6.6. OVERCOMING BARRIERS TO ENVIRONMENTAL SITE DESIGN

Despite the clear benefits of ESD techniques, it may be difficult to apply some of them in many communities across the state at the present time. The primary reason is that the geometry, location, and design of development projects is largely dictated by local subdivision codes and zoning ordinances. In some cases, these codes discourage or even prohibit ESD techniques. In other cases, development review authorities are hesitant to approve innovative ESD techniques because of fears they may create real or perceived problems. While potential barriers differ in every community, some frequently cited problems are that ESD techniques may:

- Restrict access for fire trucks and emergency vehicles
- Increase future municipal maintenance costs
- Drive up construction costs
- Make it more difficult to plow snow
- Generate future problems or complaints (e.g. inadequate parking, wet basements, etc.)
- Interfere with existing utilities

These real or perceived local problems must be directly addressed in order to gain widespread adoption of ESD techniques. Communities may also need to carefully reevaluate their local codes and ordinances to overcome barriers to ESD.

Effective methods for promoting code change are to (1) use Code and Ordinance Worksheets to evaluate potential conflicts within local development codes and (2) establish a local site planning roundtable to assist in identifying necessary code changes. Roundtables involve key stakeholders from the local government, development, and environmental communities that influence the development process. These approaches are discussed in detail in **Appendix 3-B** of **Chapter 3** of this Handbook.

6.7. ENVIRONMENTAL SITE DESIGN EXAMPLES

6.7.1. Example 1: Rural Residential Subdivision

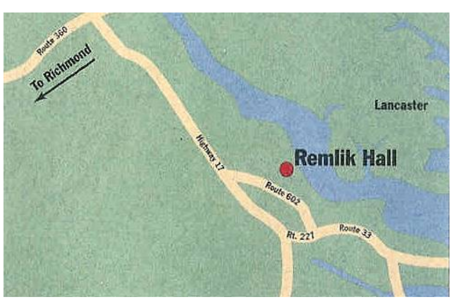


Figure 6.111. Location Map for Remlick Hall Farm/Subdivision

This example, earlier documented in the Chesapeake Bay Foundation's publication ***A Better Way to Grow*** (1996), is located near the hamlet of Remlick, in rural Middlesex County, Virginia. The subdivision is situated on the banks of Lagrange Creek, a tributary of the Rappahannock River, which drains directly into the Chesapeake Bay. **Figure 6.111** is a location map.

Figure 6.112 is an aerial view of the original Remlick Hall Farm site before the development began. **Figure 6.113** is a site plan of the farm under the pre-development conditions.

