Chapter 3

Watershed Protection and *Smart* Site Design Requirements

What's in this Chapter?

Section 3.1 discusses the elements of a Smart site design approach and define terminology that is used throughout the remainder of this manual.

Section 3.2 describes the process of effective runoff reduction with green infrastructure for integrated stormwater management at different scales, at which stormwater runoff is avoided, minimized, and managed from downspout to river mouth.

Section 3.3 discusses site inventory and assessment protocols and checklists as well as descriptions of special management areas, which are areas that possess characteristics and/or limitations that affect the manner in which runoff reduction strategies may be implemented on a site.

Section 3.4 describes permanent stormwater design targets that are delineated into categories of runoff reduction, pollutant removal, and off-site mitigation.

3.1 Elements of *Smart* Site Design

3.1.1 What are Green Infrastructure and Runoff Reduction? (common terminology)

Tennessee's approach to permanent stormwater management on new and redevelopment projects addresses the following goals for protecting watershed hydrology and municipal and private property: 1) recharging groundwater and maintaining a natural hydrologic balance, 2) maintain water quality and ecological services that have historically characterized Tennessee's abundant natural water resources, and 3) prevent localized flooding. This is accomplished through a process that includes an integrated approach for stormwater management using a combination of structural and nonstructural strategies (ie. practices), which can be defined by the following common terms:

- **Stormwater Management:** any action taken to minimize and mitigate the negative impacts of hydrologic modification and pollutant additions (associated with stormwater infrastructure. This includes physical devices and techniques, but also more general strategies like minimizing fertilizer and pesticide use, reducing illicit discharges to drains, etc. Note that management will often take place between storm events through preventative approaches, though the purpose is to minimize contaminant availability and hydrologic impact during those events.
- **Stormwater Control Measures (SCMs):** are *Measures* meant to directly affect the flow of stormwater and/or contaminants, and that have defined specifications and standards. These Measures have one or both of two parts: 1) a defined surface *Management* to encourage infiltration and contaminant removal; and/or 2) a clear *Protocol* defining engineering design, installation, and maintenance. A *Measure* such as a "good forest" has just a Management, a *Measure* such as a manufactured stormwater treatment device has just an engineering *Protocol*, and a "bioretention cell" has both.

- **Management:** a clearly defined state of soil and vegetation that provides the desired degree of infiltration and contaminant removal under the design conditions. This design condition is considered to be 15 years following stabilization, when the site has reached a reasonable level of maturity and is undergoing only gradual changes. The Management is the defined desired endpoint, and depends on a series of Techniques to get from the current disturbed condition to that endpoint. A Management has clearly defined specifications in the Manual including vegetation type and density, soil hydrologic characteristics, etc. The term Cover is sometimes used to describe a Management that has minimal inputs.
- **Technique:** Method or operation that progresses or sustains progress from one state of management to another higher-functioning management. These can fall in either of two general categories:
    1) Methods of getting from "here" to "there"; from the presumed worst-case condition immediately following development to the desired *Management* endpoint. The *Techniques* used in a specific site design will vary greatly depending on these starting conditions. For example, if an area of "good forest" is left undisturbed, no Technique at all is necessary to achieve a "good forest" *Management*. On the other hand, if the post-construction condition is a bare highly-disturbed mixture of surface and subsoil and is heavily compacted by traffic, the required Techniques to achieve a "good forest" *Management* in 15 years may well include the following: soil ripping; soil amendments; temporary vegetative cover; slope erosion control to allow establishment of the temporary vegetation; planting of trees of a specified type, size, and density; and perhaps fertilization and irrigation schemes and other maintenance requirements.
    2) The operations necessary to maintain the required trajectory towards the desired design condition, and to maintain that condition once it is achieved. In other words, the Protocol for maintenance of a "good forest" *Management* may refer to *Techniques* for tree thinning, tree fertilization, and invasive removal. Note that the Protocol for a "fair forest" *Management* might refer to the same *Techniques*, but with less intensive requirements.

Figure 3.1: Stormwater management approach of storm drain stenciling, which identifies drains that discharge to local streams and states a no dumping regulation.

3.1.2 Design Goals and Approaches

Successful permanent stormwater management programs and plans integrate effective management early on in the planning process, prevent rather than mitigate stormwater impacts, and conserve site resources and lead design with the terrain in mind. In the following sections of this chapter, we introduce ***Smart*** site design as a process to achieve watershed protection elements in new development, maximize use of project site resources for stormwater management, and assist in minimizing the total treatment volume required for structural runoff reduction practices.

The goal of ***Smart*** site design is to plan how to generally reduce runoff volume while minimizing changes to pre-development site hydrology, and mitigate other environmental impacts as spatially close to the impact as possible. The benefits of ***Smart*** site design are most apparent when incorporated into the site planning process as early as possible. This typically requires that certain considerations and allowances for green infrastructure are made in the project concept phase. When applied early, the ***Smart*** site design approach can sharply reduce stormwater runoff and pollutants generated by development. This can reduce both the size and cost of stormwater conveyance infrastructure.

There are three guiding principles that help achieve a ***Smart*** site design. These guiding principles will ensure that the required runoff treatment volume (and cost) is as low as possible under given site conditions and project considerations. The guiding principles are as follows:

1. ***Avoid*** generating stormwater runoff all together by preserving natural features.
2. ***Minimize*** impacts of necessary land disturbance and total impervious surfaces.
3. ***Manage*** stormwater runoff with green infrastructure.

The ***Smart*** site design techniques described in the following section are proactive management practices that minimize treatment volumes and the need for structural practices as well as ensure the longevity of a hydrologically-functional project site.

***Smart* site design objectives include:**

- Avoiding the generation of stormwater runoff;
- Managing stormwater (quantity and quality) as close to the point of origin as practically possible and minimizing the use of large or regional-scale collection and conveyance systems;
- Preserving natural areas, topography, vegetation, and soils to reduce overall impact on watershed hydrology;
- Using simple, nonstructural methods for stormwater management that are lower in cost and lower maintenance needs than structural controls;
- Creating multifunctional landscapes; and
- Using natural drainage pathways (the site's hydrology) as a framework for site design.

Actions that can be taken to reach objectives:

- Shrinking cleared/disturbed land area and impervious surface footprints
- Increasing travel distances of concentrated runoff
- Maximizing sheet flow and vegetated areas
- Minimizing site and lot slopes
- Use open conveyances with undisturbed soil bottoms.

