This PDF file is an excerpt from the EPA guidance document entitled *National Management Measures to Control Nonpoint Source Pollution from Urban Areas* (November 2005, EPA-841-B-05-004). The full guidance can be downloaded from http://www.epa.gov/owow/nps/urbanmm/index.html.

National Management Measures to Control Nonpoint Source Pollution from Urban Areas

Management Measure 4: Site Development

November 2005

MANAGEMENT MEASURE 4
SITE DEVELOPMENT

4.1 Management Measure

Plan, design, and develop sites to:

- Maintain predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, or detain runoff;
- Protect areas that provide important water quality benefits or are particularly susceptible to erosion and sediment loss;
- Limit effective impervious area[a] by design and the use of management practices;
- Limit land disturbance activities, such as clearing and grading and cut-and-fill, to reduce erosion, sediment loss, and soil compaction; and
- Preserve natural drainage features and vegetation to the extent possible.

4.2 Management Measure Description and Selection

4.2.1 Description

The goals of this management measure are to reduce the generation of nonpoint source pollution, maintain predevelopment hydrology, and mitigate the impacts of urban runoff and associated pollutants from all site development, including activities associated with roads, highways, and bridges. Included in this section are management practices that can be applied during the site planning and review process to ensure that nonpoint source pollution and increases in the volume and rate of runoff are appropriately managed before, during, and after construction.

Although the goals of Management Measure 3 (watershed protection) are similar, this measure is intended to apply to individual sites at the catchment level (see Figure 1.3) rather than larger watersheds or regional drainage basins. The site development and watershed protection management measures are intended to complement each other and be used together within a comprehensive framework to control runoff and reduce nonpoint source pollution.

[a] Effective impervious area is the portion of total impervious cover that is directly connected to the storm drain network (Sutherland, 1995). These surfaces usually include street surfaces and paved driveways and sidewalks connected to or immediately adjacent to them, parking lots, and rooftops that are hydraulically connected to the drainage network (e.g., downspouts run directly to gutters or driveways).

Programs designed to control increased runoff and nonpoint source pollution resulting from site development should include:

- Predevelopment planning and review processes to ensure watershed/subwatershed and site-level natural resource and performance goals are achieved;
- Guidance on assessing and designing sites to maintain predevelopment site hydrology;
- Appropriate pollution prevention practices to be incorporated into site development and use.
- Site plan review and conditional approval processes to ensure the preservation of environmentally sensitive areas and areas necessary for maintaining natural hydrology and water quality; and
- Requirements for erosion and sediment control plan review and approval prior to issuance of appropriate development permits.

In addition to the preceding provisions, the following objectives should be incorporated into the site development process:

- During site development, disturb only the smallest area necessary to perform current activities to reduce erosion and off-site transport of sediment.
- Avoid disturbance of unstable soils or soils particularly susceptible to erosion and sediment loss.
- Favor sites where development will conserve natural drainage areas and sensitive environmental features, and minimize erosion, sediment loss, and soil compaction.
- Revegetate the site as soon as possible after disturbance, preferably with native vegetation.
- Protect and retain existing vegetation to decrease concentrated flows, maintain site hydrology, and control erosion.
- Minimize imperviousness to the extent practicable.
- Develop and implement inspection and maintenance procedures to ensure that landscapes are maintained to avoid water quality impacts.
- Use natural hydrology as a design element, and avoid alteration, modification, or destruction of natural drainage features.
- Design sites to preserve vegetated or natural buffers adjacent to receiving waters.

- Reforest areas within the same watershed in proportion to the acreage cleared of trees.
- Use porous pavements for areas of infrequent use (see section 5.3.2.3 in Management Measure 5).

The use of site planning and evaluation can significantly reduce the size of controls required to retain runoff and sediment on-site. Long-term maintenance burdens can also be reduced. Good site planning can attenuate runoff from development and can improve the effectiveness of the conveyance and treatment components of an urban runoff management system (Anacostia Restoration Team, 1992).

4.2.2 Management Measure Selection

This management measure was selected because the practices associated with it have been shown to be effective in protecting natural drainage features, reducing runoff quantity, and improving runoff quality. Site evaluation and protection of features that promote infiltration, filtration, and on-site detention will protect receiving water quality, maintain baseflow in receiving waters, and prevent or reduce further degradation of stream channels. Development in and around urban areas is inevitable as population growth puts pressure on suburbs and rural areas. This management measure recommends standards for new development that reduce environmental damage caused by development.

4.3 Management Practices

Many of the management practices in this section are considered "better site design techniques," planning techniques that are intended to be used to guide the layout of new developments to reduce the total effective impervious area, conserve natural habitats, and better distribute and infiltrate runoff. All aspects of an individual site, including soil types, slopes, and the location of environmentally sensitive features such as wetlands, forests, and meadows, should be examined to identify areas that should be preserved or restored. Better site design techniques can be used to identify the most efficient building and infrastructure layouts. It can also be used to develop a comprehensive strategy to reduce the quantity of runoff leaving the site and minimize the amount of pollutants generated on-site.

There are many advantages to better site design. Environmentally friendly site designs are more likely to be accepted by local governments and the community, thereby speeding plan approval. Site designs that preserve community open space also reduce the burden on the local government to provide recreational areas. In addition, better site design techniques reduce the amount and cost of infrastructure, which also in turn reduce engineering and maintenance costs. For example, runoff storage requirements for a low-impact development neighborhood in Pierce County, Washington, were reduced by more than 75 percent and the cost was 20 percent less than for conventional designs. These cost savings resulted primarily from the reduced size of runoff detention structures and the elimination of catch basins and pipes (Zickler, 2002).

Low-impact development practices can provide substantial benefits in terms of reducing the occurrence of combined sewer overflows (CSOs). Temporarily storing runoff in urban areas can greatly reduce the peak flow into storm water systems and provide a cost-effective way to mitigate basement flooding and CSOs (USEPA, 1999). Two communities in Indiana successfully implemented street surface storage of runoff to reduce the occurrence of CSOs in a cost effective manner while also reducing peak flows to wastewater treatment plants. The distributed storage controls also offered some water quality benefits by temporarily detaining runoff during storms (USEPA, 1999).

From a marketing perspective, studies have shown that lots abutting forested or other open space are initially valued higher than lots with no adjacent open space, and over time they appreciate more than lots in conventional subdivisions (Arendt, 1996). For example, lots in an open space subdivision in Amherst, Massachusetts, experienced a 13 percent greater appreciation in value compared to a conventional development after 20 years, even though the lots in the conventional development were twice as large (Arendt, 1996).

From a quality-of-life standpoint, site designs that incorporate pedestrian paths and common open space foster a greater sense of community among residents. House lots are closer together, encouraging communication among neighbors. Additionally, common open space provides recreational opportunities that further encourage community interaction.

Finally, better site design offers environmental benefits, including protection of ecologically significant natural resources, reduction of runoff, and preservation of open space and wildlife habitat. Maintaining open space also increases the opportunity for alternative sewage and wastewater disposal and treatment practices such as land treatment, spray irrigation, and reclamation and reuse. In addition, the flexibility of better site design allows designers to site these wastewater treatment systems in the areas of the development best suited for them.

Overall, the practices presented in this management measure provide many advantages over conventional developments and can be implemented in most communities. In some cases, however, outdated development rules can discourage or prohibit some of these practices. Watershed managers should review the local building codes and regulations that govern new developments to determine whether better site design techniques are allowed or encouraged and work with the appropriate authorities to remove these impediments.

The second edition of the Bay Area Stormwater Management Agencies Association's *Start at the Source*, which was originally published in 1997, is an excellent resource on site design issues for watershed managers. This publication emphasizes the importance of considering runoff quality in the early stages of land planning and design. The new edition has been updated and expanded to include commercial, industrial, and institutional development, as well as a technical section that provides more detailed information on the characteristics, applications, design criteria, maintenance, and economics of the practices discussed in the document. More information about ordering this publication when it becomes available is provided on the Bay Area Stormwater Management Agencies Association's Web site at http://www.basmaa.org/ (BASMAA, no date).

Pembroke Woods Subdivision, Emmittsburg, Maryland

Pembroke Woods is a 43-acre low impact development residential subdivision that the designers hail as the first subdivision designed and under construction using the *Low-Impact Development Design Strategies: An Integrated Design Approach* manual developed by Prince George's County, Maryland (2000a). The designers have identified significant cost savings for this development compared to the traditional development plan created in the 1990s. These include

- Eliminating the need for 2 storm water management ponds that had been envisioned in a prior concept plan for the site, yielding construction cost savings of $200,000.

- In place of those 2 storm water management ponds, 2.5 acres of undisturbed open space and wetlands were conserved, with cost savings realized in eliminating wetland mitigation costs.

- An additional 2 lots were created by revising the site plan, increasing the site yield from 68 to 70 lots and adding $90,000 to the project value.

- Approximately 3,000 linear feet of roads were converted from urban road to rural road, replacing curb & gutter with grass bioswales, yielding a savings of $60,000 in construction costs. Also, reducing the road with from 36 feet to 30 feet in the rural road section of the development reduced paving costs by 17 percent.

A brief project overview and contact information can be found at http://www.buckeyedevelopment.net/lowimpactdevelopment.htm.

4.3.1 Site Planning Practices

4.3.1.1 Select site designs that preserve or minimize impacts to predevelopment site hydrology and topography

Retaining the existing topography of a development site assists in maintaining natural drainage features and depressional storage areas that help infiltrate and attenuate flows and filter pollutants. Depressional storage areas, commonly found as ponded areas after storms or during the wet season, aid in reducing runoff volumes and trapping pollutants. To help preserve natural drainage, a developer can (Goldman et al., 1986):

- Construct buildings and parking areas on existing flat terrain;
- Locate buildings and roads along existing contours;
- Orient long buildings with the major portion parallel to contours;
- Stagger floor levels to adjust to gradient changes; and
- Fit the development to the topography.

4.3.1.2 Protect environmentally sensitive areas

Sites should be developed to avoid destroying wetlands, seeps, bogs, fens, springs, surface water bodies, and catchment areas that are important for sustaining the hydrology of the land. In addition, riparian buffers, both forested and covered with grasses, should be preserved to protect surface water bodies. Steep slopes and highly erodible areas need to be protected to avoid landslides and soil movement into water bodies.

The increase in storm water runoff that results from urban development can dramatically impact the ecology of wetlands and other areas by altering characteristics of hydrology, water quality, and soil (USEPA, 1996). Urban development can also result in ecological changes due to fragmentation and habitat destruction. If the development of a site changes runoff characteristics, measures should be taken to prevent negative impacts to wetlands and other features. For example, Pohlig Builders of Malvern, Pennsylvania, incorporated measures to protect wetlands into its building plan after homeowners opposed the construction of seven high-end homes adjacent to a wetland area. Pohlig designed a vegetative filter strip to buffer runoff from the homes and provide treatment before runoff reached the wetlands. The filter strip was designed to eventually grow into a wooded area to enhance aesthetics and benefit water quality. A level spreader was added to convert concentrated runoff to sheet flow that can be more effectively treated, and extra erosion and sediment control measures were used during construction. The total additional cost of these measures was $30,000 (NAHB, 2003).