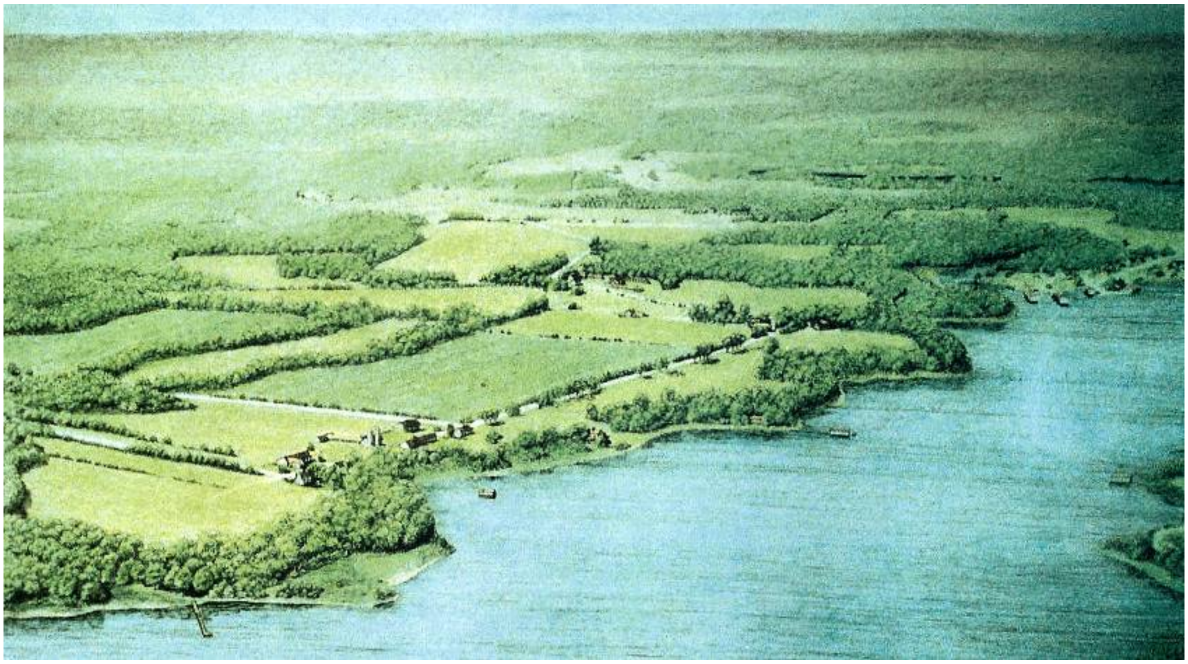


Figure 6.112. Aerial View of Remlick Hall Farm Prior to Development

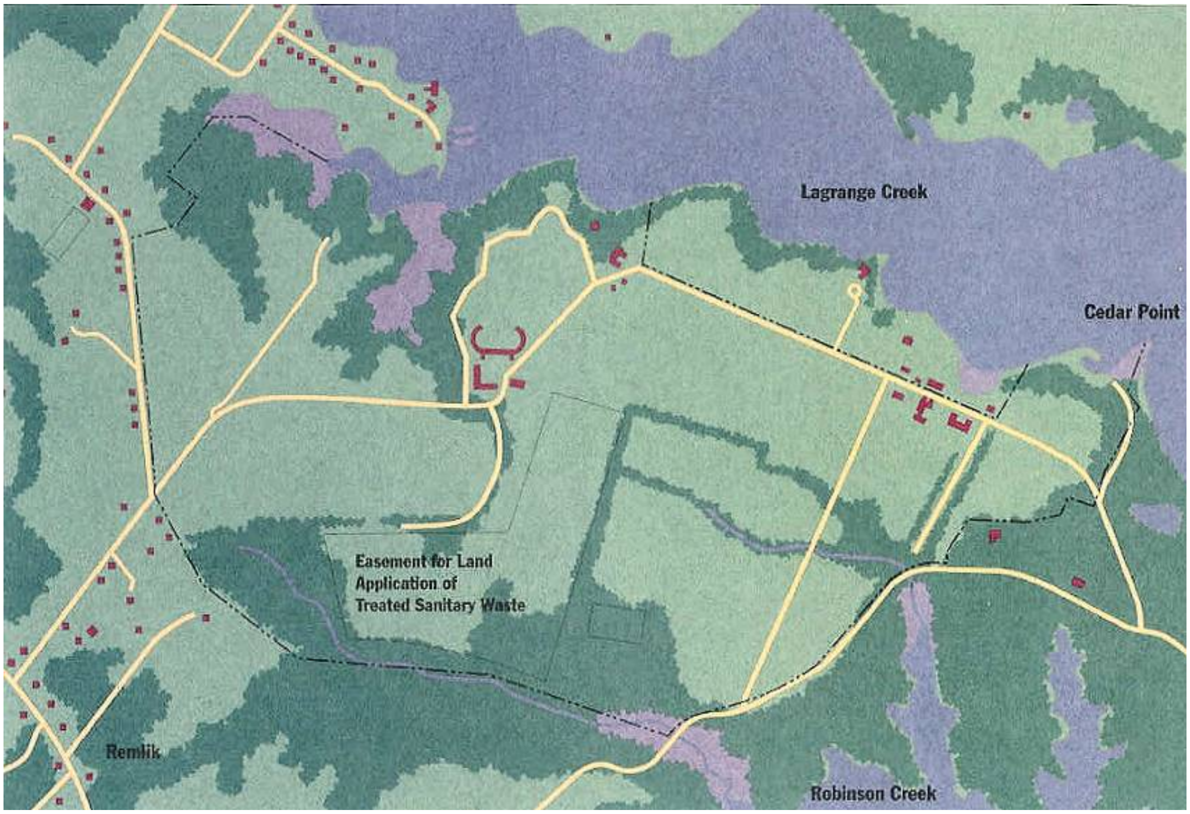


Figure 6.113. Site Plan of Remlick Hall Farm Prior to Development

The Remlick Hall property is a working farm. The farm produces grain crops and hay and also serves as a center for stabling and training horses. Located in the floodplain, the farmland on the property contains prime agricultural soil. Land in the center of the farm has been designated to be fertilized using treated sewage sludge from a nearby subdivision.

The farm and surrounding area is intended for agricultural and rural conservation, according to the Middlesex County comprehensive plan. The county's Low Density Rural Zoning District applies to the property. The zoning permits residential development at a maximum density of one home per 40,000 square feet, which is slightly less than an acre. A stated purpose of the zoning district is the protection of rural character and agricultural and forestry uses. In reality, however, typical development at this density assures the very elimination of the things it is intended to protect.

Clustering development is an effective way to allow development and also save farmland and open space in rural areas undergoing suburbanization. And as far as the Chesapeake Bay is concerned, farmland is preferable to developed land. Properly managed farmland minimizes polluted runoff and maintains the land's permeability to infiltrate stormwater.

The site plan in **Figure 6.114(a)** depicts a layout of residential lots typical of conventional subdivisions. It contains a total of 84 lots: 19 one-acre lots, 58 two- to four-acre lots, and seven lots five- to 15-acres in size. As is typical of conventional subdivisions, most, if not all, of the site is divided into lots. The limited open space that does remain consists of undevelopable land – wetlands and the sewage land application site, which by itself is too small to farm. **Figure 6.114(b)** is an aerial view of this site plan. Even with large lot development, note how much forest cover has been removed, when compared to the view in **Figure 6.112**.