Avoid: In the project concept phase, there are many actions that may be taken to preserve or improve a site's capacity to absorb rainfall and minimize runoff – or as defined within, the landscape capacity for infiltration. These include preserving undisturbed natural areas, preserving riparian buffers, preserving or planting trees, avoiding development in floodplains, avoiding steep slopes, and minimizing disturbance on erodible soils.

There is a growing body of evidence indicating that headwater streams are the formative biogeochemical features of a watershed and have a profound effect on seasonal hydrology of stream systems. This evidence is contributing to the growing unified voice of researchers and professionals that recommend natural resource managers pay specific attention to headwater streams in conservation and protection elements of policy. While riparian buffers are requirements of site development plans and municipal stormwater permits, these areas are implicit volume reduction practices that minimize the need for explicit (or structure) management practices. Riparian buffers and protected natural areas do not contribute runoff volume in the overall site mass balance approach to green infrastructure implementation. Preservation of natural areas allows a designer to use "self-crediting" features on the site design plan. This may be accomplished by a combination of the following approaches: preserve natural topography within project layout, use natural drainage flowpaths and vegetated swales instead of storm pipes and curb and gutter, drain runoff to pervious areas, preserve landscape capacity for infiltration with minimizing grading extents, and berming and terraforming sloped areas to create small areas of depressional storage in infiltratable soils.

Minimize: Reducing impervious surface coverage reduces the need for runoff reduction and green infrastructure. When appropriate the following actions will reduce the volume of runoff for management in stormwater control measures: 1) reduce roadway lengths and widths, 2) reduce building footprints, 3) reduce parking area footprints, 4) reduce setbacks and frontages, 5) use fewer or alternative cul-de-sacs, 6) fit layout to terrain, 7) reduce limits of clearing and grading, and 8) utilize open space development.

Manage: Once all efforts are taken to avoid and minimize stormwater generation, there will be the need to implement structural SCPs to capture, manage, infiltrate, treat, and reuse runoff on site or in off-site mitigation projects. A suggested list of stormwater control practices including design specifications can be found in Chapter 5 of this manual. Check with you local municipal stormwater program for a list of locally-approved SCPs.

3.2 Watershed Protection – From Downspout to River Mouth

3.2.1 Green Infrastructure at Multiple Scales

Development patterns (e.g. where people live), community design, population density, and water availability have been intractably linked throughout the course of history. These development factors significantly affect how communities function in terms of water use and quality. Decisions are made regarding water resources on a daily basis that affect lifestyles, quality of life, and the overall sustainability of regions. Managing critical water and land resources through ***Smart*** site design can reveal multiple benefits to communities related to economic prosperity and good quality of life experiences for citizens. Water resource management is done using the watershed as the operational unit. We now know that using a watershed approach to development is also crucial for the sustainable growth of our communities.

The greatest benefit of implementing permanent stormwater management through green infrastructure and smart site design will be seen at the watershed scale in the improved quality and protection of our rivers and streams. By utilizing practices on multiple spatial scales (single lot, streetscape, neighborhood, city) to mimic natural hydrology at the watershed level, we will experience healthier streams and rivers in our communities. Community planning actions at the watershed-scale that will work to achieve this include:

1. **Compact and Mixed-Use Development** – Using small lots, higher densities, and a connected street system, compact designs are a strategy for reducing development footprints of city centers. Mixed-use development also decreases footprints by increasing transportation options and minimizing the need for wide/large freeways.
2. **Street Networks** – Creating a network of well-connected streets enhances traffic circulation while decreasing road footprints.
3. **Infill and Redevelopment** – Reusing existing impervious surfaces and existing infrastructure minimizes the generation of additional stormwater runoff.
4. **Stormwater Management Retrofits** – Investing in replacing gray infrastructure with green infrastructure decreases the impact on streams and rivers that receive urban runoff from existing developments.
5. **Open Space Development** – Clustering houses into one area and preserving open space minimizes land disturbance, protects native soils and vegetation, and creates opportunity for disconnection practices.

The fundamental difference between conventional and ***Smart*** site design development is the way in which a project is initially conceived. A conventional development typically deals with runoff as something to move away from the project site as quickly as possible. A ***Smart*** site design development project is conceived with rainfall and runoff management in mind throughout the planning phase, by placing value on the natural landscape capacity to absorb rainfall and preserving these elements of a site. When runoff is generated in excess of the landscape capacity, then that runoff is managed as close to its source as possible. Implementing the following principles in the concept phase of project development will ensure that the minimal amount of stormwater runoff is generated, therefore minimizing the size and extent of runoff reduction practices.

From the watershed scale to lot scale, the elements of ***Smart*** site design may be implemented in different applications to guide community development, neighborhood design, and individual parcel layout. The following tables outline the course of water resources from rainfall on a rooftop, through a watershed, and into receiving surface waters, and document how management practices have changed to achieve a watershed approach. Table 3.1 examines applications in a residential setting. Table 3.2 in a commercial setting.

Table 3.1: From Rooftop to Stream: Stormwater Management in a Residential Setting (Adapted from NAS 2009).

Approach	What it is	What it replaced	How it works
Land-Use Planning	Early site assessment	Performing stormwater management design after site layout	Map and design plan submitted at earliest stage of project development review showing environmental, drainage, and soil features
Conservation of Natural Areas	Maximize forest canopy, green space	Mass clearing	Preservation of priority forests and meadow and reforestation of turf areas to intercept rainfall
Earthwork Minimization	Conserve soils with good infiltration as well as existing contours	Mass grading and soil compaction	Construction practices to conserve soil structure and only disturb small site footprint
Impervious Cover Minimization	Smart site design	Large streets, lots and cul-de-sacs	Narrower streets, permeable driveways, clustering lots, and other actions to reduce pavement
Runoff Reduction – Impervious Surface Disconnection and Rainwater Harvesting	Using rooftop runoff	Directly connected roof gutters	A series of practices to capture, disconnect, store, infiltration, or harvest rooftop runoff
Runoff Reduction – Infiltration and Filtration	Front yard bioretention and vegetated swales	Drainage from roof to roadway; curb/gutter and storm drain pipes	Grading to treat roof, lawn, driveway, and roadway runoff using vegetated depressional storage and conveyance
Peak Reduction and Treatment	Linear wetlands	Large detention ponds	Long, multi-celled, forested wetlands located in the stormwater conveyance system
Aquatic Buffers and Managed Floodplains	Stream buffer management	Unmanaged stream buffers (building, mowing up to the stream bank)	Active revegetation of buffers and restoration of degraded stream channels

Table 3.2: From Rooftop to Stream: Stormwater Management in an Industrial Setting.