4.3.1.3 Practice site fingerprinting

The total amount of disturbed area in a site can be reduced by "fingerprinting" development, i.e., placing development in the most environmentally sound locations on the site and minimizing the size of the disturbed area and ultimate development footprint. Fingerprinting places development away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces and restoration areas, areas with trees to be saved, and temporary and permanent vegetative forest buffer zones. At a subdivision or lot level, ground disturbance is confined to areas where structures, roads, and rights-of-way will exist after construction is complete. Other site-level fingerprinting practices include reducing paving and compaction of highly permeable soils, minimizing the size of construction easements and material storage areas, minimizing impervious areas in the site design, clearly demarcating the disturbance area, maintaining existing topography and drainage divide, and disconnecting impervious areas (Prince George's County, Maryland, Department of Environmental Resources, 2000a).

4.3.1.4 Use cluster development

Cluster development is used to concentrate development and construction activity on a limited portion of a site, leaving the remainder undisturbed. Figures 4.1 and 4.2 show schematics of a residential cluster development and a rural cluster development. Clustering allows the design of more effective urban runoff management systems and reduces overall site-level erosion and sediment impacts. It also provides a mechanism to preserve environmentally sensitive areas and reduce infrastructure such as wastewater treatment systems, roads, sidewalks, and parking areas.

In addition to its environmental benefits, clustering can result in cost savings for municipalities because clustering and infill development typically require less new infrastructure, such as urban runoff treatment systems. The imposition of density controls may preclude clustering. Although minimum lot size requirements are useful in some instances, such as farmland preservation (see

Management Measure 3), zoning ordinances should not preclude the implementation of clustered development as an alternative to conventional suburban development.

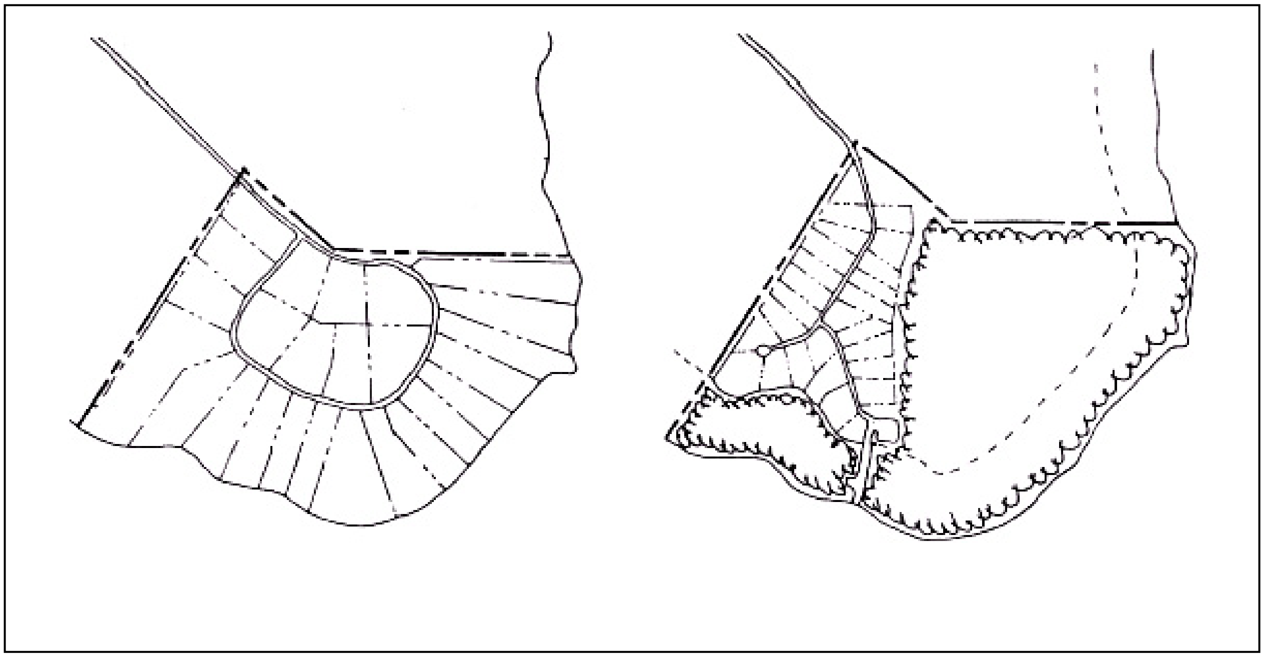

Figure 4.1: Schematic of a residential cluster development (Schueler, 1995).

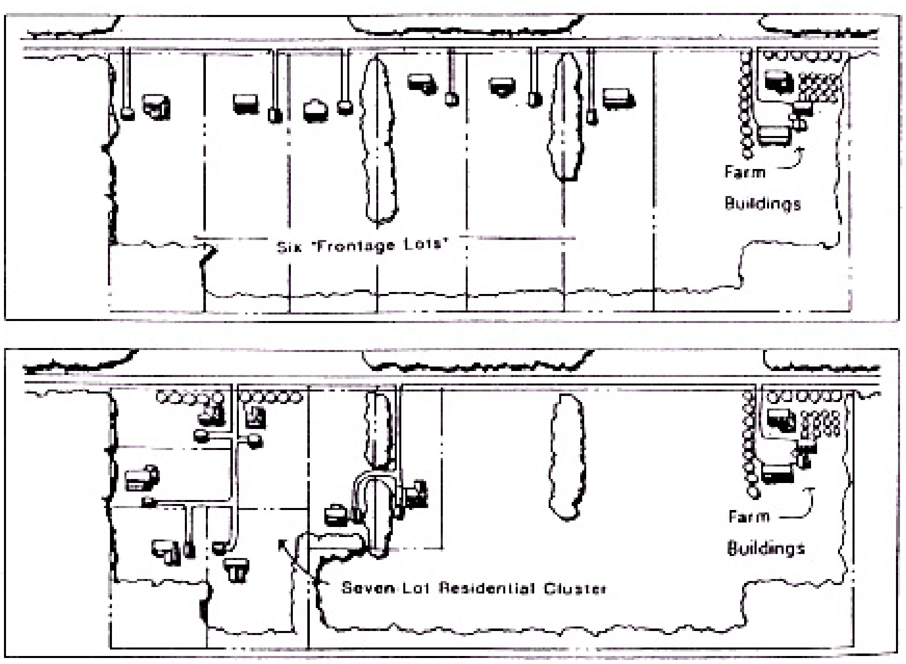

Figure 4.2: Schematic of a rural cluster development (Schueler, 1995).

4.3.1.5 Create open space

Open space development is a technique that concentrates development on one area of a site in exchange for open space in another area. Benefits associated with open space design include:

- A 40- to 60-percent reduction in impervious cover compared to conventional development designs;
- Increased property values;
- Reduced construction and development costs;
- Common recreational facilities (i.e., pedestrian paths, picnic areas, and athletic fields);
- Reduced infrastructure;
- Improved quality of life; and
- The use of community onsite/decentralized systems (see Nutrient Export case study below).

The following are some techniques for conserving open space:

- *By-right open space development*. This technique allows increased density on one portion of a site in exchange for open space on another portion. A large percentage of this open space can be dedicated as conservation land. To encourage open space development, municipalities can draft ordinances so that this is a "by-right" option, as opposed to a special exception or variance.
- *Density compensation*. This technique allows developers to increase housing density to offset potential housing lots lost to on-site buffers or other conservation lands.
- *Storm water credits*. Credit is given for implementation of source controls that reduce runoff volumes and pollutant concentrations before the remaining runoff reaches structural controls. Because performance is typically measured by comparing influent runoff to effluent runoff, storm water credits benefit operators of structural controls because credit for pollutant removal occurs before treatment.
- *Property tax credit*. The property tax credit is a technique for reducing, deferring, or exempting property taxes on conservation land. Typically, conservation easements are exchanged for the property tax credit.
- *Density bonus*. This bonus allows developers to increase density above base zoning density in exchange for conserving natural areas.
- *Off-site mitigation*. This term refers to the restoration or creation of wetlands in a designated off-site area if on-site wetlands are adversely affected and on-site mitigation is not feasible.

Randall Arendt (1996), in his book, *Conservation Design for Subdivisions: A Practical Guide for Creating Open Space Networks*, presents a plain-language, illustrated guide for designing open space subdivisions. This publication is available from Natural Lands Trust, Inc., 1031 Palmers Mill Road, Media, PA 19063; phone 610-353-5587. The following topics are covered:

- Open space vs. conventional developments;
- Economic, social, and environmental benefits of open space designs;
- Roles and responsibilities of stakeholders in site development;
- A stepwise approach to designing an open space subdivision (discussed below);
- Ideas for creating an interconnected open space network;
- Seven case studies;
- Methods to modify existing regulations to encourage open space design;
- Management techniques for conservation lands;
- Sample house plans for open space subdivisions;
- Sample advertisements for developers to capitalize on open space design benefits; and
- Model ordinance provisions.

Arendt's multi-step process for creating conservation subdivisions involves two stages. The first, called the background stage, involves identifying the characteristics of the surrounding landscape and existing development and analyzing and delineating significant features of the site. The second stage involves integrating the site's feature information into a map and prioritizing conservation lands based on the features deemed most important, while maintaining the quantity of land necessary to develop the site to the desired density.

The background stage involves examining the surrounding landscape and existing development to identify conservation areas. It includes the following practices:

(1) *Understanding the locational context*. The layout of new development should consider proximity to traditional small towns or villages; if existing development is nearby, the design of the new community should reflect and extend the historical streetscape and pattern. In rural areas located away from existing development, informal, irregular, "organic" layouts can be used successfully without detracting from the surrounding landscape.

(2) *Mapping natural, cultural, and historic features.* A thorough analysis of a site's special features that may enhance or constrain development is an important step in planning a new development. Special features might already have been identified in a natural resources inventory conducted by local government or land trust organizations. The site analysis should include site visits and identify the conservation areas described in this section.

    The following conservation areas are legally or logistically unbuildable and therefore must be avoided:

    - *Wetlands*. Tidal and non-tidal saltwater and freshwater wetlands and the dry upland buffers surrounding them should be identified as areas to be conserved because they filter runoff, provide critical habitat at the land-water interface, and offer opportunities for recreation and environmental education. Soil survey maps, National

Wetlands Inventory maps, state or environmental agency wetland maps, or on-site delineations can be used to determine the extent of wetland habitat on the site.

