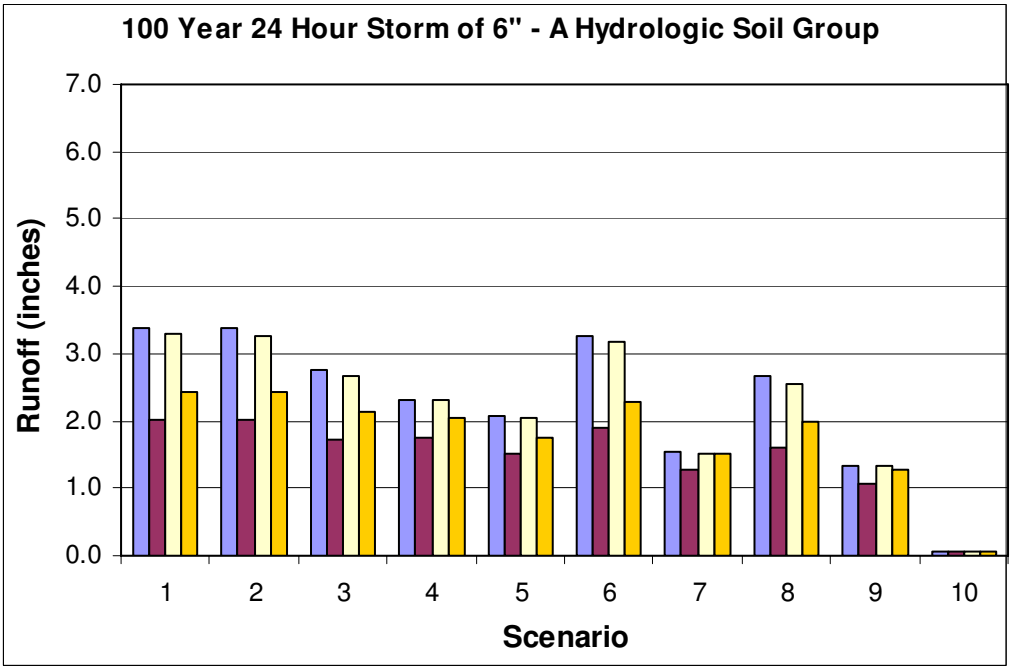
Figure 1 Oblique Aerial View of Four Subdivision Designs