Approach	What it is	What it replaced	How it works
Pollution Prevention	Drainage mapping	No map	Analysis of the locations and connections of the stormwater and wastewater infrastructure from the site
	Hotspot site investigation	Visual inspection	Systematic assessment of runoff problems and pollution prevention opportunities at the site
	Rooftop management	Uncontrolled rooftop runoff	Use of alternative roof surfaces or coatings to reduce metal runoff, and disconnection of roof runoff for stormwater treatment
	Exterior maintenance practices	Routine plant maintenance	Special practices to reduce discharges during painting, powerwashing, cleaning, sealcoating, and sandblasting
	Extending roofs for no exposure	Exposed hotspot operations	Extending covers over susceptible loading/unloading, fueling, outdoor storage, and waste management operations
	Vehicular pollution prevention	Uncontrolled vehicle operations	Pollution prevention practices applied to vehicle repair, washing, fueling, and parking operations
	Outdoor pollution prevention practices	Outdoor materials storage	Prevent rainwater from contact with potential pollutants by covering, secondary containment, or diversion from storm drain system
	Waste management practices	Exposed dumpster or waste streams	Improved dumpster location, management, and treatment to prevent contact with rainwater or runoff
	Spill control plan and response	No plan	Develop and test response to spills to the storm drain system, train employees, and have spill control kits available on site
	Greenscaping	Routine landscape and turf maintenance	Reduce use of pesticides, fertilization, and irrigation in pervious areas, and conversion of turf to forest or bioretention
	Employee stewardship	Lack of stormwater awareness	Regular ongoing training of employees on stormwater problems and pollution prevention practices
	Site housekeeping and stormwater maintenance	Dirty site and unmaintained infrastructure	Regular sweeping, storm drain cleanouts, litter pickup, and maintenance of stormwater infrastructure
Runoff Treatment	Stormwater Retrofitting	No stormwater treatment	Filtering retrofits to remove pollutants from most severe hotspot areas
Illicit Discharge	Detection and Elimination	Outfall analysis	Monitoring of outfall quality to measure effectiveness

3.2.1.1 Watershed Scale

Approaches to avoid and minimize stormwater runoff are essentially design decisions that reduce impervious surface footprints. These design decisions are best implemented during the concept and initial development phase of a project. If these approaches are implemented correctly, then overall stormwater management costs will be minimized for a project.

Alternative and/or vertical (taller) building designs should be considered to reduce impervious rooftop area. Consolidate functions and buildings or segment facilities to reduce the footprint of individual structures. Figure 3.2 shows the reduction in impervious footprint by using a taller building design (Rhode Island, 2011).

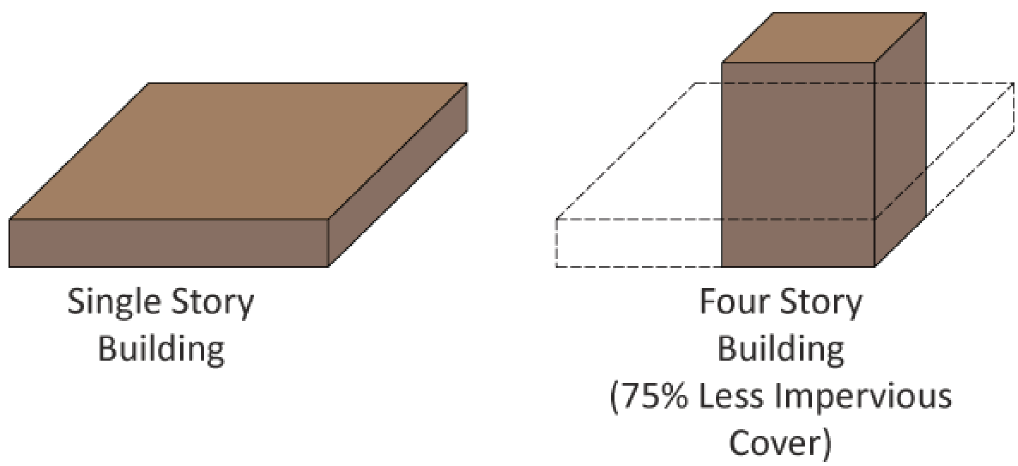


Figure 3.2: Simplistic representation of how a vertical design decreases the total amount of impervious surface created.

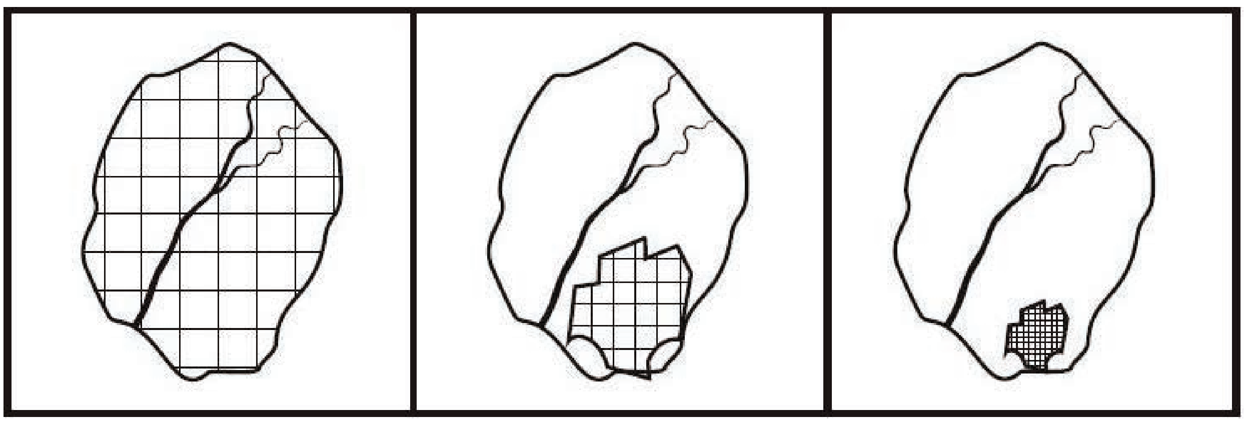
Higher housing densities may also better protect water quality, especially at watershed scale. According to the American Housing Survey, 35% of new housing is built on lots between two and five acres, and the median lot size is just below one-half acre (Census, 2001). Local zoning may encourage building on relatively large lots, in part because local governments often believe that it helps protect their water quality (US EPA, 2006). Communities have assumed that low-density development at the site level results in better water quality. Such conclusions are often drawn from analysis that assumes a one-acre site has one or two homes with a driveway and a road passing by the property and the remainder of the site is well-established lawn. However, this logic overlooks two key caveats.: first, that the "pervious" surface remaining in low-density development is in fact additional land disturbance and may create a hydrologic response that looks more similar to impervious surface than predevelopment forests, and that secondly, low-density developments often require more off-site impervious infrastructure for utilities, transportation, and safety (US EPA, 2006).