- *Floodplains*. The 100-year floodplain, which can be determined from floodplain maps published by the Federal Emergency Management Agency (FEMA) (see Management Measure 2), should be left undeveloped to preserve a continuous riparian greenway and to prevent damage to property from flooding. To preserve views of the water on wooded sites, lower tree limbs can be removed. (This may be a reasonable alternative to developing closer to the water's edge.) Zoning requirements might dictate an additional 50- to 100-foot setback from the 100-year floodplain.

- *Slopes*. Slopes of more than 25 percent should not be developed because of their high potential for erosion. Slopes between 15 and 20 percent can be developed using special site planning but should be avoided when possible. Slope maps can be prepared from USGS topographic maps by an engineer, planner, or landscape architect, but site visits should confirm these conditions.

The following conservation areas typically are legally buildable but are historically or ecologically significant or desirable, and therefore they should be avoided when other land is available for development.

- *Soils*. Soil surveys, whether they are based on existing maps produced by NRCS or data gleaned from on-site testing, identify well-drained soils suitable for treating wastewater, poorly drained soils that might result in leaky basements or wetland conditions, and steep or stony soils that would be difficult to build on. Existing soil survey data might not be detailed enough to characterize site conditions, depending on the spatial variability of soil types in the region. High-intensity soil surveys and site surveys that are accurate to 0.1 acre should be used in highly variable circumstances.

- *Significant wildlife habitats*. Habitat for threatened or endangered wildlife, including travel corridors to food sources, homes, and breeding grounds, should be conserved. An additional buffer of open space is recommended. These habitat locations might have been officially documented already by state or local agencies. Habitat for wildlife species that are not threatened or endangered should also be considered for conservation areas where possible. Continuity in habitat areas is important; land that connects two isolated habitat areas provides a valuable corridor that extends the usable habitat for the species of concern.

- *Woodlands*. Woodlands often provide valuable wildlife habitat and contribute to the aesthetic value of a property. Where areas are mostly forested and clearing is required for site development, however, areas of mature forest or areas with unique species composition should be of higher conservation priority. In areas where woodland is not the predominant land use, as much of the existing tree cover as possible should be conserved on the property. An effort should be made to maintain corridors that connect forested areas to provide as much continuous forested habitat as possible.

- *Farmland*. Agricultural lands can be conserved as open space if desired, although relatively small fields might not be lucrative and could pose a more significant water quality risk compared to residential development due to specific land management practices (tilling, fertilizer application) associated with agriculture. Another option for agricultural fields is to let them succeed to a more natural meadow state with grasses, wildflowers, and shrubs that could provide habitat for many birds and small mammals.

- *Historic, archaeological, and cultural features*. Areas with historic significance can be identified from official lists such as the National Register of Historic Places and state and local inventories of historic and cultural resources. Landowners and local historians should also be consulted for detailed information about a site's history. Although historic areas are not always protected from demolition, if other areas of the property are equally suitable for development, historic resources should be preserved.

- *Views into and out from the site*. Development should be designed to blend well with the surrounding landscape. Because developers typically want to site buildings to take advantage of attractive views, they often build in areas where structures are highly visible. Siting buildings away from the pinnacles of ridges and hills, designing buildings with lower profiles, and preserving or planting trees to shield buildings from view are all techniques that can be used to reduce the visual impact of development on the landscape. Views can be created by cutting a limited number of trees to create "view tunnels," or trimming lower limbs to create "view holes" through the foliage.

- *Aquifers and their recharge areas.* An aquifer recharge area is where water moves downward to the water table. In other words, recharge areas replenish groundwater. Unconfined aquifers are not covered by a layer of impermeable rock and are open to receive water from the land surface. Unconfined aquifers are typically recharged in topographically high areas or through sandy or gravelly soils. These areas should be conserved as open space to maintain ground water recharge. They should also be buffered with vegetation to filter solids and associated pollutants from runoff.

After background information has been obtained, the next step is to integrate the information and prioritize conservation areas. Typically, all of the features mentioned above are drawn onto overlay sheets or entered into a geographic information system (GIS). Once the significant features are shown together, areas most suitable for development become obvious. Where some conservation areas need to be sacrificed to achieve the development objectives, decisions must be made regarding ranking the conservation areas based on how special, unique, irreplaceable, environmentally valuable, historic, or scenic they are. Figure 4.3 shows an example site before development, developed with a conventional strategy, and developed with consideration of locational context and conservation areas (Arendt, 1996).

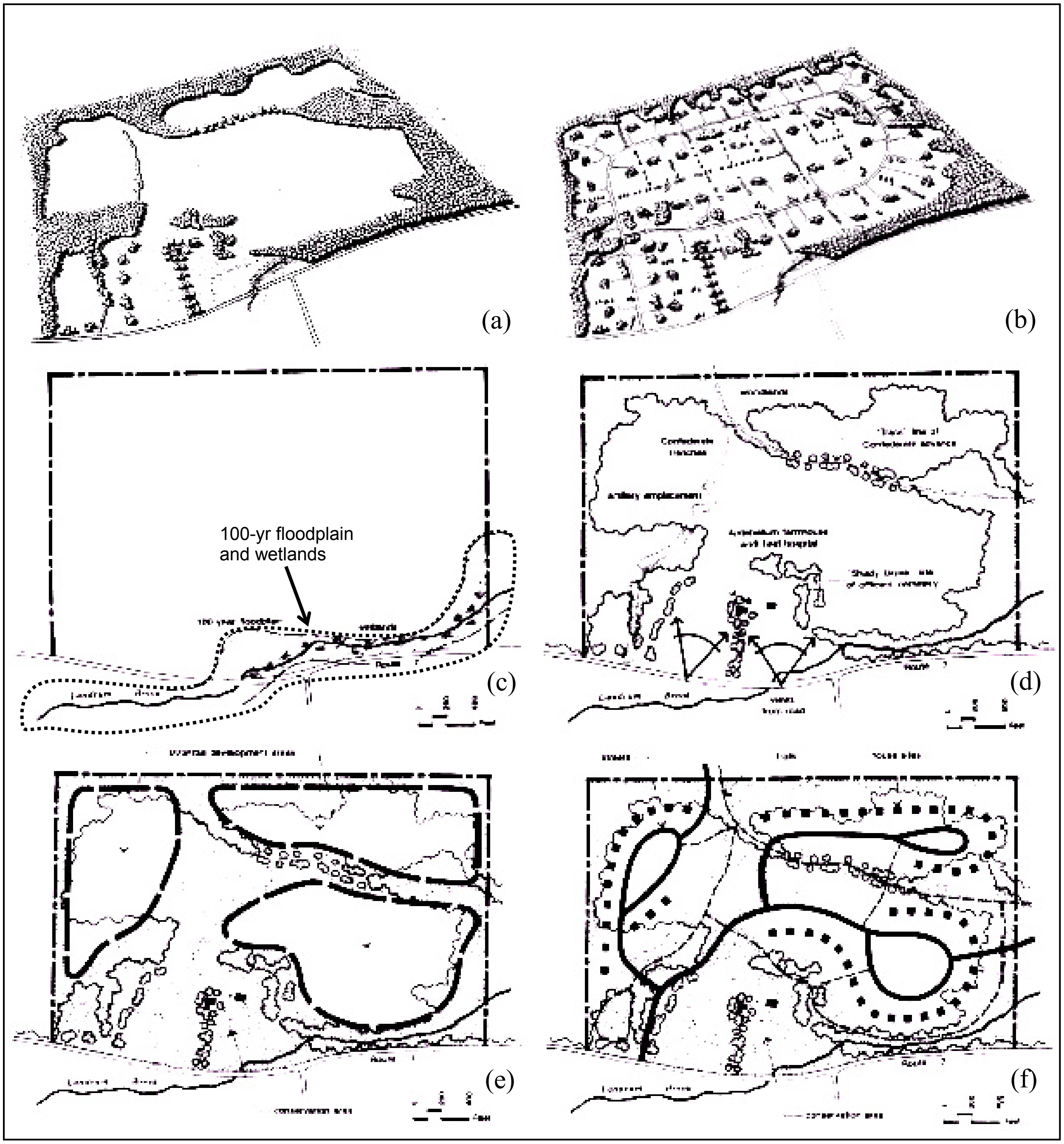

Figure 4.3: Development of a conservation subdivision. The site before development (a) and as designed with conventional development (b); identification of legally unbuildable (c) and legally buildable (d) conservation areas with features to be protected; and delineation of potential development areas (e and f) (adapted from Arendt, 1996).

Comparison of Traditional and Low Impact Development Scenarios in Delaware

The Brandywine Conservancy and the Delaware Department of Natural Resources and Environmental Control presented a case study in *Conservation Design for Stormwater Management* (Delaware DNREC and the Brandywine Conservancy, 1997). The case study compares conventional site development to several alternative, low impact development scenarios at Chapel Run, a 96-acre site in Sussex County, Delaware. The Chapel Run site is located in a rural area and is categorized by Sussex County as a primarily agricultural area where low-density residential development is permitted. Conservation areas that were identified through a site investigation include a large area of woodland, much of which is on well-drained soils that generate little or no runoff, and a small area with steep slopes.

The proposed conventional design dictates dividing the site into 142 lots ½ acre in size. The conventional design does not take into consideration the sensitive areas identified in the site assessment and results in a site with 100 percent of the area disturbed after clearing and grading. Overall site imperviousness under conventional development would be 29 percent, assuming conventional road widths. On-site runoff management would be accomplished by a curb and gutter system that conveys runoff to two detention basins.

Two alternative designs were developed for the Chapel Run site: the parkway design and the village cluster design. Figure 4.4 shows lot layouts for the conventional and conservation designs. Table 4.1 shows a theoretical side-by-side comparison of the three types of developments with respect to lot size and layout, amount of disturbed and impervious area, hydrology, and costs. Table 4.2 shows differences in itemized costs for infrastructure and management practices between conventional and low impact alternative designs.