This spread-out development pattern requires 20,250 linear feet of roadway at a VDOT standard width of 20 feet. This translates into 10.83 acres of new impervious surface area on-site for roads and driveways alone. Other hard surfaces and the roof tops associated with each new home contribute yet more impervious surface area, for a total of 26.3 acres. The polluted runoff shed by these surfaces, in combination with the individual septic systems serving the homes, is likely to pollute local waters above and below ground.

The site plan of the cluster subdivision alternative for Remlick Hall, depicted in **Figure 6.115(a)**, contains a total of 52 lots in three clusters. The two westernmost clusters together contain a total of 44 lots with a minimum size of 7,500 square feet, or slightly less than one-sixth of an acre. This lot size requires the use of shared septic facilities – one large drainfield serving a number of homes. The third cluster of homes is grouped near the existing complex of farm buildings and residences at the eastern end of the property. Eight high-end residences occupy lots of approximately one acre in this cluster. **Figure 6.115(b)** is an aerial view of this site plan. When compared to the view in **Figure 6.112**, note that virtually all of the forest cover is preserved.

The cluster plan preserves the rural character, field and shoreline vistas, and large acreages of forest and workable farmland for the enjoyment of all residents. It requires 9,750 linear feet of roadway, a 53 percent reduction in road length from the conventional plan alternative. The cluster plan saves $525,000 in development costs, largely due to the sizable reduction in road length over the conventional plan. Reduction in road length and width (from 20 feet wide to 18 feet) also pays off in less polluted runoff. The original CBF publication documents information regarding land use coverage, stormwater pollutants, and the construction costs of the two alternative plans.