In the experimental scenario below (Figure 3.3), the USEPA used commonly accepted hydrologic models to examine the question of which type of development (high density or low density) protects overall watershed services better. At the watershed scale, there is less overall runoff generated from a high-density development than a low-density development due to the fact that there is more preserved undisturbed areas in the high-density development, which will naturally absorb much of the frequent small storm precipitation.

Scenario 1 | **Scenario 2** | **Scenario 3**

Scenario 1	Scenario 2	Scenario 3
Impervious cover = **20%**	*Impervious cover =* **38%**	*Impervious cover =* **65%**
Runoff/acre = **18,700 ft^3/yr**	*Runoff/acre =* **24,800 ft^3/yr**	*Runoff/acre =* **39,600 ft^3/yr**
Runoff/unit = **18,700 ft^3/yr**	*Runoff/unit =* **6,200 ft^3/yr**	*Runoff/unit =* **4,950 ft^3/yr**

Figure 3.3: Total average annual stormwater runoff for all scenarios (US EPA, 2006).



10,000 houses *built on* **10,000 acres** *produce:*	**10,000 houses** *built on* **2,500 acres** *produce:*	**10,000 houses** *built on* **1,250 acres** *produce:*
10,000 acres x 1 house x 18,700 ft^3/yr of runoff =	2,500 acres x 4 houses x 6,200 ft^3/yr of runoff =	1,250 acres x 8 houses x 4,950 ft^3/yr of runoff =
187 million ft^3/yr of stormwater runoff	**62 million ft^3/yr of stormwater runoff**	**49.5 million ft^3/yr of stormwater runoff**
Site: *20% impervious cover*	***Site:*** 38% impervious cover	***Site:*** 65% impervious cover
Watershed: *20% impervious cover*	***Watershed:*** 9.5% impervious cover	***Watershed:*** 8.1% impervious cover

Figure 3.4: 10,000-acre watershed accommodating 10,000 houses (US EPA, 2006).

3.2.1.2 Project Site Scale

Mixed-use development can also reduce parking lot footprint with shared parking. Shared parking can be defined as parking utilized jointly among different buildings and facilities in a single area to take advantage of different peak parking characteristics that vary by time of day or day of the week. Since most parking spaces are only used part time, shared parking arrangements are designed to more efficiently meet the needs of areas that exhibit a mix of uses with varying peak parking demands. For example, many businesses or government offices experience their peak business hours during the daytime on weekdays, while restaurants and bars peak in the evening hours and on weekends. This presents an opportunity for shared parking arrangements where several different groups can use an individual parking lot without creating conflicts (RIDEM, 2011).

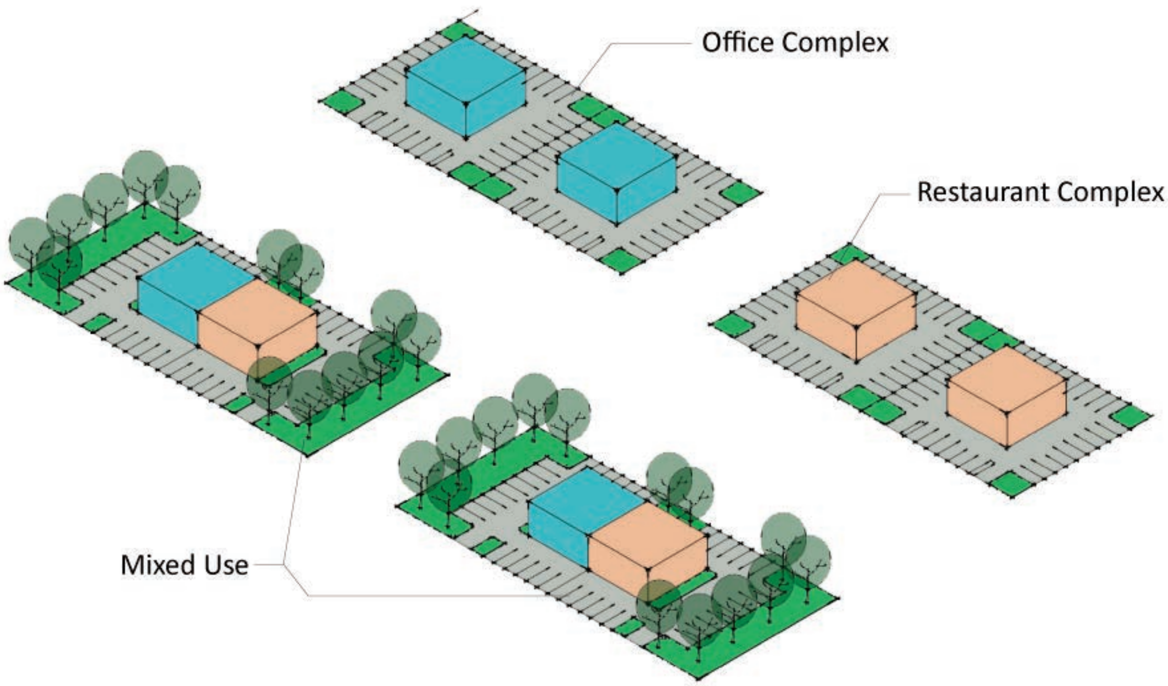


Figure 3.5: Example of separate complex development and mixed-use development.

Mixed-use development is not a new planning concept. Many of the region's older downtowns and neighborhood centers have homes, shops, offices, and schools built closer together and connected by a fine grid of streets that allow people to walk, bike or take transit in order to meet their daily needs. This approach not only replicates the pedestrian-friendly character of the older parts of the cities, but also benefits water quality by reducing the overall amount of impervious surface dedicated to streets and parking lots (US EPA, 2009).

Residential road layout generally fall into 3 categories: grid, curvilinear, and hybrids of the two. As illustrated in the figure and table below, grid and curvilinear layouts have practical benefits, and hybrid designs attempt to take the best features of the two (Hinman, 2005).

Table 3.3: Description of residential road layout.