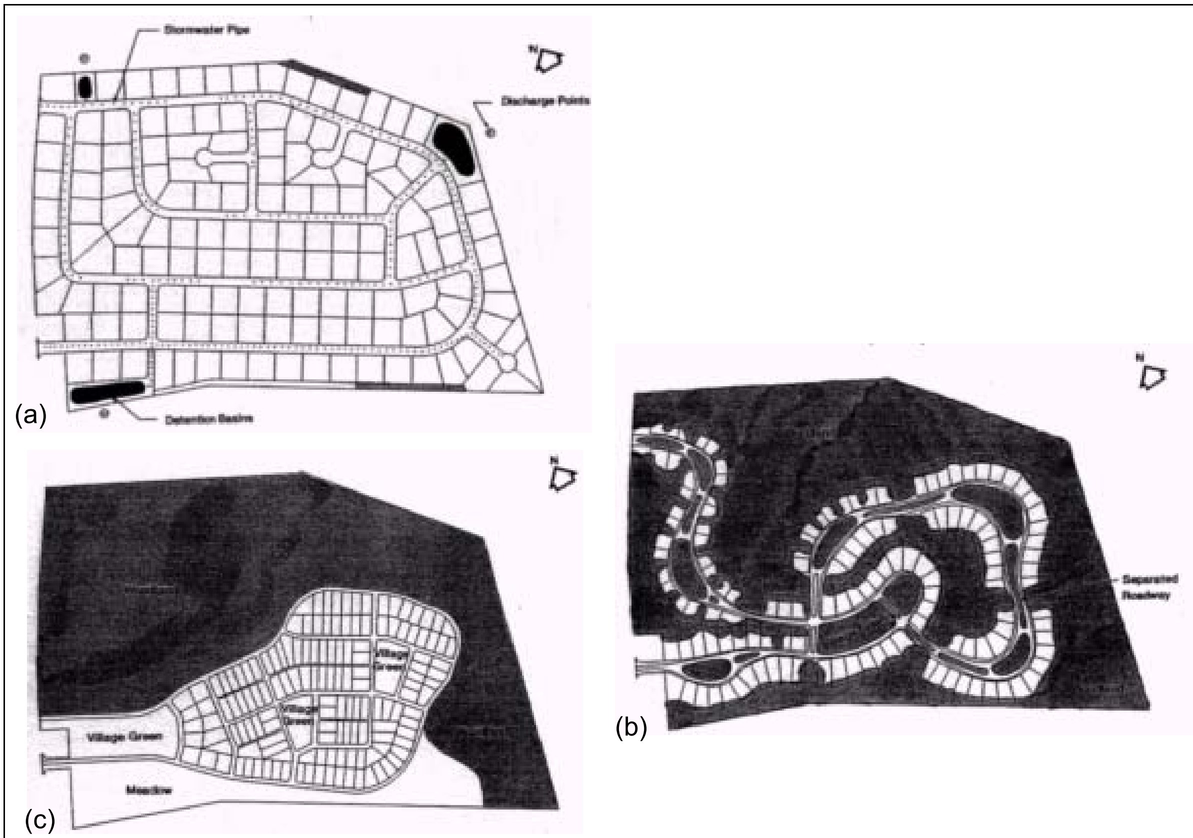

Figure 4.4: Schematic drawings of conventional (a), parkway (b), and clustered (c) development scenarios for the Chapel Run subdivision (Delaware DNREC and the Brandywine Conservancy, 1997).

Comparison of Traditional and Low-Impact Development Scenarios in Delaware (continued)

Table 4.1: Theoretical comparison of conventional and low-impact alternative designs for the Chapel Run site (DE DNREC and the Brandywine Conservancy, 1997). (Reductions are compared to the conventional design.)

Name	Conventional	Village	Parkway
Layout type	Conventional	Condensed cluster	Lots configured along curving road
Number of lots	142	142	142
Lot size	1/2-acre	1/8-acre	1/4-acre
Areas conserved	None	Woodland and high recharge areas	Woodland and high recharge areas
Percent of site in open space	0%	72.7%	49.7%
Impervious cover	29%	17.7%	14.9%
Impervious cover reduction	—	38%	48%
Street width	28 feet	20 feet	Two one-way lanes 12 feet wide with a pervious median
Undisturbed areas	0%	67.5%	59.6%
Runoff management system	Curb and gutter system that conveys runoff underground to two detention basins.	Swale conveyance system along roads that directs runoff to retention/ infiltration areas with level-spreading devices and low berms. These retention/infiltration areas are located throughout the site. Several village greens established on well-drained soils function as both recreation and infiltration areas.	Infiltration of runoff into depressed median (swales) along streets. Wide oval parkway centers used for retention/infiltration. These areas are designed with overflow piping to prevent flooding.
Average curve number[a]	78	66	65
Peak runoff rate for a 10-yr storm[a]	—	53 cfs	51 cfs
Water budget (gal) Precipitation Runoff Recharge Evapotranspiration	 114,082,682 31,584,217 31,280,103 51,223,261	 114,082,682 21,812,868 34,001,079 58,208,796	 114,082,682 17,782,776 35,502,938 60,802,278
Costs [b] Total Per lot	 $2,460,200 $17,325	 $1,174,716 $8,273	 $887,705 $6,259

[a] From USDA-NRCS's TR-55 model.
[b] Total cost for the Parkway design shown here differs from total cost published in DE DNREC and the Brandywine Conservancy (1997). Total cost shown here is based on itemized costs, provided in Table 4.2. These are conservative estimates, as in most cases additional costs such as grading have not been taken into account.

Comparison of Traditional and Low-Impact Development Scenarios in Delaware (continued)

Table 4.2: Theoretical comparison of itemized costs for conventional and low-impact alternative designs for the Chapel Run site (DE DNREC and the Brandywine Conservancy, 1997).

Name	Conventional	Village	Parkway
Street			
Length installed	13,388 ft	11,828 ft	7,800 ft
Unit cost	$150/linear ft	$85/linear ft	$85/linear ft
Total cost	**$2,008,200**	**$1,005,380**	**$663,000**
Storm water detention ponds			
Number installed	3	0	0
Unit cost	$16,000 per pond		
Total Cost	**$48,000**	**$0**	**$0**
Storm water pipe			
Length installed	16,000 ft	2,000 ft	3,000 ft
Unit cost	$22/linear ft	$22/linear ft	$22/linear ft
Total cost	**$352,000**	**$44,000**	**$66,000**
Endwalls/inlets			
Number installed	40	5	10
Unit cost	$1,300 each	$1,300 each	$1,300 each
Total cost	**$52,000**	**$6500**	**$13,000**
Berms			
Length installed	0	1050 ft	1000 ft
Unit cost		$10/linear ft	$10/linear ft
Total cost	**$0**	**$10,500**	**$10,000**
Swales			
Length installed	0	22,570 ft	20,600 ft
Unit cost		$4.50/linear ft	$4.50/linear ft
Total cost	**$0**	**$101,565**	**$92,700**
Check dams			
Number installed	0	90	82
Unit cost		$75 each	$75 each
Total cost	**$0**	**$6771**	**$6150**
Reforestation			
Acres reforested	0	0	12.8
Unit cost			$2,925/ac
Total cost	**$0**	**$0**	**$36,855**
Total [a]	**$2,460,200**	**$1,174,716**	**$887,705**

[a] Total cost for the Parkway design shown here differs from total cost published in DE DNREC and the Brandywine Conservancy (1997). Total cost shown here is based on itemized costs. These are conservative estimates, as in most cases additional costs such as grading have not been taken into account.

4.3.2 On-Lot Impervious Surfaces

4.3.2.1 Reduce the hydraulic connectivity of impervious surfaces

Pollutant loading from impervious surfaces can be reduced by preventing the direct connection of the impervious area to an impervious conveyance system. This can be done in a number of ways, including:

(1) Routing runoff over lawn areas to increase infiltration;

(2) Discouraging the direct connection of downspouts to storm sewers, or the discharge of rooftop downspouts to driveways, parking lots, and gutters;

(3) Substituting swale and pond systems for curbs and gutters to increase infiltration; or

(4) Reducing the use of storm sewers to drain streets, parking lots, and backyards by routing runoff overland using curbless systems, curb cuts, sloped sidewalks, and bioretention cells.

If runoff is directed over lawns, care should be taken to alleviate soil compaction. Urban lawns that are highly disturbed and compacted do not necessarily function as pervious surfaces (for more information on managing runoff from lawns and landscaping, see Management Measure 9).

Figure 4.5 shows schematic representations of impervious areas that are directly connected and not directly connected (BASMAA, 1997).

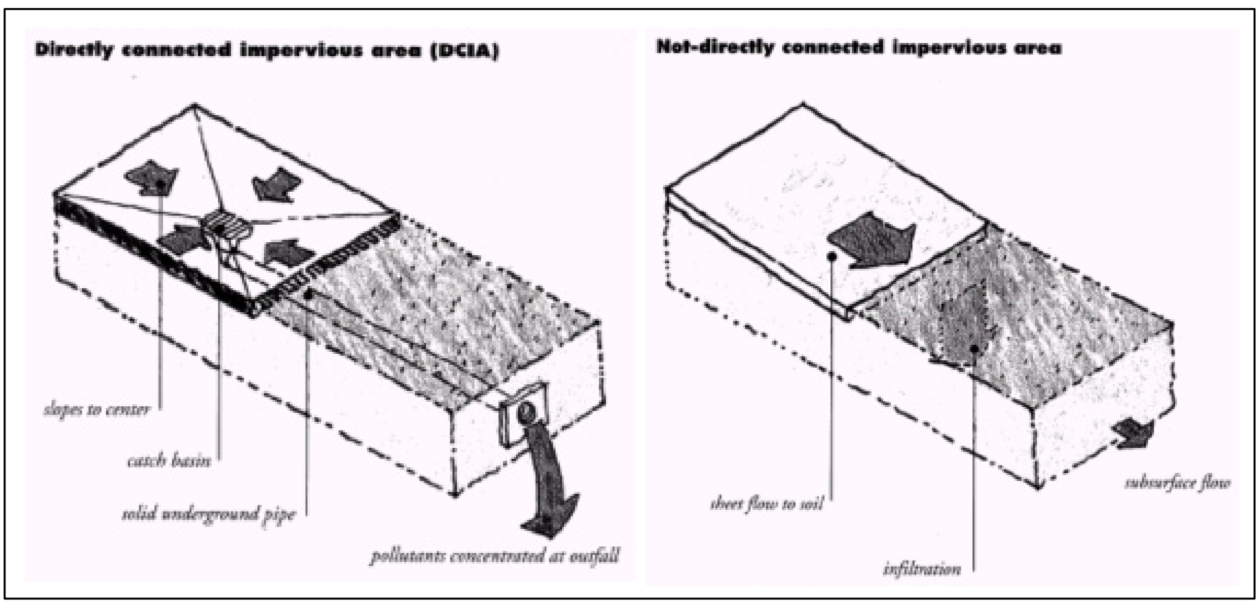

Figure 4.5: Schematic representation of directly connected and not-directly connected impervious areas (BASMAA, 1997).

The Urban Runoff Pollution Mitigation ordinance passed by the City of Santa Monica, California, requires new developments to implement management practices to collect precipitation, increase infiltration, and manage urban runoff on-site rather than after it enters the storm drain system. Infiltration trenches are the most common on-site practices for single-family homes in the city, but biofilters, swales, and porous pavement are also used. Since 1995, when the ordinance came into effect, 600 new developments have implemented management practices, resulting in a 1.2 million-gallon decrease in storm water runoff for each storm of 0.1-inch rainfall or greater (Shapiro, 2003).