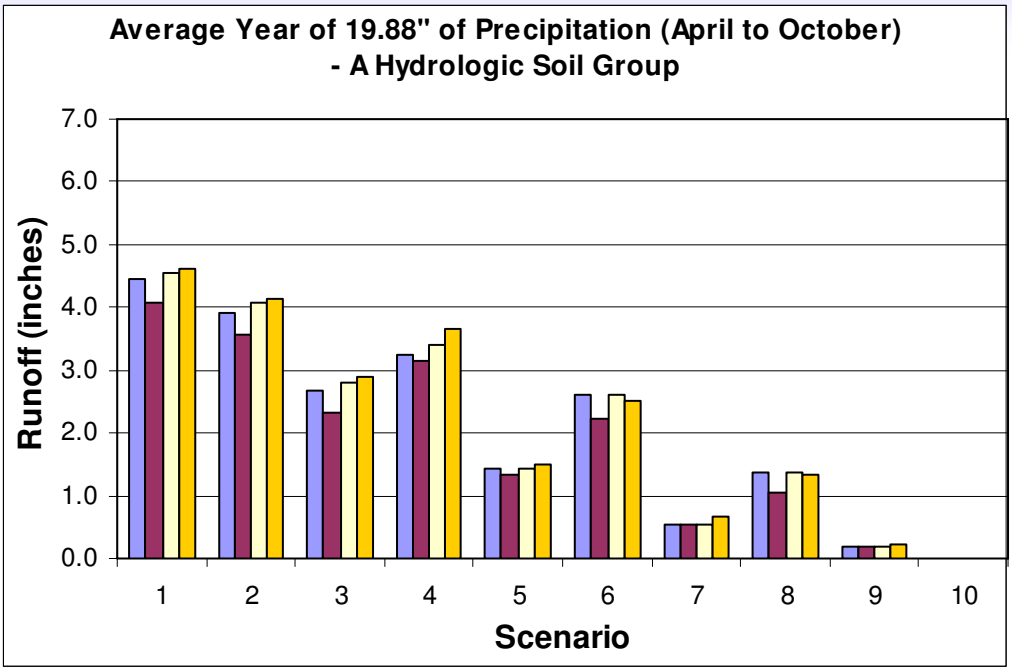


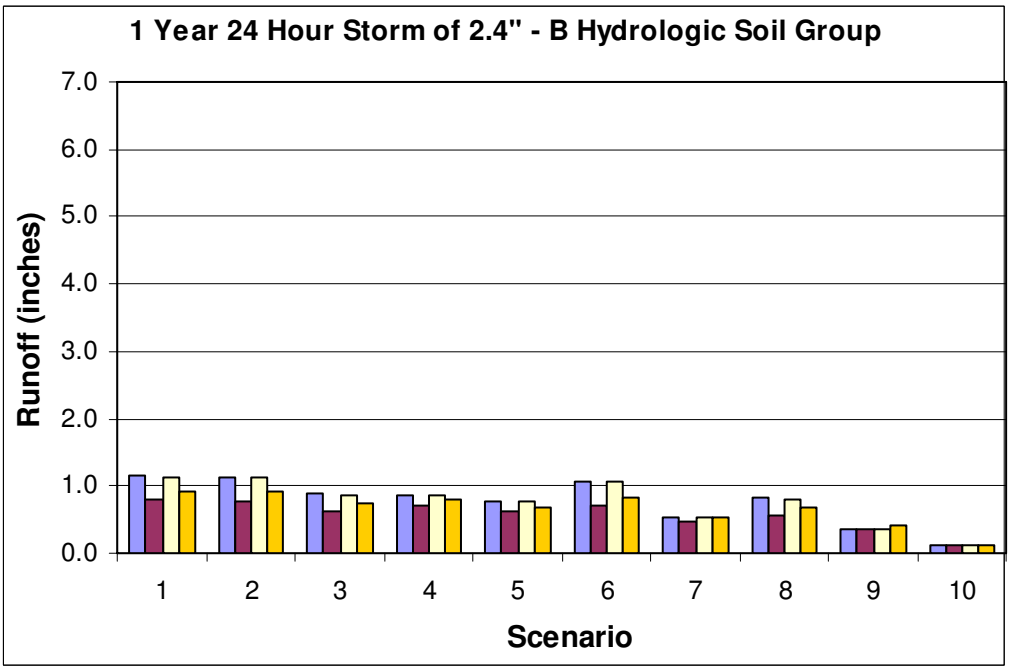
From Land Division Control Guide (Southeast Wisconsin Regional Planning Commission, 2001).

Figure 2a-i Runoff Depth for Infiltration Practices, Precipitation, and Soil Group Scenario Combinations for the Four Development Types






Average Year of 19.88" of Precipitation (April to October)
- A Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
7
8
9
10
Scenario