Road pattern	Impervious coverage	Site disturbance	Vehicle Efficiency	Biking, Walking, Transit
Grid	27-36%	Less adaptive to site features and topography	More efficient – disperses traffic through multiple access points	Promotes by more direct access to services and transit
Curvilinear	15-29%	More adaptive for avoiding natural features, and reducing cut and fill	Less efficient – concentrates traffic through fewer access points and intersections	Generally discourages with longer, more confusing, and less connected system

Figure 3.6: From left to right: grid, curvilinear, and hybrid pattern (AHBL Engineering).

Streets offer unique opportunities for handling and treating their runoff, but conventional street design practices focus primarily on moving the automobile and diverting runoff to the curb and gutter, contributing to increased runoff volume and poor water quality (US EPA, 2009). Residential streets and private streets within commercial and other development should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency access. Many communities require minimum street widths that are much wider than needed to support travel lanes, on-street parking, and emergency access. Access streets in subdivisions often are wider than the collector and higher order streets that receive their traffic. Ironically, excessively wide streets encourage excessive speed as well (RIDEM, 2011). Narrower streets can be used in most residential development that generate less than 500 average daily trips (ADT), perhaps widths of 22–26 feet (Cook, 2007). Narrower streets could also be feasible for streets with 500–1,000 ADT (US EPA 2014).

Road length also is an important issue. Road length should first be addressed from a macro level planning perspective. Obviously overall dense patterns of development result in dramatically less road construction than low density patterns, holding net amount of development constant. High-density development and vertical development contrast sharply with low density sprawl, which has proliferated in recent years and has required vast new highway systems throughout urban fringe zones (RIDEM, 2011).

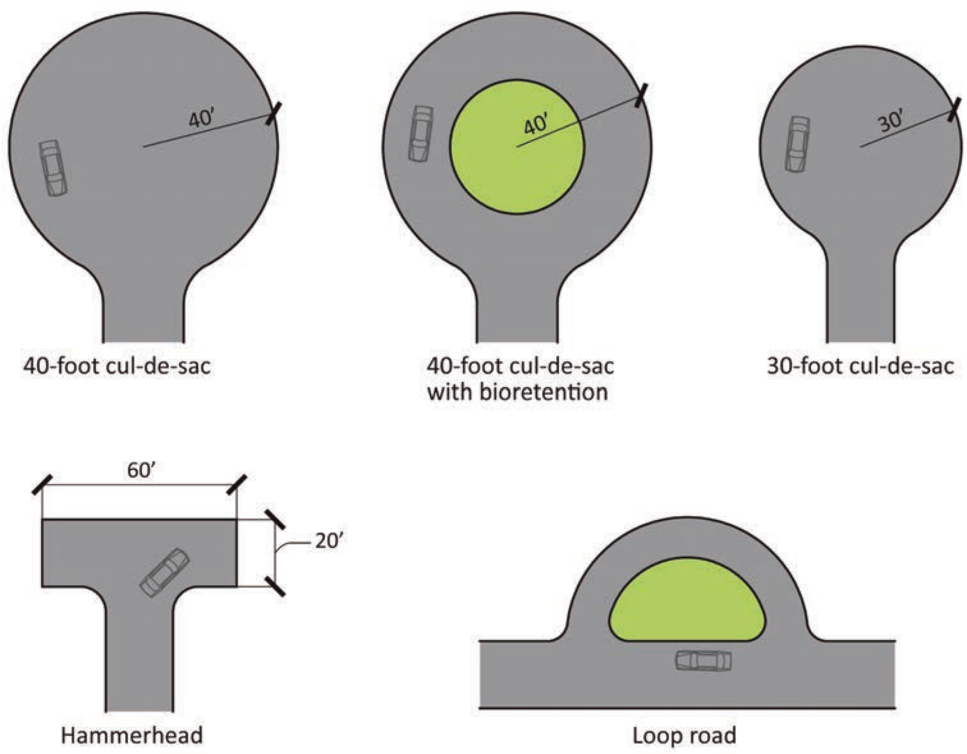


Figure 3.7: Various road designs. (adapted from Schueler, 1995).

Parking lots, like streets, make up large areas of impervious surface and contribute to polluted runoff. Set appropriate parking ratios for development projects and allow businesses to count underused nearby on-street parking spaces toward meeting their parking requirements.

Cul-de-sacs can also needlessly increase impervious area. In general, cul-de-sac should be discouraged; however, a number of alternatives are available where topography, soils, or other site-specific conditions suggest this road design.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac (Fig. 3.6). These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerhead tee or a loop. Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and many school buses usually do not enter individual cul-de-sacs (RIDEM, 2011).

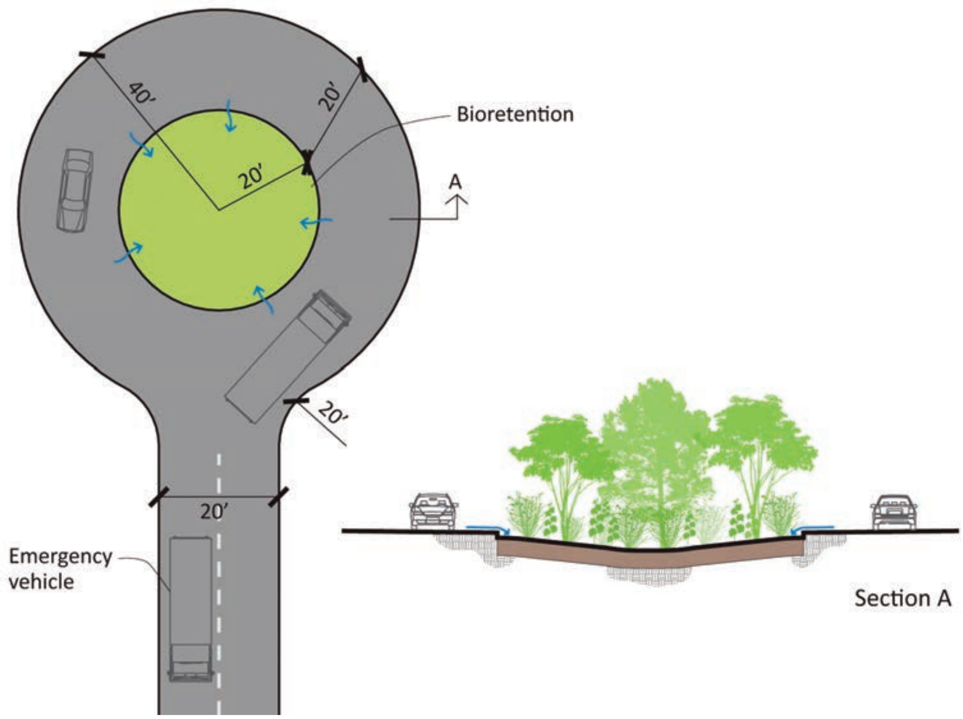


Figure 3.8: Cul-de-sac with bioretention.