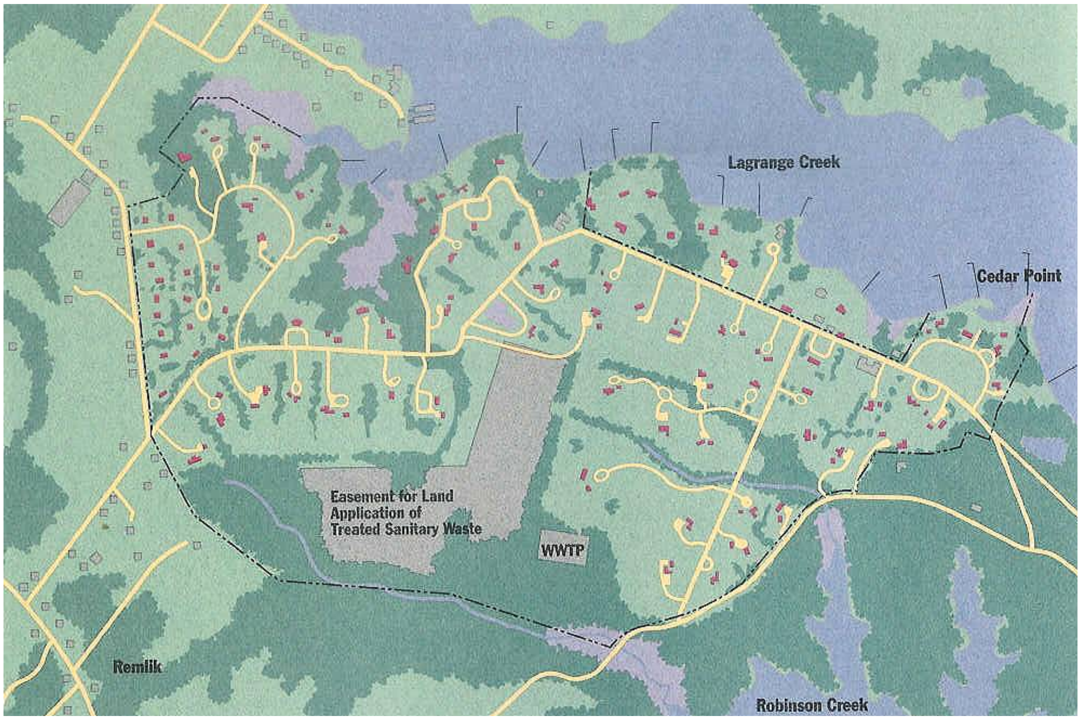
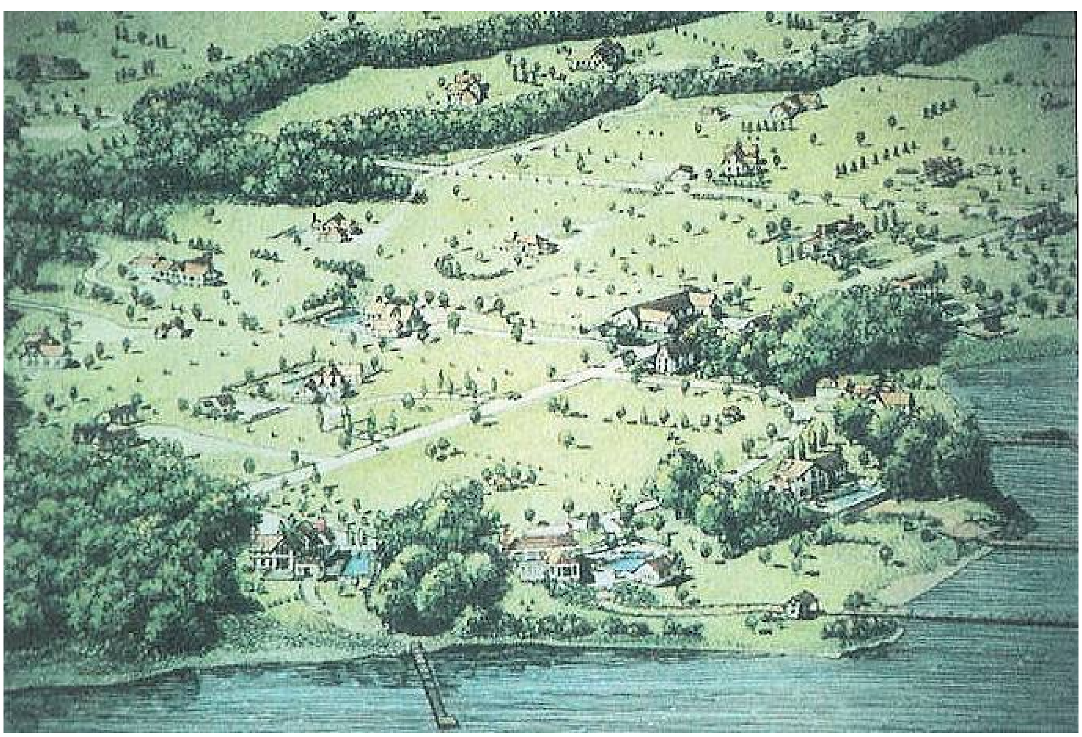