1 Year 24 Hour Storm of 2.4" - B Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
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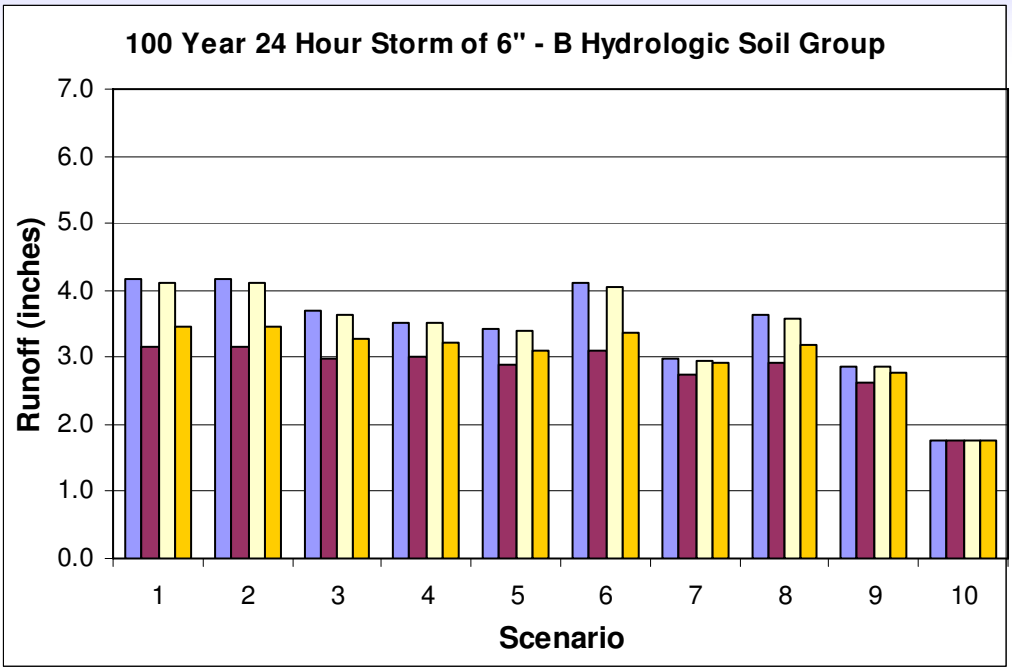
8
9
10
Scenario


100 Year 24 Hour Storm of 6" - B Hydrologic Soil Group
Runoff (inches)
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6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
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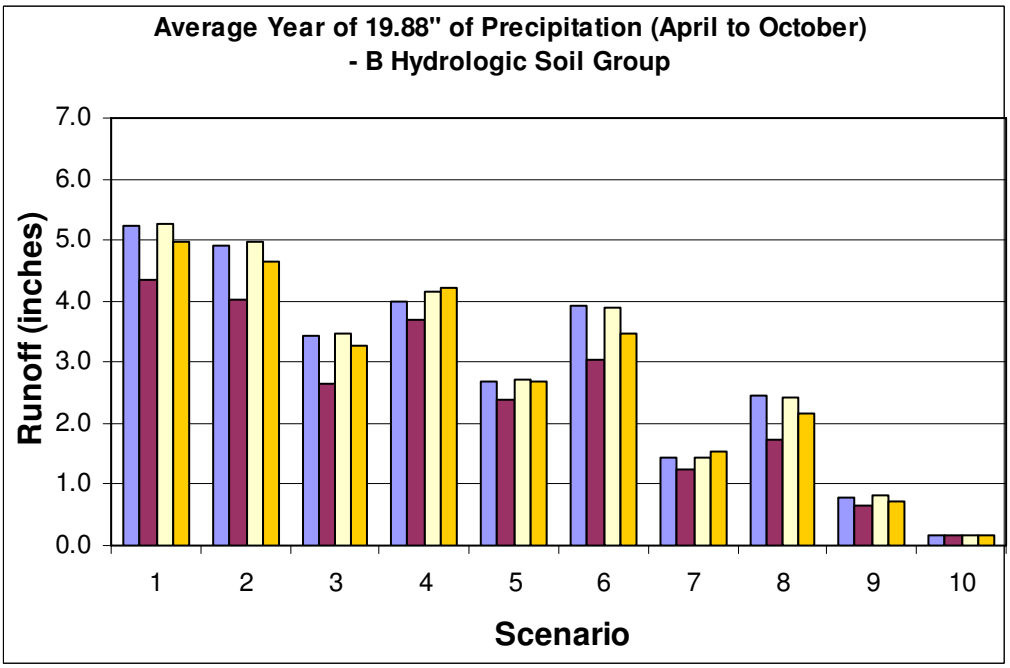
9
10
Scenario