Right-of-ways (ROWs) are pieces of land reserved for transportation, utilities and other uses. One inch of rain falling on one block of typical city street (40’ x 300’) generates some 6700 gallons of stormwater runoff. This runoff can become a problem for communities in the form of downstream flooding and non-point source pollution or it can become a resource providing moisture for neighborhood vegetation if captured close to the source. Many ROWs are un-vegetated, featuring only earthen areas of compacted dirt or uniform gravel. These areas can be turned into rain gardens that infiltrate stormwater from neighborhood streets. ROWs are legally and logistically easier to work in than the street itself, making them good locations for volunteer-led neighborhood tree-planting efforts and green infrastructure projects (McAdam, 2010).

Figure 3.9: A low-density street in Knoxville, TN (Source: SMART Center).

Figure 3.10: Some street retrofitted with linear bioretention, bike lane, and street trees (Source: SMART Center).

Eliminating curbs and gutters on streets will typically require installation of a grass or vegetated swales to accept the stormwater runoff from the street. Traditional curbs and gutters are very effective at quickly collecting and delivering stormwater runoff to a central location for storage and possibly treatment. As a result, they provide no opportunity for removal of pollutants. Elimination of curbs and gutters and the introduction of vegetated swales, bioretention and filter strips to collect and convey runoff are suitable for a range of conditions. Where adequate space exists and traffic conditions will allow, this approach will allow for filtering, infiltration, and reduction of peak runoff volumes and flow velocity. (Cook, 2007)

3.2.1.3 Lot Scale

Structural SCMs can also be used in conjunction with the previously mentioned nonstructural approaches for runoff reduction. SCM design specification and implementation information can be found in Chapter 5. These practices are designed to capture a specific volume of runoff from the impervious surfaces of a residential or commercial site and can be integrated into a larger site plan.

Lot scale stormwater management is greatly effective because it captures and manages stormwater runoff close to the point of origin. Using a system of small, diffuse structural measures to meet runoff reduction and pollutant removal targets is generally less demanding with regards to the level of complexity in engineering design and needed physical materials. However, this approach requires more coordination between property owners and their involvement in the maintenance of structural measures to ensure they are functioning as designed.

Figure 3.11: Photographs of lot scale runoff reduction measures. Left: a roadside vegetated verge (ie. no curb or gutter) that accepts roadway runoff, uses engineered soils to infiltrate runoff, and conveys excess runoff to a small treatment wetland. Right: a residential rain garden captures and infiltrates runoff from half of the house rooftop and driveway.

3.2.2 The Role of Redevelopment

Redevelopment is defined as new construction on a site that has pre-existing uses. Promoting infill development and redevelopment is desirable because it takes pressure off the suburban fringes, thereby preventing sprawl, and it minimizes the creation of new impervious surfaces. However, redevelopment is more complex because of the need to upgrade existing infrastructure, the limited availability and affordability of land, and the complications caused by rezoning. These sites also may require cleanup or remediation before redevelopment can occur (see section 3.3 for special management areas). Innovative zoning incentives along with careful selection of SCPs are needed to achieve fair and effective stormwater management systems in these areas.

Table 3.4: From Rooftop to Stream: Stormwater Management in Redevelopment Projects.

Approach	What it is	What it replaced	How it works
Smart Site Design	Site design to prevent pollution through minimizing impervious cover	Conventional site design	Designing redevelopment footprint to restore natural area remnants, minimize needless impervious cover, and reduce hotspot potential
Runoff Volume Reduction – Disconnection and Rainwater Harvesting	Rooftop treatment on the roof or in the landscaping	Traditional rooftops and directly connected downspouts	Use green roofs to reduce runoff generation; Use rain tanks to capture and reuse rainfall; Use rain gardens to capture and infiltrate parking lot and rooftop runoff.
Soil Conservation and Reforestation	Runoff reduction in pervious areas and increased tree canopy	Impervious or compacted soils and turf grass	Reduce runoff from compacted soils through tilling and compost amendments; Providing adequate rooting depth for mature tree development.
Runoff Reduction – Subsurface	Increase permeability of impervious cover	Impermeable asphalt or concrete	Use of permeable pavements to decrease runoff and infiltrate/store in subsurface.
Runoff Reduction – Vegetated	Runoff treatment in the street	Sidewalks, curb and gutter, and storm drains	Use bioretention planter boxes to capture, filter, and/or infiltrate runoff.
Runoff Treatment	Filtration for water pollutants	Catch basins and storm drain pipes	Use underground sand filters or other devices to treat hotspot runoff.

Approach	What it is	What it replaced	How it works
Municipal Good Housekeeping	Street cleaning	Unswept streets	Targeted street cleaning on priority streets to remove trash and sediment/solids.
Watershed Planning	Off-site stormwater treatment or mitigation	On-site waivers	Stormwater retrofits or restoration projects elsewhere in the watershed to compensate for stormwater requirements that cannot be met on-site.

3.3 Site Inventory and Assessment

Smart site design may only be fully attained with a complete and thorough initial site inventory and assessment of existing hydrologic function and documentation of special management conditions. The section below outlines the components of a site inventory and assessment, as well as delineates special management areas based upon the presence of native and built conditions.

There are many conditions that affect the way water moves through a site. As the MS4 permit states, pre-development infiltrative capacity of soils at the site, otherwise defined as a site's ***landscape capacity*** throughout the remainder of this manual, must be taken into account when determining runoff reduction requirements. ***Special management areas***, defined later in this chapter, must also be taken into account through conditional design requirements in order to ensure the protection of water quality and SCM function. Local stormwater programs must create provisions that allow development to occur under these special circumstances while not setting requirements that force design and implementation to go above and beyond practicable efforts.

3.3.1 Protocols and Checklists

The intended use of a project site greatly affects the selection and performance of stormwater management approaches, the implementation of smart site design and selection of stormwater control measure. Characteristics that delineate land use types are described in generalities below:

- **Rural:** Impervious surface is generally widely dispersed, significant percentage of acreage is in managed turf, and areas are especially suited for minimization and avoidance approaches as well as vegetated infiltration controls. Generally the existing condition for a greenfield development project.
- **Residential:** Medium to high density residential developments (< 1/3 acre lot size), generally limited open space relative to rural areas, and measures are likely to be proximate to homes and buildings, creating a greater need to address safety, mosquito, and maintenance considerations.
- **Roads and Highways:** Linear corridors that typically generate high stormwater pollutant loads due to vehicle traffic and road maintenance activities (ie. deicing), and limitations on use of measures are generally dependent on adequate space for pretreatment as well as design for large storm conveyance.
- **Commercial:** Variable size and managements of drainage areas, potential for large sub-basin drainage scale measures, and limitations due to site-specific characteristics and flowpath routing.
- **Industrial:** Variable size and managements of drainage areas, high potential for hotspots, and limitations due to site-specific characteristics and flowpath routing.