In Prince George's County, Maryland, Cheng et al. (no date) measured runoff from adjacent watersheds to compare the effects of conventional versus low-impact subdivision design. One watershed was developed using conventional subdivision design (curb, gutter, and pipe storm drainage), while the other watershed was developed using low-impact development (LID) techniques, including curbless roads, networks of grassy swales to convey runoff, and bioretention areas (with drop inlet structures where necessary to convey concentrated flows during larger storms). After two years of monitoring, the researchers found that the average peak flow rate of the LID site was 56 percent of that of the conventional site, and surface runoff volume for the LID site was 60 percent of that of the conventional site. Only 15 percent of rainfall was converted to runoff in the LID watershed compared to 19 percent in the conventional watershed, and the LID site had delayed runoff hydrographs and a higher frequency of small flow rates compared to the conventional site, which had a higher frequency of larger flow rates.

Gap Creek Low Impact Development Subdivision, Sherwood, Arkansas

The Gap Creek subdivision in Sherwood, Arkansas, was designed using a low impact development approach that involved implementing such practices as street designs that flow with the existing landscape, minimal site disturbance and preservation of native vegetation, preservation of natural drainage features, and a network of buffers and greenbelts that protect sensitive areas. The approach resulted in significant economic benefits arising from lower development costs, higher lot yield, and greater lot values (NRDC, 1999).

The developer took advantage of the open space that was preserved to maximize the number of lots that were adjacent to the uncleared areas, enhancing their marketability and increasing the value of those properties. The LID plan reduced the amount of site clearing and grading, yielding lower site preparation costs.

Additionally, enhancing natural drainage features resulted in less money spent on drainage infrastructure such as piping, curbs, gutters, and other runoff conveyance features. An additional cost savings was realized with shorter and narrower streets, which also reduced imperviousness. For example, the developer reduced street width from 36 to 27 feet and retained trees close to the curb line, resulting in savings of nearly $4,800 per lot.

The greater lot yield and high aesthetic curb appeal also resulted in larger profits. The developer was able to sell lots for $3,000 more than larger lots in competing areas and sold nearly 80 percent of the lots within the first year. Additional benefits can be found in 23.5 acres of green space and parks (Toolbase Services, no date).

The economic benefits are expected to exceed $2 million over original projected profits. Additional benefits of the LID design include lower landscaping and maintenance costs and more common open space and recreational areas.

4.3.2.2 Practice rooftop greening

Rooftop greening has become an increasingly common practice in Europe and other parts of the world. This practice involves growing vegetation on the roofs of businesses and homes to intercept rainfall and promote evaporation rather than runoff (Natural Carpets, 1998). Rooftop mats are typically multilayered and include prevegetated coir fiber mats, a mineral-based substrate, and a synthetic matrix (see Figure 4.6). The coir fiber mat absorbs rainfall; the mineral substrate provides the plants with nutrients; and the synthetic matrix promotes drainage. Mats can be used on roofs with slopes of up to 30 degrees and are capable of reducing runoff by two-thirds (see Figure 4.7). These mats provide benefits other than runoff reduction, including:

- Visual aesthetics
- Protection of roofs from damaging solar radiation, wind, and precipitation
- Insulation
- Noise reduction
- Habitat for wildlife

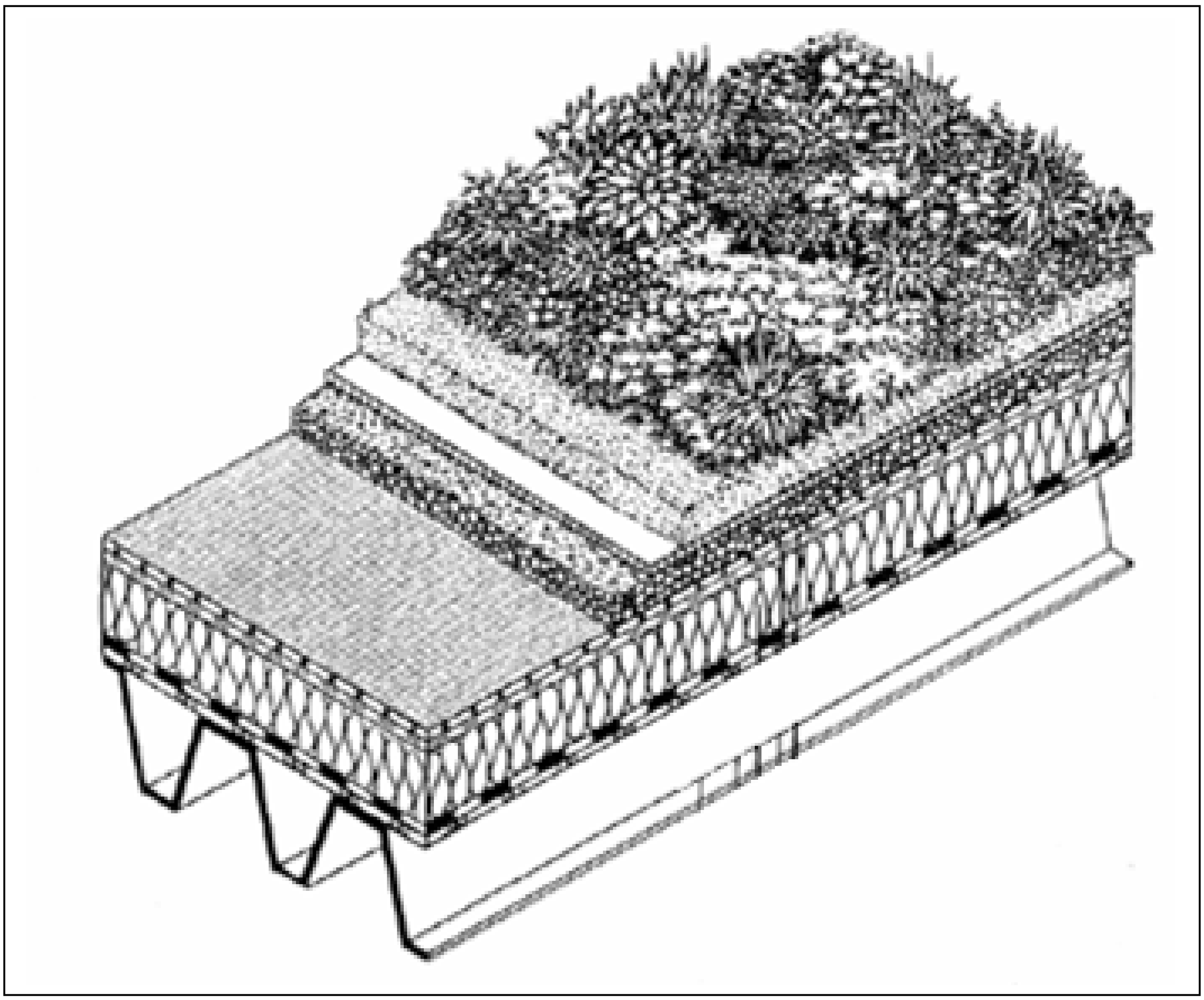

Figure 4.6: Components of the vegetated roof cover (USEPA, 2000).

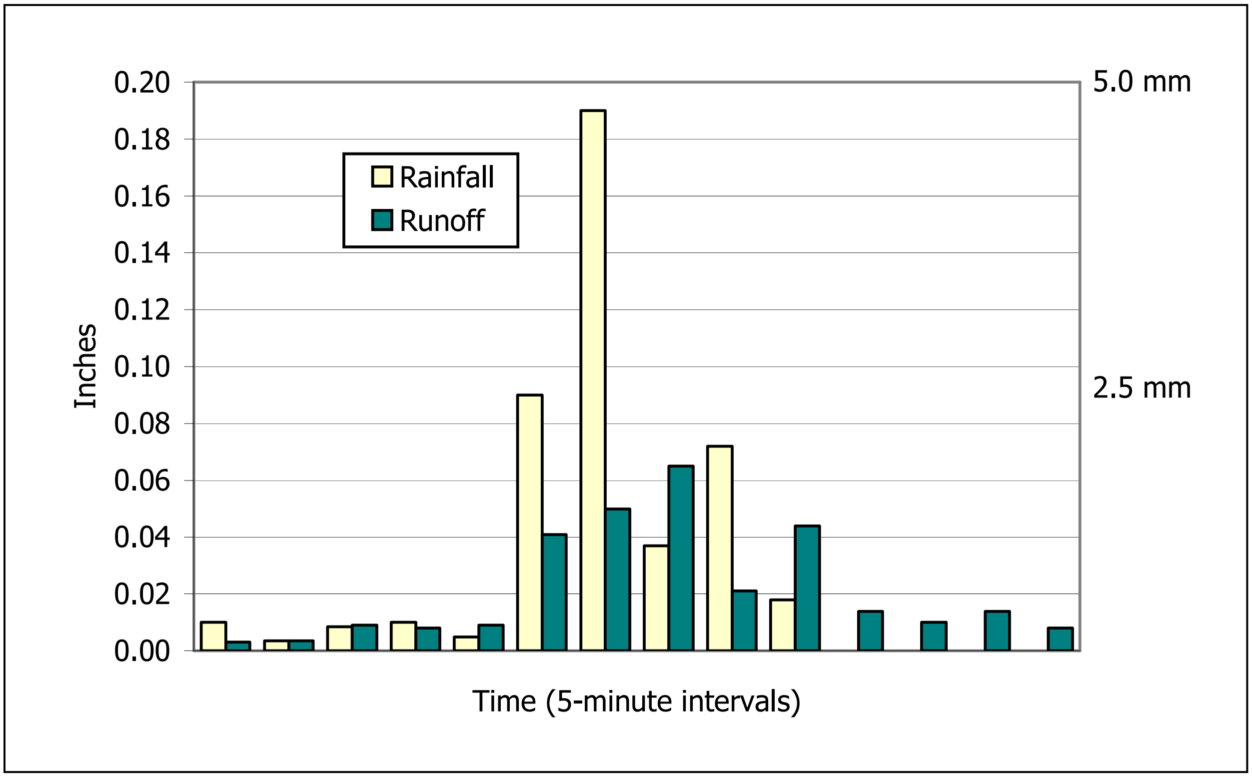

Figure 4.7: Runoff attenuation efficiency for a 0.4-inch rainfall event with saturated media (USEPA, 2000).

- Dust-trapping
- Evaporation and ambient cooling

Vegetation should be well-adapted to the growing conditions of the area where it is installed. Maintenance includes a limited amount of irrigation on steep slopes and periodic fertilization and weeding. Additional roof support might be necessary because the mats, when saturated with water, can add 5 to 17 pounds per square foot.