Average Year of 19.88" of Precipitation (April to October)
- B Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
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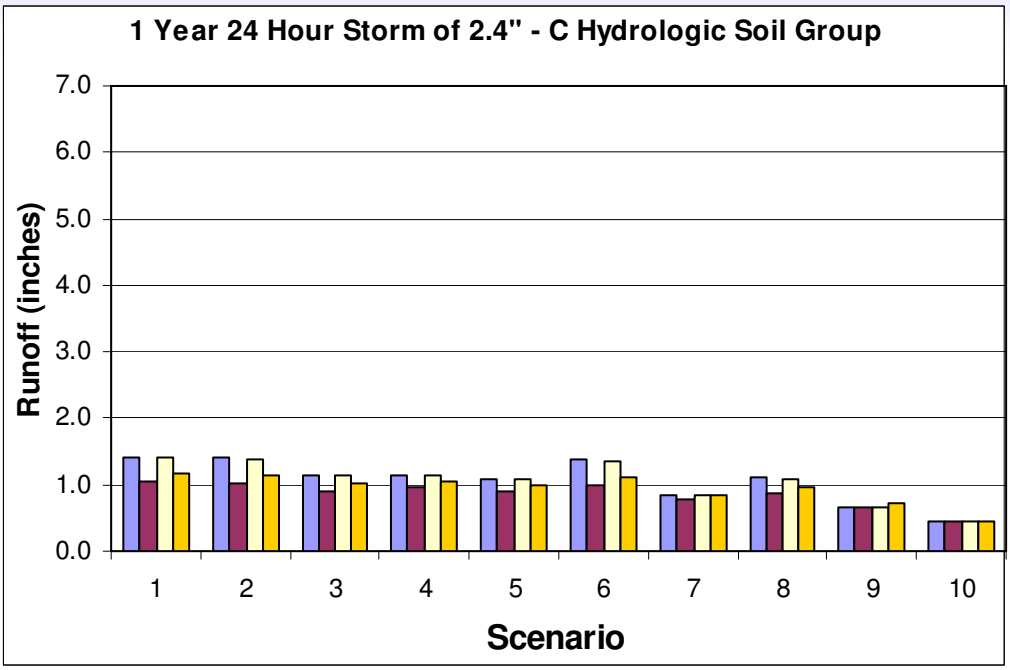
Scenario


1 Year 24 Hour Storm of 2.4" - C Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
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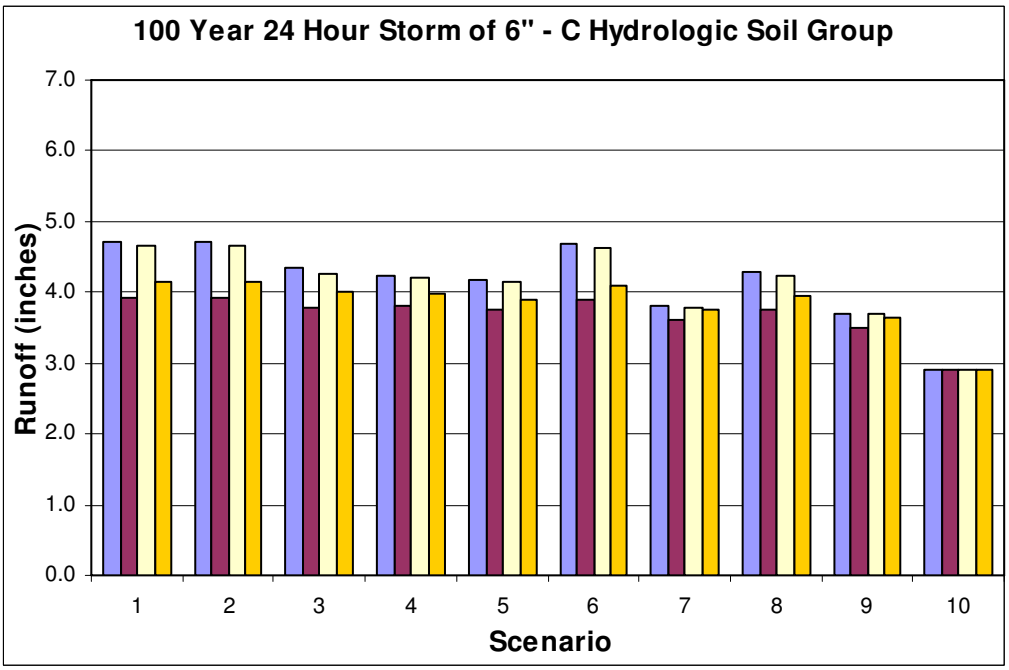
Scenario