The following table shows how specific SCMs are recommended or considered conditional for use within a project land use context (Table 3.5).

Table 3.5: Stormwater Control Measure Recommendations Based on Project Land Use.

Stormwater Control Measure	Rural	Residential	Roads & Highways	Commercial	Industrial
Filter Strips[1]	preferred	preferred	preferred	preferred	limited[2]
Infiltration Areas	preferred	preferred	conditional[2]	limited[3]	conditional[2,3,5]
Bioretention	preferred	preferred	conditional[2]	limited[2]	conditional[2,5]
Permeable Pavement	limited[6]	limited[6]	limited[6]	preferred	conditional[2,5]
Vegetated Swales	preferred	preferred	preferred	limited[7]	limited[7]
Managed Vegetated Areas	preferred	preferred	preferred	preferred	preferred
Rainwater Harvesting	preferred[4]	preferred[4]	NA	conditional[4]	conditional[4]
Manufactured Filter Device	limited[9]	limited[9]	preferred*	preferred*	preferred[2]
Stormwater Wetlands	preferred[2*]	preferred[2*]	preferred[2*]	preferred[2*]	preferred[2*]
Green Roofs	limited[8]	limited[8]	NA	limited	limited

* *Preferred method for water quality treatment where infiltration is not allowed.*
Preferred – Most effective selection.
Limited – Likely not the best selection, but may be applicable. May have conditional use requirements.
Conditional – May be permitted under certain conditions and needs granted approval from the local stormwater program.

1 Filter Strips include sheet flow to infiltration areas.
2 May require pretreatment depending on land use and pollutant loading.
3 Intended for residential or other small impervious surface areas.
4 Requires a designated reuse activity.
5 Depending on land use, may limit infiltration and require additional maintenance.
6 Maintenance requirements.
7 Drainage area and large storm conveyance.
8 Typical residential roof geometry restricts application.
9 Excessive maintenance burden of underground systems in residential areas.

Existing Hydrologic Function: The first step in creating a conceptual development plan is to document existing site conditions, which greatly affect site hydrology and have an impact on the practicality and successful implementation of runoff reduction practices. Designers must identify any physical constraints at the project site that may restrict or preclude the use of particular SCMs and determine the ***landscape capacity*** for infiltration of rainfall. The primary factors to assess are described in detail below. More detailed site investigations may be required to adequately address some constraints and may be necessary on a site-by-site basis.

1. **Soil Texture:** The most relevant soil information is the Hydrologic Soil Group classifications and can be found for most areas in the web soil database (NRCS site link). In areas that are not mapped, field core data must be provided to describe soil texture and color as well as any redoximorphic features. Soil hydraulic conductivity information may be found in the web soil survey (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) but also must be verified through one of the suggested field tests (See Appendix A).
2. **Depth to Water Table:** Shallow water tables may lead to SCM failure or contamination of groundwater if certain practices are used. This information may be found in soil surveys and should be verified through field observations.
3. **Depth to Bedrock:** Shallow bedrock may limit the effectiveness of infiltration practices. Depth to bedrock information must be either obtained through the soil survey or determined through field observations.
4. **Topography:** This is the overall lay of the land and dictates the flow of surface water and groundwater. Topography may be found in online databases for conceptual planning purposes or surveyed in the field using surveyor's equipment for complete project design. Land slope governs the way water moves in overland flow and concentrated flow and has a large influence on retention capacity

of a site. Slope can be determined using topographic maps (1:24,000) but must also be documented through a detailed site survey at the scale required for plan submission by the local stormwater program.

5. **Contributing Drainage:** This is the land area that drains to a point of interest. For structural SCMs, the contributing drainage area must be determined from the final grading plan in order to accurately design the system.

3.3.2 Special Management Areas

These areas are those that possess a characteristic or condition that either limits the use of runoff reduction techniques or changes the design of structural practices to accommodate for the condition. These are divided into two general categories, natural conditions and built conditions. They are described below. These conditions are those that limit the landscape capacity for infiltration, and therefore affect the applicable runoff reduction approach and design level for practices. If these conditions exist on your site, then actions must be taken either through SCM selection or design to account for these conditions. Check with your local stormwater program for special procedures.

1. **Natural Conditions**: Natural conditions that create special management areas are those that are characteristic to the physiographic region and limit the landscape's capacity to infiltrate stormwater runoff. Conditions of concern for green infrastructure design are described below. Additional conditions may be identified by the local stormwater program.

   a. **Karst geology** – a unique type of landscape that is formed by the dissolution of rocks, such as limestone and dolomite. Karst areas have aquifers and a high potential to contain large preferential pathways in soil overburden that are directly connected with the groundwater. This is a concern regarding green infrastructure design because increasing infiltration in a karst area may lead to structural failures in subsurface layers and above ground structures. See Appendix B for detailed guidance on green infrastructure design in karst geology.

   b. **Steep Slopes/Erodible Soils** – a combination of steep topographic relief (greater than 25%) and non-colloidal soils that are easily erodible. This is a concern in green infrastructure design because the preferred method for runoff reduction and pollutant removal is through infiltration. The preferred method of development on sites containing steep slopes is to protect these areas (e.g. exclude in extent of site disturbance) and not increase the amount of run-on to these areas. If this is not possible, the options for use of green infrastructure on steep slopes is to: 1) re-vegetate or use biotechnical stabilization practices, 2) divert water away from the steep slope area, to a lower elevation without causing erosion, and 3) use a combination of terracing and vegetative filter strips on the slope as a stormwater control measure.

   c. **High Water Table** – areas that have a seasonally high water table that exists within 4 feet of the soil surface. This limits the use of infiltration-based green infrastructure practices and may indicate desirable conditions for stormwater wetlands. If this condition exists on only a portion of a project site, the remainder of the project site would be better suited for infiltration-based practices.

   d. **Shallow Soils** – soil profiles that measure less than 4 feet above bedrock or confining soil layer. The presence of shallow soils on a site limits the effectiveness of infiltration-based stormwater control measures and may indicate the need for alternative pollutant removal goals (rather than runoff reduction). If this condition exists on only a portion of a project site, the remainder of the project site would be better suited for infiltration-based practices.

   e. **Low Permeability Soils** – soils that have low infiltration rates and therefore cause rainfall to runoff the surface at a relatively faster rate than soils with high infiltration rates. These soils have high clay content and may be the result of compaction.

   f. **Sensitive or Impaired Receiving Waters** – areas within the watershed boundaries of a sensitive or impaired waterway (designated by a state or local program) may have unique requirements for stormwater management that changes the selection and design of green infrastructure practices. For a list of impaired waterways, access the State's 303(d) list at the Tennessee Department of Environment and Conservation's website :

   (http://www.tn.gov/environment/water/water-quality_publications.shtml)

Check with your local municipal program for information on local sensitive water resources and additional requirements.