In response to a court order requiring $3 billion in storm water improvements, Atlanta is targeting commercial buildings for the installation of green roofs, with the anticipation that the resulting decrease in storm water runoff volume will provide water quality benefits. Commercial buildings are being targeted because commercial rooftops cover a huge amount of surface area in the city (Copeland, 2002).

Moran et al. (2004) studied runoff quality from two green roofs installed in North Carolina. They found that each green roof retained approximately 60 percent of the total recorded rainfall during a nine-month observation period. The green roofs reduced average peak flow by approximately 85 percent. Water quality data indicated higher concentrations of total nitrogen and total phosphorus were present in the green roof runoff than in the control roof runoff and in the rainfall at each green roof site. The researchers attribute this to nitrogen and phosphorus leaching from the soil media, which was composed of 15 percent compost. A soil column test of three different green roof soil media indicated that reducing organic matter in the soil media will

Rooftop Meadow Demonstration Project, Philadelphia, Pennsylvania

Rooftop meadows typically use foliage and a lightweight soil mixture to either absorb or filter and detain rainfall (Miller, 1998). Roof meadows are designed to control low-intensity storms by intercepting and retaining or storing water until the peak storm event has passed, while allowing the runoff from higher-intensity storm events to be safely conveyed away from the building. The plants help retain the hydrologic function of intercepting and delaying rainfall runoff by capturing and holding precipitation in the foliage, absorbing water in the root zone, and slowing the velocity of direct runoff by extending the flowpath through the vegetation.

A rooftop meadow demonstration project in Philadelphia, Pennsylvania, consists of a 3,000-ft^2 roof installed and monitored on top of an existing structure. The roof system was intended to mimic natural hydrologic processes of interception, storage, and detention to control the 2-year, 24-hour storm event. There are several distinguishing features of this rooftop meadow: (1) a synthetic underdrain layer that promotes rapid drainage of water from the surface of the roof deck; (2) a thin, lightweight growth medium that permits installation on existing conventional roofs without the need for structural reinforcement; and (3) a meadow-like setting of perennial *Sedum* varieties that have been selected to withstand the range of seasonal conditions typical of the Mid-Atlantic region without the need for regular maintenance.

The installed roof meadow is 3.4 inches thick, including the drainage layer, and weighs less than 5 lb/ft^2 when dry and less than 17 lb/ft^2 when saturated. The moisture content of the medium at field capacity is 45 percent of the volume. The saturated infiltration capacity is 3.5 inches per hour.

The runoff characteristics of the roof were simulated using rainfall records for 1994 from eastern Pennsylvania. The model predicted a 54 percent reduction in annual runoff volume and attenuation of 54 percent and 38 percent, respectively, for the 2- and 10-year, 24-hour Type II storm events. Monitoring of the pilot project for real and synthetic storm events was also conducted for a period of 9 months at 28- and 14-ft^2 trays. The most intense storm monitored was a 0.4-inch, 20-minute thunderstorm. The storm event occurred after an extended period of rainfall had fully saturated the medium. Although 44 inches of rainfall were recorded during this period, only 15.5 inches of runoff were generated from the trays. Runoff was negligible for storm events with less than 0.6 inch of rainfall. This demonstration project shows the advantages of reducing peak runoff rates on overloaded systems for a majority of the storm events and shows that some existing structures can be retrofitted to reduce runoff.

reduce the amount of nutrient leaching. Based on the results of this study, caution should be used when implementing green roofs in nutrient-sensitive watersheds; green roof components such as soil media composition should be selected with consideration of receiving water limitations.

Dunnett and Kingsbury (2004) describe examples of both large-scale and residential applications of green roofs and living walls, and they include technical information about constructing these structures in *Planting Green Roofs and Living Walls.* The authors cover structural engineering concerns as well as factors such as plant selection and environmental considerations that are important for the success of green roofs and living walls. The book is available for purchase at the Timber Press Web site at http://www.timberpress.com.

Another resource for information about green roofs is the proceedings of a conference entitled Green Roofs for Healthy Cities. A CD-ROM of the proceedings can be purchased from http://www.greenroofs.org/portland/proceedings.php and includes information on green roof design and implementation, technical research, and policy developments.

A Better Site Design Approach to Runoff Management: Low Impact Development

The goal of low impact development (LID) is to maintain and enhance the predevelopment hydrologic regime of urban and developing watersheds. LID focuses on managing runoff in small, cost-effective landscape features on each lot rather than conveying runoff to large, costly storm water ponds located at the bottom of large drainage areas. Hydrologic functions such as infiltration, ground water recharge, and depressional storage are maintained using simple, small-scale practices such as bioretention facilities. A key objective of LID is to reduce the hydraulic connectivity of impervious surfaces. For example, instead of allowing storm water to run from a downspout down a driveway and into a storm sewer, direct the runoff onto a lawn or other pervious area. By disconnecting rooftop runoff from the storm drainage system, a community can decrease the volume of water conveyed to a storm drain by as much as 50 percent (Pitt, 1986) and avoid treatment and storage costs, decrease system maintenance costs, and reduce instream impacts. To avoid soggy areas in lawns, water can be directed to specially designed depression storage areas such as bioretention or infiltration areas.

The following is a list of fundamental practices of the LID approach that can be included in runoff management plans. These practices are presented in two publications by the Department of Environmental Resources of Prince George's County, Maryland: *Low-Impact Development Design Strategies: An Integrated Design Approach* (2000a) and *Low Impact Development Hydrologic Analysis* (2000b).

- *Use hydrology as the integrating framework.* Hydrology is used as the key feature when designing a development. Areas that play a critical role in the movement of water (e.g., streams, riparian and buffer areas, floodplains, wetlands, and ground water recharge sites) are identified first. Alternative layout schemes are then evaluated in terms of their impact on site hydrology. Key objectives are to minimize the amount of impervious cover created and to make created impervious areas function as "ineffective" impervious areas that are not directly connected to a storm drain network.
- *Think micromanagement.* Site hydrology is analyzed and dealt with at small scales. Using natural drainage as a design element, integrated management practices are scattered throughout the site, allowing for runoff distribution and the retention of natural hydrologic functions such as infiltration, depressional storage, and interception.
- *Control runoff at the source.* Management of runoff at or near the sources eliminates the need for large-scale runoff management practices such as concrete conveyance systems and storm water ponds.
- *Incorporate safety features into the design of management practices*. LID practices can require diversions or drainage to allow for overflow of runoff from large storms and storm events that occur during saturated conditions. This emergency drainage will protect the longevity of the structural practice against damage from high runoff volumes and flow velocities and enhance the acceptance of LID in the community.
- *Use simple, nonstructural methods.* Natural hydrologic functions rely on simple processes that promote infiltration, depressional storage, and interception of storm water. These characteristics can be implemented throughout the site using simple methods that incorporate native plants, soil, and gravel.
- *Create a multifunctional landscape.* A goal of the LID approach is to create a landscape where runoff is micromanaged and controlled at the source. Runoff management practices and natural landscape features can be used in tandem to reduce postdevelopment runoff volume and maintain the predevelopment time of concentration.

The Prince George's County LID publications can be ordered through the Internet at EPA's National Service Center for Environmental Publications Web site at http://www.epa.gov/ncepihom. They can also be ordered by phone, fax, or mail from USEPA/NSCEP, P.O. Box 42419, Cincinnati, Ohio 45242-2419, toll-free 800-490-9198, fax 513-489-8695.

4.3.2.3 Relax frontage and setback requirements

Developers interested in increasing open space or conservation areas typically increase housing density by creating smaller lots or clustered developments and pool the space “savings” in a large open area accessible to all. This can be accomplished by reducing front, side, and rear yard setbacks and decreasing frontage distances. In addition to increasing housing density for open space development designs, relaxing frontage and setback requirements also decreases impervious cover. This occurs because narrower side yards mean narrower lots, which can in turn lead to shorter subdivision streets; shorter front yard setbacks lead to shorter driveways and sidewalks.

Frontage distance can be reduced by providing garage access through rear alleys. This approach eliminates driveways and allows homes to be sited on narrower lots. This helps reduce road frontage requirements and accommodate more homes on a given amount of road. Because of their limited traffic, the alleys can be paved with alternative treatments to retain more pervious area.

Areas with high potential for significant storm damage, earthquakes, or other catastrophes should take into consideration the appropriate setback distance to ensure emergency access in case of building collapse.

4.3.2.4 Modify sidewalk standards

Many conventional subdivision codes require paved sidewalks on both sides of the street in widths that range from 4 to 6 feet. Communities that want to reduce impervious cover and increase the use of pervious areas for runoff treatment should consider the following (always considering public safety first):

- Allowing sidewalks on only one side of the street or building them only where there is pedestrian demand;
- Increasing the distance between sidewalks and the street so sidewalk runoff has a better chance of infiltrating into the grass border area and not becoming street runoff. This will provide water quality as well as safety benefits;
- Grading sidewalks so that runoff drains into the yard rather than toward the street;
- Reducing the width of very wide sidewalks. Communities should consider the implications of reducing sidewalk widths, including pedestrian demand and wheelchair access, on a case-by-case basis. Three feet will typically allow passage for one wheelchair. Sidewalks in highly commercial areas and government centers should accommodate two wheelchairs abreast, but it may be appropriate for some residential areas to reduce sidewalk width to three feet.
- Maintain sidewalk widths but use porous pavement (see Management Measure 5).

4.3.2.5 Modify driveway standards

In a sense, driveways are small-scale parking lots that are designed to accommodate two to four cars. Typical residential driveways and parking pads often total 400 to 800 square feet. Communities that want to reduce driveway impervious cover should consider:

- Shortening driveway length by shortening front yard setback requirements;
- Narrowing driveway widths;
- Encouraging the use of driveways that are shared by two or more homes; and
- Providing incentives for use of alternative driveway surfaces that allow for infiltration, such as porous pavers, gravel, or a two-track surface with grass in between.

4.3.3 Residential Street and Right-of-Way Impervious Surfaces

The largest percentage of impervious cover in residential neighborhoods is typically associated with the streets, driveways, and sidewalks that together aid in the transport of people to and from their various destinations. Management practices associated with residential streets and their rights-of-way typically are focused on minimizing impervious cover or treating runoff. In general, these objectives can be achieved by developing, updating, or revising codes, ordinances, and standards that determine the size, shape, and construction of residential streets and their rights-of-way.