100 Year 24 Hour Storm of 6" - C Hydrologic Soil Group
Runoff (inches)
7.0
6.0
5.0
4.0
3.0
2.0
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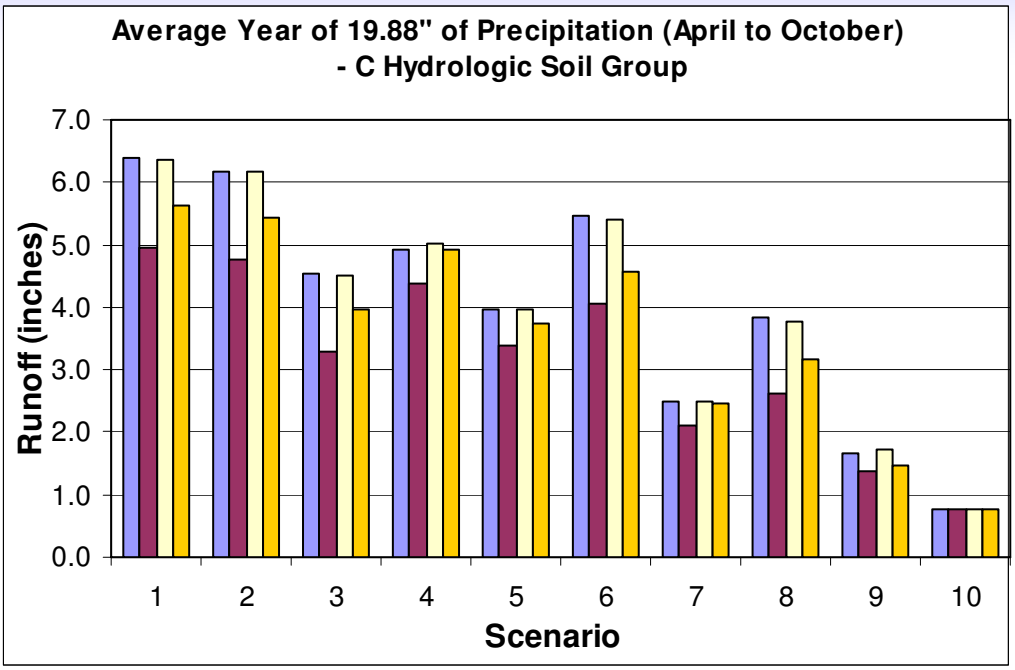
Scenario



Legend:

Conventional Curvilinear | Urban Cluster | Coving | New Urbanism

4.5 Using Native Plants to Improve Water Quality

Once viewed as obstacles and land planning headaches, natural systems are now being recognized as a solution to water resource management problems. Using natural systems instead of trying to avoid or eliminate them has proven to be a low-cost Best Management Practice (BMP) in land development and watershed restoration projects. Incorporating native plant materials into water management projects can improve water quality, provide additional and improved wildlife habitat, and, because they are optimally adapted to local conditions, minimize maintenance. The six projects described below are in place in southeastern Pennsylvania, functioning successfully, and easily adaptable for a variety of regulatory and non-regulatory projects.

The regulatory (reactive) issues focus mainly on stormwater management. Natural systems BMPs can be integrated into the National Pollution Discharge Elimination System (NPDES- II), Stormwater Management ACT 167 Planning Program, and Municipal Separate Storm Sewer Systems (MS4). The following two paragraphs from the Pennsylvania Comprehensive Stormwater Management Policy illustrate the thrust of the regulatory focus.

> Unmanaged or poorly managed stormwater can result in stream bank scour, stream destabilization, sedimentation, loss of groundwater recharge, loss of base flow, localized flooding, habitat modification and water quality and quantity impairment. Conversely, properly managed stormwater through properly constructed and maintained best management practices (BMPs) can remove pollutants, facilitate ground water recharge through retention and infiltration, provide base flow for surface water and maintain the stability and the environmental integrity of waterways and wetlands. To provide long-term protection and sustainability of ground and surface water resources, stormwater should be managed at the source or origin as an environmental resource to be protected rather than as a waste to be quickly discharged and moved downstream.
>
> Fundamentally, the goals of the policy are to improve and sustain ground and surface water quality and quantity through the use of planning practices and BMPs that minimize the generation of stormwater runoff, provide ground water recharge and minimize the adverse effects of stormwater discharges on ground and surface water resources. This policy also supports the fulfillment of the state's obligation