2. **Built Conditions** – As with natural physical conditions, pre-existing built (or anthropogenic) conditions on a project site may also affect site hydrology and successful implementation of runoff reduction measures. These are described below:
   a. **Brownfield/Soil Contamination** – Previously designated contamination due to a pre-existing land use on the project site. These conditions generally need to be remediated to a level where green infrastructure and site development will not transport contaminants downstream or into groundwater.
   b. **Pollution Hotspots** – land use characteristics that pose a relatively higher potential to contribute to surface or groundwater pollution due to the nature of contaminants that are associated with the operations and land use. Some examples of these are, but not limited to, gasoline stations, trash collection areas, mulching operations, chemical storage facilities, car washes, nurseries, etc.
   c. **Groundwater Pollution Potential** – projects that contain land use characteristics that have the potential to contribute groundwater pollution if infiltration was used on site.

3.4 Site Design Targets

The MS4 permit requires a design to meet specific performance standards for the management of the first inch of a representative rainfall event. Runoff reduction is the preferred approach, as it can achieve both volume reduction and pollutant removal. Through the site assessment, if it can be shown that site limitations exist that make it a hardship to achieve performance goals with runoff reduction, then provisions allow for a designed system to address a secondary set of performance goals to reduce runoff to the maximum extent possible and treat all remaining runoff from the first inch of rainfall for pollutant removal.

The following is a preference-based list of characteristics for systems of stormwater control measures within the Tennessee Runoff Reduction Assessment Tool (TNRRAT) to show performance-based outcomes:

1) Measures that increase infiltration, as those meet all three overarching goals of reducing runoff, protecting baseflow, and removing pollutants.
2) Measures that reduce runoff without infiltration (capture and reuse), as these minimize the long-term stream degradation and generally result in a decrease of pollutants reaching a stream.
3) Measures that solely treat the runoff to remove pollutants without affecting total runoff volume.

Smart site design may be accomplished along a spectrum of levels depending on landscape capacity and existing site conditions. The applicable level of design is determined through the site assessment process as well as during the pre-concept design meetings between the project manager/developer and the local stormwater program. The three basic design levels are described below.

Primary – ***SCMs for Runoff Reduction:*** These project designs meet the minimum runoff reduction requirement for new development and redevelopment projects through Smart Site Design to achieve optimal practice performance and maintain landscape capacity.

Secondary – ***Pollutant Removal Treatment:*** These project designs are implemented in areas deemed unable to meet the Primary design level minimum requirement for runoff reduction by site assessment protocols or other special management conditions. These projects meet the secondary minimum requirement for 80% TSS removal.

Tertiary – ***Resource Protection for Special Conditions or Mitigation:*** These project designs go above the minimum 1” retention standard in that the site utilizes the full elements of Smart site design to protect natural features, design stormwater management facilities for a greater design rainfall capture depth, and minimize disturbance (i.e. managing stormwater run-on from adjacent, existing areas, or retrofitting). Retrofit or redevelopment projects meeting this level may be eligible to generate mitigation credits, depending on the local municipal program.

Elements of *Smart* Site Design

1. **Minimize impervious surfaces** – shrink the impervious footprint of sites by reducing the width of roads, replacing impervious surfaces with permeable alternatives, and avoiding gridded street layouts.
2. **Preserve, protect, create, and restore ecologically sensitive areas** – during development stages, take actions to protect perennial streams, wetlands, 100-year floodplains, karst features, and steep slopes.
3. **Prevent or reduce thermal impacts to streams** – create and maintain riparian buffer vegetation and use practices that disconnect runoff from impervious surface conveyances and directs it onto permeable areas.
4. **Avoid or prevent hydromodification of streams and other waterbodies** – Minimize the number of stream crossings or other water resources modificiations to prevent water quality and resources degradation due to hydromodification.
5. **Protect trees and other native vegetation** – limit the clearing of native vegetation, integrate open green spaces when possible, and include provisions to protect existing trees and their root systems during the site development process.
6. **Protect native soils** – Avoid removing the topsoil layer and compaction, and use construction phasing to minimize disturbance footprint.

REFERENCES

AHBL Civil & Structural Engineers/Planners. WWHM Comparison Analysis Project Memo. Tacoma, WA, February 2002.

Cook, Edward A. 2007. Green Site Design: Strategies for Stormwater Management. J. Green Building Vol. 2, No. 4. pp. 46-56.

Hinman, Curtis. Low Impact Development: Technical Guidance Manual for Puget Sound. Washington State University Pierce County Extension and Puget Sound Action Team. Olympia, WA. 2005.

McAdam, James. Green Infrastructure for Southwestern Neighborhoods. January 2010, Version 1. Watershed Management Group. Tucson, AZ.

Rhode Island Department of Environmental Management and Coastal Resources Management Council. Rhode Island Low Impact Development Site Planning and Design Guidance Manual. 2011.

Schueler, T. Site Planning for Urban Stream Protection. Silver Spring, MD: 1995.

U.S. Census Bureau. American Housing Survey for the United States in 2001. Washington, DC.: 2001.

U.S. Environmental Protection Agency. Protecting Water Resources with Higher-Density Development. EPA 231-R-06-001. Washington D.C.: 2006.

U.S. Environmental Protection Agency. Stormwater Management Handbook Implementing Green Infrastructure in Northern Kentucky Communities. Ft. Wright, Kentucky: 2009.

U.S. Environmental Protection Agency. "Narrower Residential Streets."2014. <http://water.epa.gov/polwaste/npdes/swbmp/Narrower-Residential-Streets.cfm>

U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response (5101T) Green Parking Lot Resource Guide, February 2008. EPA-510-B-08-001.

Virginia Department of Environmental Quality. "Site planning and design considerations." Virginia Stormwater Management Handbook. 2012.