4.3.3.1 Decrease street pavement width and length

Streets typically make up the largest percentage of transport system impervious cover in residential neighborhoods. Communities can significantly reduce this type of cover in new developments by revising street standards so that street pavement widths are based on traffic volume, on-street parking needs, and other variables rather than requiring all streets to have one universal width. Additionally, communities can encourage developers to design street networks that minimize the total length of pavement. The length of residential streets can be reduced by altering the design and placement of new development. Techniques include:

- Reducing frontage distances and side yard setbacks;
- Allowing narrower lots;
- Clustering smaller lots;
- Reducing the number of non-frontage roads; and
- Eliminating long streets that serve only a small number of homes.

4.3.3.2 Decrease street right-of-way width

A street right-of-way is a public easement corridor through which people, vehicles, runoff, utility services, and other items and materials move in, out, and around the development. A right-of-way usually includes the street itself, its gutters and curbs, and some amount of land on either side of the street, which might contain sidewalks, utility easements, or other components. Options for minimizing right-of-way widths include:

- Eliminating some right-of-way components;
- Placing sidewalks on only one side of the street;
- Running utility pipes, cables, and other infrastructure underneath street pavement (this can result in traffic congestion from road construction if the infrastructure needs to be repaired or replaced); or
- Reducing street and sidewalk widths where appropriate.

On-street parking is a variable that should be closely examined in communities where reducing impervious cover is a goal. Some communities have implemented a concept known as “queuing streets.” Queuing streets generally have one travel lane and one or two parking lanes. Cars wait between parked cars until approaching traffic passes before proceeding to the travel lane. This approach also helps slow traffic, which can improve safety.

Street width must provide for utility work (common utilities include water, sewer, gas, cable, phone, power, and fiber optics). If the street width is reduced, utilities can be installed together in a concrete trench with a removable top for maintenance access (Matsuno, 2003).

When considering these options, it is important to remember that public safety should not be compromised and traffic engineering principles must still be a significant design factor. In addition, areas with high potential for significant storm damage, earthquakes, or other catastrophes should take into consideration the appropriate right-of-way width to enable passage of emergency vehicles.

The Headwaters Project: A Sustainable Community

In 1998 the Department of Planning and Development in Surrey, British Columbia, initiated the Headwaters Project to develop a real example of a sustainable community. Part of this project is the *East Clayton Neighbourhood Concept Plan* (The Headwaters Project, 2000), a green infrastructure plan that is an integrated system of “green” streets and affordable housing sites. It has narrow streets that use one-third less blacktop than typical roadways. Storm water management is achieved through natural infiltration, which minimizes runoff and avoids downstream flooding events. Information about East Clayton and a copy of the concept plan are available at http://www.sustainable-communities.agsci.ubc.ca/projects/Headwaters/PDF/toc.pdf

4.3.3.3 Use alternative cul-de-sac designs

Cul-de-sacs (roads with one open and one closed end) are a popular design element in community road networks. The intent of cul-de-sacs is to provide more homebuyers with premium, “end-of-the-road” lots. The typical “bulb” found at the closed end of a cul-de-sac, however, represents a particularly large concentration of impervious cover. Communities can reduce the amount of impervious cover created by bulb-ending cul-de-sacs by

- Eliminating cul-de-sac streets altogether;
- Using alternative designs for turnarounds, such as a T-shaped turnaround or a looped road;
- Reducing the radius of the turnaround bulb; or
- Incorporating a pervious cover island in the center of the turnaround bulb that accepts runoff.

As with modifications of street right-of-way width, public safety should not be compromised and traffic engineering principles must still be a significant design factor for this practice. Existing fire codes may dictate cul-de-sac width. Figures 4.8 and 4.9 show five turnaround options at the end of a residential street and the amount of impervious cover created by each option (Schueler, 1995).

4.3.4 Parking Lot Impervious Surfaces

Parking lots are considered by some to be one of the most damaging land uses in the urban landscape (CWP, 2000). Not only are parking lots very efficient at concentrating and delivering a large amount of runoff to receiving waters, thus exacerbating erosion problems, but they also act as a repository for pollutants associated with automobiles, which include nutrients, trace metals, and hydrocarbons.

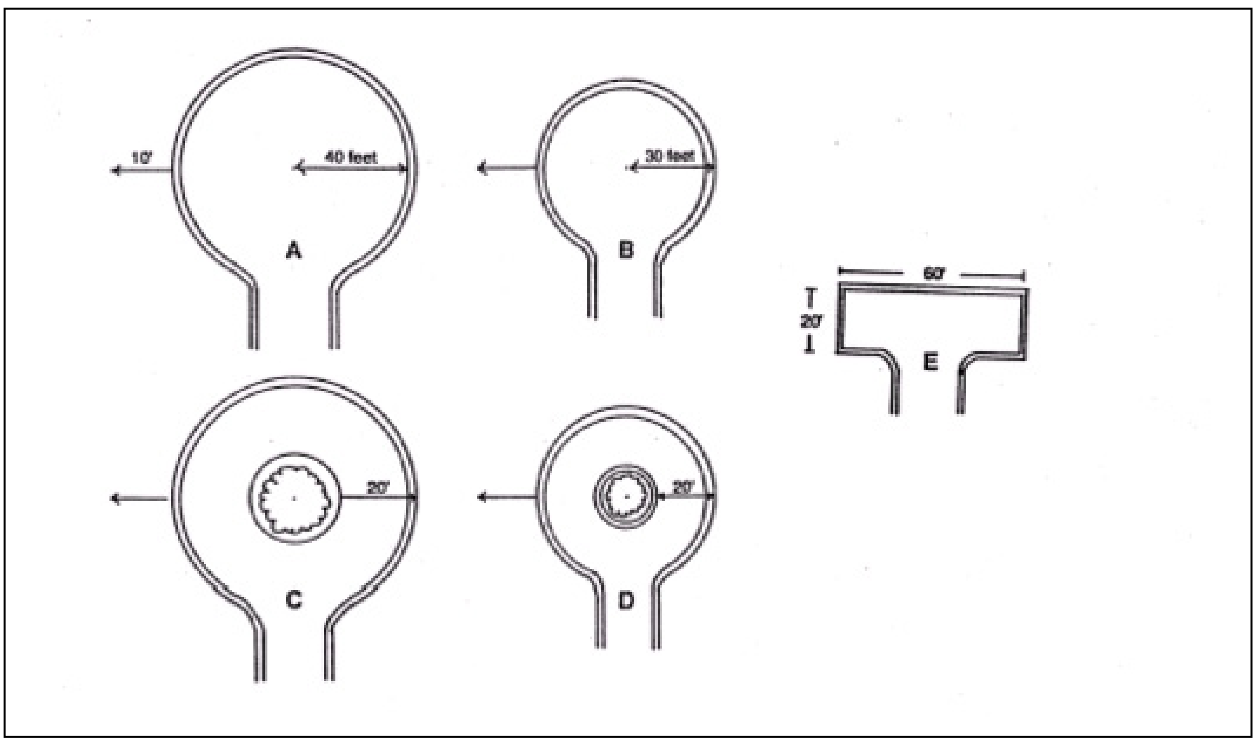

Figure 4.8: Five turnaround options at the end of a residential street (Schueler, 1995).

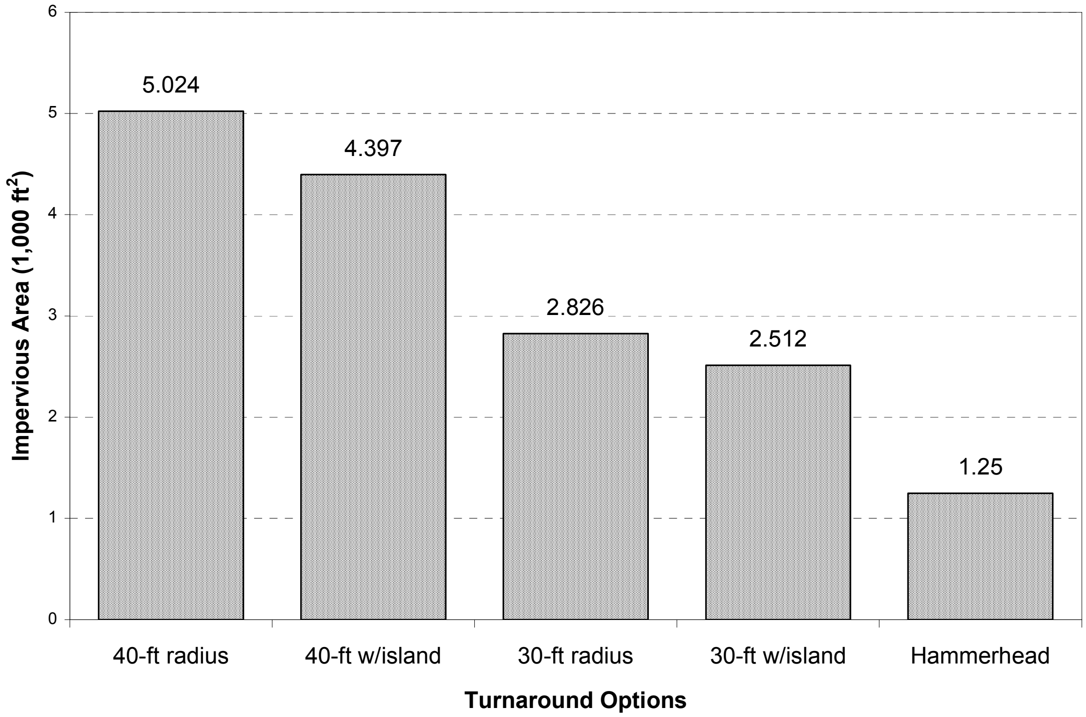

Figure 4.9: Impervious cover created by each turnaround option shown in Figure 4.8 (Schueler, 1995).

Innovative Turf Parking Lot Installation at a Connecticut Shopping Mall

The owners of Westfarms Mall, in the suburbs of Hartford, Connecticut, planned a 310,000-ft^2 expansion that required an additional 4 acres of overflow parking (Wilson et al., 1998). Local zoning boards and members of the community balked at this proposal because of the high ratio of impervious-to-pervious surfaces and concern for the quality and quantity of runoff generated by the new additions.

The traditional solution for handling the increased runoff was to install a large runoff detention pond, which would have cost $1million and was looked upon unfavorably by both the community and the mall owner. A 4-acre turf parking lot was implemented as an alternative and allows rainfall to infiltrate and recharge the ground water supply. To better support automobile traffic, the lot consists of a plastic honeycomb grid filled with sand and soil and laid atop a bed of crushed stone. Additionally, rooftop runoff is diverted to a tank located under the lot and the collected runoff is used to irrigate the turf. The turf would not hold up to everyday traffic, but overflow parking is needed only during the Christmas shopping season when the grass is dormant.

The cost of installing the turf lot was $500,000, which is half the cost of installing a pond. Even though the turf installation was more expensive than traditional pavement installation, the mall owner estimated that the installation would break even within 5 years because of lower maintenance requirements. An additional benefit of this innovative design was for the mall owner to gain the support of community members and local planning commissions.