continued on page 8

USING NATIVE PLANTS TO

continued from page 1

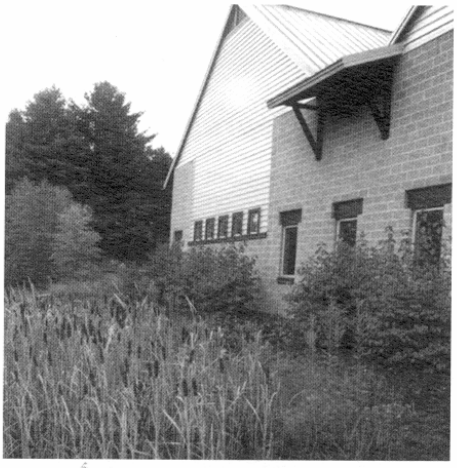
under 25 Pa. Code Section 93.4a to protect and maintain exiting uses and the level of water quality necessary to protect those uses in all surface waters and to protect and maintain water quality in special protection waters. Special protection waters are Pennsylvania's highest quality surface waters and include Exceptional Value (EV) and High Quality (HQ) waters.

The non-regulatory (proactive) use of natural systems is being implemented on a community watershed basis through Pennsylvania's Growing Greener program. Growing Greener encourages the identification and remediation of non-point source pollution by local residents, farmers, schools, and municipalities. The BMP projects described here, all of which use native plants, were initiated at the community watershed level and, in some cases, were completed with the help of community volunteers.

1. **Regional Water-Quality Management.** A six-acre municipal water-quality facility filters runoff from upstream agricultural fields and provides uptake for phosphorus and nitrogen. A forebay provides a three-year maintenance for sediment being transported through the system, which is maintained by the municipality. The filtration area is immediately adjacent to active sports fields and a rails-to-trails network and is surrounded by mixed-use residential properties. The facility supports a diverse wildlife population including migrating waterfowl, wading birds, amphibians, and reptiles while aiding in stormwater management for the watershed. Plantings, installed by community volunteers, include soft stem bulrush, bur reed, duck potato, yellow and blue iris, pickerelweed, rice cut grass, black willow, button bush, swamp rose, silky dogwood, arrowwood, and chokeberry. (Lititz Run, Warwick Township, Lancaster County)

Lititz Run, Warwick Township, Lancaster County

Pocopson Township, - Chester County



2. **Infiltration/Stormwater Management.** Collaboration between the architect and planner produced an innovative solution to stormwater management at minimal costs. A no-gutter roof system flows directly into a created wetland basin, eliminating the need for pipes and gutters. Wetland plantings include broadleaf cattail, soft rush, and mixed sedges. (Pocopson Township, Chester County)
3. **Stormwater Management/Aesthetics/Maintenance**. A low-lying area adjacent to a community walking trail and park was difficult to maintain. Designers converted the area to a wetland, which now filters runoff before it enters Cocalico Creek and provides an aesthetic component to a public area through the use of aquatic and aquatic emergent plants, wildflowers, and flowering shrubs. Community volunteers helped install the wetland. Plantings include duck potato, bur reed, soft stem bulrush, soft rush, woolgrass, buttonbush, silky and red osier dogwoods, arrowwood, and an assorted wildflower meadow mix. (Cocalico Creek, Ephrata Borough, Lancaster County)

Cocalico Creek Borough, Lancaster County

IMPROVE WATER QUALITY

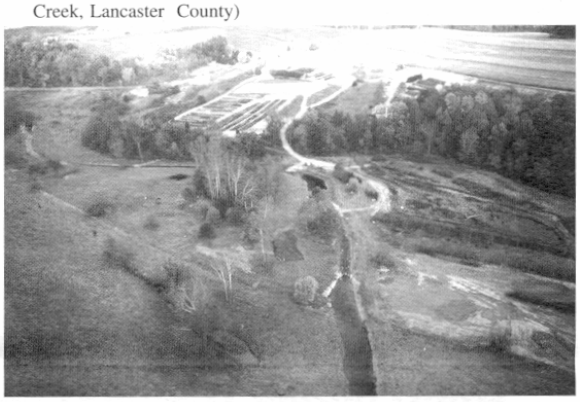
Lititz Run, Millport Conservancy - Warwick Township, Lancaster County

4. **Riparian Buffer.** Riparian (streamside) buffers provide bank stability, shading to reduce water temperatures, wildlife corridors, nutrient uptake, and organic material for the stream. State and federal governments are aggressively promoting riparian buffers as a BMP. The federal program for farmers, Conservation Reserve Enhancement Program (CREP), compensates agricultural landowners for converting marginal streamside pastures into riparian corridors. The corridors also provide a sense of structure to the landscape. The six-year-old buffer shown here consists of black willow, sycamore, red maple, black gum, river birch, black and red chokeberry, winterberry, and poplars. (Lititz Run, Millport Conservancy - Warwick Township, Lancaster County)

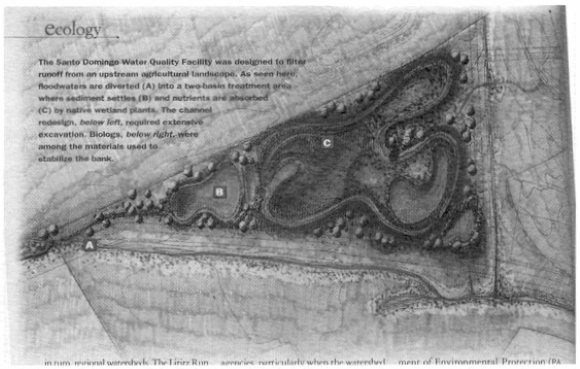
Downingtown Middle School, Downingtown, Chester County

5. **Schools.** Teachers are using a designed wetland area built adjacent to their school as an outdoor classroom for environmental studies. The project is consistent with recent Pennsylvania Education Curriculum Standards for Ecology and Environment. Emergent wetland plantings include soft stem bulrush, soft rush, lurid sedge, dark green bulrush, and woolgrass. (Downingtown Middle School, Downingtown, Chester County)

6. **Natural Channel Design.** A stream relocation project included the creation of 10 acres of wetlands. The stream channel was overwide, shallow, and unable to transport sediment. As a result, the streambanks contributed over 1,500 tons of eroded sediments to the water channel per year. The restoration project connected the channel to the active floodplain to reduce erosion significantly, increase and improve aquatic wildlife habitat, and transport sediment. The former channel was used to create wetlands. Plantings include live transplants of silky dogwood, black willow, and arrowwood. Additional riparian buffer plants include sycamore, red maple, green ash, river birch, pin oak, and black gum. (Octoraro Creek, Lancaster County)



Octoraro Creek, Lancaster County



Mark Gutshall is President of LandStudies, Inc. and founder of Octoraro Native Plant Nurseries. LandStudies was responsible for all of the design-build projects shown above.

4.6 Prairie Restorations: What to Expect and Why

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Foreword

Within the first year of a prairie planting we receive calls asking "Where's the prairie, all I see are weeds?" Because of the methods of prairie restoration site selections, site preparation, site maintenance, and the growth habit of prairie plants, a large number of weeds are present in the initial establishment phase of the prairie planting. Hopefully, the following narrative will help to explain the process involved in prairie restoration and what should be expected from your prairie planting.

Year One

Site Preparation

In most cases, agricultural fields, old pastures, and fallow fields are selected for prairie plantings. This is not surprising, since historically these areas were probably once prairie or savanna and were converted to farm fields because of their excellent soils.

In preparing a prairie planting, the same farm practices and equipment a farmer uses to prepare his field are also employed in prairie site preparation. Depending on the situation, it may be necessary to apply herbicides to kill weedy vegetation, or may involve disking, tilling, and recontouring. However, these practices are extremely conductive to the establishment of non-native weeds. The farmer is able to apply selective herbicides to control most weeds. The prairie restorationist is limited in this regard, since the herbicides are also lethal to many prairie plants.