Traditionally, developers have provided an overabundance of parking as a convenience for shoppers, workers, and landowners. A goal of watershed managers should be to reduce the surface area of parking lots and integrate runoff treatment practices to reduce adverse impacts, while still providing enough spaces to meet the expected parking demand. This reduction can be accomplished by implementing better site design practices, such as:

- Redesigning building and parking area layouts to reduce walking distances and provide more efficient layouts.

- Ensuring that the number of spaces built reflects actual demand. Site planners should design the lot size to correspond to minimum local parking requirements and consider ways in which this requirement can be reduced. For example, less parking is needed if access to public transportation is provided. Also, a parking area can be shared if localities in close proximity have different peak parking times. For instance, a retail establishment with peak demand during weekdays can share parking with a church whose peak demand is on the weekend.

- Sizing parking lot dimensions to meet everyday demand and designating additional "spillover" parking areas to handle peak demand. Because these spillover areas will receive less traffic, alternative paving techniques (see Management Measure 5) can be used to increase infiltration.

- Reducing the dimensions of the normal parking spaces if allowable. Also, developers can designate a percentage of the available parking spaces for use by compact cars and reduce their dimensions correspondingly.

- Building multilevel parking structures when feasible. (Parking structures can sometimes be impractical from a cost standpoint.) Green roofs can be used on these parking garages to reduce imperviousness.

- Converting parking lot islands to bioretention areas (see Management Measure 5).

- Building below-grade parking where it does not affect groundwater or other subsurface resources.

- Working with municipalities to regulate the maximum number of parking spaces allowed in development, rather than a minimum.

When parking area is reduced, functional landscaping can be used to improve the aesthetics of the site and to allow room for the installation of runoff treatment practices such as infiltration basins, filter strips, and dry swales or detention practices like those described in Management Measure 5.

4.3.5 Xeriscaping Techniques

Xeriscaping is a landscaping concept that maximizes water conservation by using site-appropriate plants and an efficient watering system. It involves the use of landscaping plants that need minimal watering, fertilization, and pesticide application, and practices that reduce water demand. For instance, mulching can help retain water and humidity and reduce the need for irrigation. Shading and windbreaks can reduce evaporation, particularly from young plants. In contrast to overhead sprinklers, drip irrigation waters plants directly on the roots without wetting plant leaves, helping to reduce evaporation and control disease. Timers are available that allow automatic watering with drip irrigation systems. Watering early in the morning can also reduce evaporation, and prevent the propagation of disease that often results from leaving foliage wet overnight (Relf, 1996). Xeriscaping can reduce the contribution of landscaped areas to nonpoint source pollution, and it can reduce landscape maintenance by as much as 50 percent, primarily as a result of the following (Clemson University Cooperative Extension Service, 1991):

- Reduction of water loss and soil erosion through careful planning, design, and implementation;
- Reduction of mowing by limiting lawn areas and using proper fertilization techniques; and
- Reduction of fertilization through soil preparation.

The specific benefits resulting from xeriscaping will vary based on the local climate and site conditions.

In 1991 the Florida legislature adopted a xeriscape law that requires state agencies to adopt and implement xeriscaping programs. The law requires that rules and guidelines be adopted for the implementation of xeriscaping along highway rights-of-way and on public property associated with publicly owned buildings constructed after July 1, 1992. Local governments are tasked with determining whether xeriscaping is a cost-effective measure for conserving water. If so, local governments are to work with the state water management districts in developing their xeriscape guidelines. Water management districts will provide financial incentives to local governments for developing xeriscape plans and ordinances. These plans must include:

- Landscape design, installation, and maintenance standards;
- Identification of prohibited plant species (invasive exotic plants);
- Identification of controlled plant species and conditions for their use;
- Specifications for maximum percentage of turf and impervious surfaces allowed in a xeriscaped area;
- Specifications for land clearing and requirements for the conservation of existing native vegetation; and
- Monitoring programs for ordinance implementation and compliance.

The law also includes a provision requiring local governments and water management districts to promote the use of xeriscape practices in existing developed areas through public education programs. California has passed a law requiring all municipalities to consider enacting water-efficient landscape requirements.

Water Conservation and Xeriscaping in Albuquerque, New Mexico

The City of Albuquerque, New Mexico, recently adopted a new strategy to encourage water conservation and to ensure a lasting water supply for years to come (Bennett, 1999). The strategy includes

- Reducing per capita water consumption by 30 percent.
- Developing facilities to treat and distribute city-owned surface water in combination with more limited use of the aquifer.
- Developing systems to use reclaimed wastewater and low-quality shallow ground water to irrigate landscaped areas in specific corridors of the community.
- Aggressive preservation of ground water quality.

The city also developed a new ordinance, the Water Conservation Landscaping and Water Waste Ordinance, that includes the following provisions:

- Prohibits irrigation water from flowing or spraying into streets, storm drains, or adjoining property.
- Limits high-water-use turf to 20 percent of the total landscape for all new developments.
- Establishes design requirements to discourage turf on steep slopes or adjacent to streets.
- Establishes water budget goals for parks and golf courses.
- Requires that new sprinkler systems on large turf areas meet minimum uniformity standards.
- Requires spray irrigation to occur between 6:00 p.m. and 10:00 a.m. from April to September.

The full text of the ordinance can be found at *www.cabq.gov/resources*.

As a result of these changes in Albuquerque's water conservation policy, the city's water consumption has decreased by 24 percent and its irrigation professionals have experienced a substantial increase in business as landowners seek smarter solutions to irrigation problems. Improvements in irrigation technology and increased public awareness are likely to further decrease water consumption.

4.4 Information Resources

In 1991 the Center for Watershed Protection published the *Consensus Agreement on Model Development Principles to Protect Our Streams, Lakes, and Wetlands*, which outlines the series of 22 nationally endorsed principles developed by the Site Planning Roundtable, a national cross-section of diverse planning, environmental, homebuilder, fire, safety, public works, and local government personnel, and details the basic rationale for their implementation. The *Consensus Agreement* can be purchased at http://www.cwp.org/.

The Center for Watershed Protection also published *Better Site Design: A Handbook for Changing Development Rules in Your Community* in 1998. This document outlines 22 guidelines for better developments and provides a detailed rationale for each principle. *Better Site Design* also examines current practices in local communities, details the economic and environmental benefits of better site designs, and presents case studies from across the country. It can be purchased at http://www.cwp.org/.

Wildlife Reserves and Corridors in the Urban Environment: A Guide to Ecological Landscape Planning and Resource Conservation, by Lowell Adams and Louise Dove (1989) reviews the knowledge base regarding wildlife habitat reserves and corridors in urban and urbanizing areas, and it provides guidelines and approaches to ecological landscape planning and wildlife conservation in such areas. It can be purchased from the Urban Wildlife Resources Bookstore at http://users.erols.com/urbanwildlife/bookstor.htm.

In 1997 Randall Arendt of the Natural Lands Trust, Inc., published *Growing Greener: Putting Conservation into Local Codes*. *Growing Greener* is a statewide community planning initiative designed to help communities use the development regulation process to their advantage to protect interconnected networks of greenways and permanent open space. The booklet can be downloaded in PDF format at http://www.dcnr.state.pa.us/growinggreener/growing.pdf.

The Low Impact Development Center was established to develop and provide information to individuals and organizations dedicated to protecting the environment and our water resources through proper site design techniques that replicate preexisting hydrologic site conditions. More information about this organization can be found on the Low Impact Development Center Web site at http://www.lowimpactdevelopment.org/ or by contacting the Center at 301-345-0440.

The Prince George's County, Maryland, Department of Environmental Resources produced two documents, *Low-Impact Development Design Strategies: An Integrated Design Approach* (EPA-841-B-00-003) and *Low-Impact Development Hydrologic Analysis* (EPA-841-B-00-002), that discuss site planning, hydrology, distributed integrated management practice technologies, erosion and sediment control, and public outreach techniques that can reduce storm water runoff from new and existing developments. Both publications can be ordered free of charge through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

Residential Streets, prepared by the American Society of Civil Engineers, the National Association of Home Builders, and the Urban Land Institute (1990), discusses design considerations for residential streets based on their function and their place in the neighborhood.

The publication presents guidance on street widths, speeds, pavement types, streetscapes, rights-of-way, intersections, and drainage systems.

The Institute of Transportation Engineers (ITE) published *Traditional Neighborhood Development—Street Design Guidelines* (1997), in which traditional neighborhood designs that support pedestrian movement over automobile traffic are discussed, and design concepts such as on-street parking, street width, and sight distances are presented. The publication also includes a practical discussion of the time needed for community acceptance and travel behavior changes. ITE also published *Guidelines for Residential Subdivision Street Design* (1993), which presents a discussion of the overall design of a residential subdivision with respect to the adequacy of vehicular and pedestrian access, minimizing excessive vehicular travel, and reducing reliance on extensive traffic regulations. It also provides design considerations for local and collector streets and intersections, including such topics as terrain classifications, rights-of-way, pavements, curb types, and cul-de-sacs. These publications are available through the Institute of Transportation Engineers, 525 School Street, SW, Suite 410, Washington, DC 20024-2797, (202) 863-5486.

Street Design Guidelines for Healthy Neighborhoods is a guidebook intended to help communities implement designs for streets that are safe, efficient, and aesthetically pleasing. This publication can be purchased from the Local Government Commission's Center for Liveable Communities Web site at http://www2.lgc.org/bookstore/topic.cfm?topicId=11.

The Congress for the New Urbanism has compiled a database of jurisdictions across the country that have adopted reduced-width street standards (Cohen, 2000). The database also includes resources related to neighborhood design and transportation. The database can be viewed at http://www.sonic.net/abcaia/narrow.htm.

EPA has compiled a number of resources on its *Low Impact Development (LID)* Web page, with links to Web sites, a literature review, fact sheets, and technical guidance. The Web site is accessible at http://www.epa.gov/owow/nps/lid/.

The Local Government Commission has published a guidebook to assist local communities in overcoming regulatory obstacles to smart growth. *Smart Growth Zoning Codes: A Resource Guide* helps planners design zoning codes that encourage the construction of walkable, mixed-use neighborhoods. The guidebook comes with a CD-ROM containing examples of the best U.S. zoning codes and other resources. The book can be purchased for $25 from http://www2.lgc.org/bookstore/topic.cfm?topicId=1.

Dunnett and Kingsbury (2004) describe examples of both large-scale and residential applications of green roofs and living walls and include technical information about constructing these structures in *Planting Green Roofs and Living Walls.* The authors cover structural engineering concerns as well as factors such as plant selection and environmental considerations that are important for the success of green roofs and living walls. The book is available for purchase at the Timber Press Web site at http://www.timberpress.com.

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