The combination of good soil, and years and years of agricultural practice allows for thousands (sometimes hundred of thousands) of weed seeds to build up in the soil. Prairie site preparation methods provide an excellent habitat for these weeds to survive and grow.

Plant Strategy

Most prairie plantings occur in spring and the initial flush of vegetation appears to be nothing but weeds. Most weed seeds will germinate in the spring immediately after the site has been prepared. Don't panic, this is supposed to happen. Exposure of the soil during site preparation has allowed for the germination of many species. Weeds associated with agricultural fields and prairie plantings are annuals (they germinate, grow, set seed, and die in one growing season). On the other hand most prairie plants are biennials (require two growing seasons to flower and perennials (continue to grow year after year from below ground organs).

Since annual plants have very little time to grow and set seed, they typically germinate early in spring, grow rapidly and tall, and produce a large number of seeds. Biennials typically form a low growing rosette the first year and flower during the second year. Perennials, since they depend on below ground structures for a large part of their existence invest in large amount of energy to root production.

Thus, annuals allocate most of their nutrients to stems, leaves, and seed and become the most conspicuous plants in the first year. Perennials, on the other hand, may be quite abundant, but since they have allocated most of their nutrients to growing roots, they are not always evident. A qualified consultant or trained ecologist can identify these small prairie perennials among the many weeds. These two contrasting plant strategies (think of it as the fable of the tortoise and the hare; we all know who eventually wins) of rapid vs. slow growth results in what many people describe as just a field of weeds. Again, don't panic, be patient. The perennial prairie plants are present.

Site Maintenance

During the first growing season, mowing at a height of six inches when the vegetation reaches about one foot is recommended. This is detrimental to the weeds and prevents them from producing seeds. However, the perennials are too small to be injured by a six-inch mowing. No watering or fertilizing is recommended this benefits the weedy species. Native perennials are adapted to the natural conditions and require no watering or fertilizer.

Year Two

All the seeds of the weedy annuals that germinated in year one have died, and if proper maintenance was done, the number of weed seeds in the soil has been greatly diminished. The perennials, with their well-established root system, now can begin to allocate a greater portion of their nutrient reserves to above ground plant parts. What one begins to observe is called succession. Succession is the process by which plant community replaces another plant community. In this case, it is the beginning of the perennial prairie species replacement of the weed community. Remember, this is not an all or none process, some weed species can persist for years. Prairie plants with their increased production of above ground structures and their superior below ground (root) system gradually out-compete and replace the weeds. Expect some prairie plants to flower in year two.

Site Maintenance

Since soil disturbance is essential for the weeds to continue to survive, it is recommended that weeds not be pulled out by roots. The area vacated by a weed by such an act leaves a small area of disturbed soil from which many seeds in the soil can emerge.

Fire is an integral part in the maintenance of a healthy native prairie. Fires have maintained native prairies for thousands of years. By investing a large portion of their nutrients to an under ground structure, they can endure most, if not all, prairie fires. Weedy annuals are afforded no such protection and can not cope with repeated fires. Again, be patient, one initial fire will not rid your prairie planting of all weeds. Burning is best accomplished in early spring or late fall.

Year Three and Four and Beyond

Burning may be required; if there is sufficient above ground dried fuel, for several consecutive years. Generally after year four, the prairie plants are well on their way and it may be necessary to burn only every two or three-years. Years three and four should become increasingly colorful as more and more of the prairie plants reach sufficient size (vigor) to flower.

Some additional questions that might be raised concerning a prairie restoration site:

1) Will there be a time when all the weeds have been replaced? No, even minor soil disturbances such as those created by ant mounds and animal tracks provide sufficient habitat for some weeds to establish.

2) Is it harmful to have some weeds? No, as long as weeds are kept to manageable levels they will not present a problem. In fact, some weeds are quite attractive when they flower.

3) Are there alternative options to burning? Not really, the prairie plants are adapted to fire, which concentrates nutrients and blackens the surface, which warms the soil in spring allowing prairie plants to begin growth early.

4) All weedy species annuals? No, some weedy species such as bluegrass are perennials. These species are not as easily removed or replaced through succession, competition, mowing or fire. While they might not be eliminated for a number of years, they can be reduced to minor components within the prairie landscape.