Figure 6.114. Site Plan and Aerial View of Conventional Subdivision Design for Remlick Hall



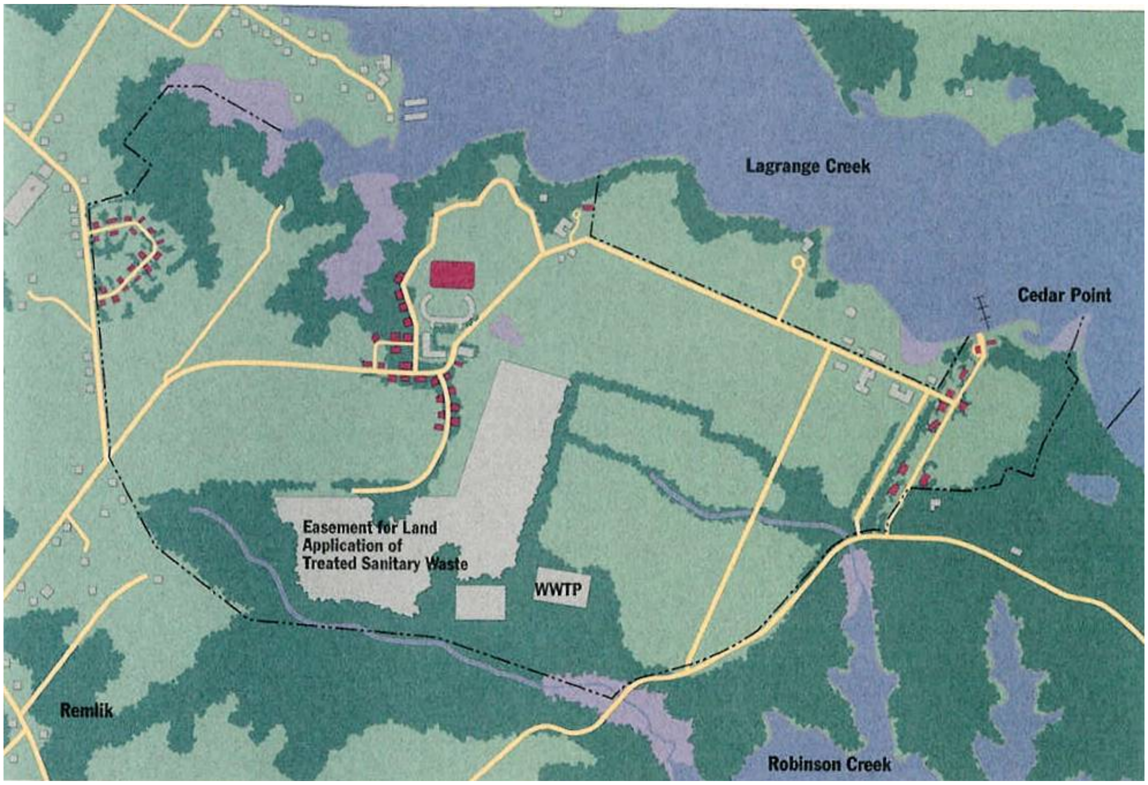


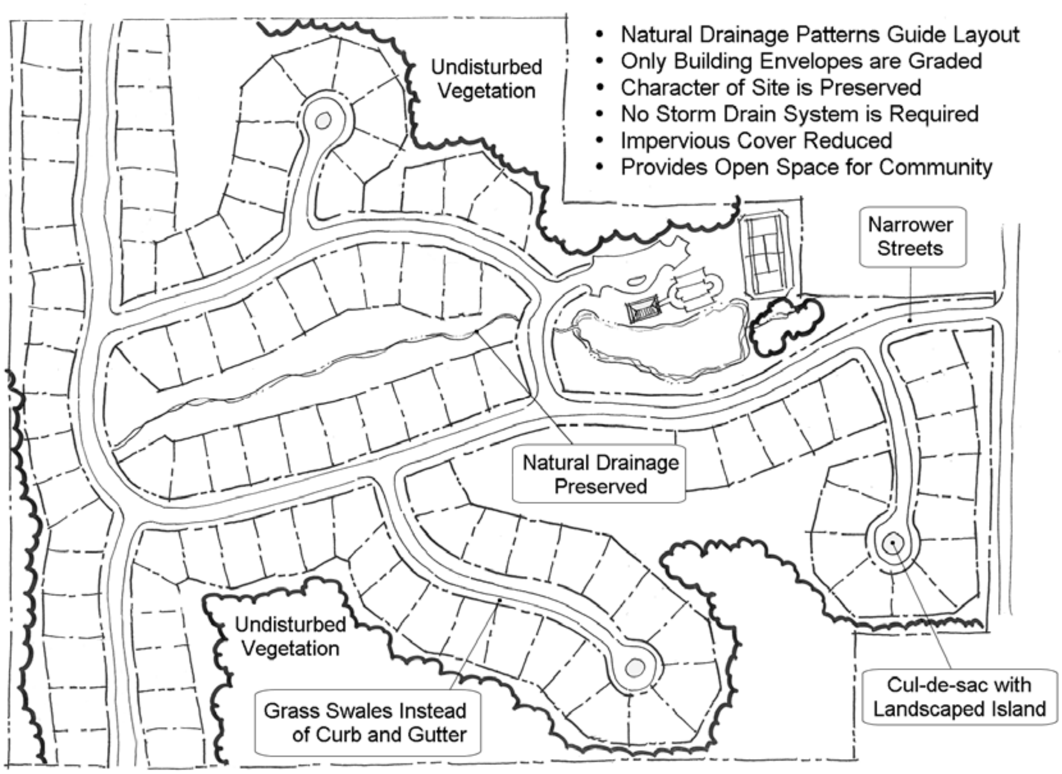
Figure 6.115. Site Plan and Aerial View of Clustering Subdivision Design for Remlick Hall

6.7.2. Example 2: Suburban Residential Subdivision A

A typical residential subdivision design on a parcel is shown in **Figure 6.116(a)**. The entire parcel except for the subdivision amenity area (clubhouse and tennis courts) is used for lots. The entire site is cleared and mass graded, and no attempt is made to fit the road layout to the existing topography. Because of the clearing and grading, all of the existing tree cover, vegetation and topsoil are removed, dramatically altering both the natural hydrology and drainage of the site. The wide residential streets create unnecessary impervious cover and a curb and gutter system that carries stormwater flows to the storm sewer system. No provision for non-structural stormwater treatment is provided on the subdivision site.

A residential subdivision employing stormwater ESD practices is presented in **Figure 6.116(b)**. This subdivision configuration preserves a quarter of the property as undisturbed open space and vegetation. The road layout is designed to fit the topography of the parcel, following the high points and ridgelines. The natural drainage patterns of the site are preserved and are utilized to provide natural stormwater treatment and conveyance. Narrower streets reduce impervious cover and grass channels provide for treatment and conveyance of roadway and driveway runoff. Landscaped islands at the ends of cul-de-sacs also reduce impervious cover and provide stormwater treatment functions. When constructing and building homes, only the building envelopes of the individual lots are cleared and graded, further preserving the natural hydrology of the site.

Figure 6.114. Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using ESD Techniques and Practices (below)

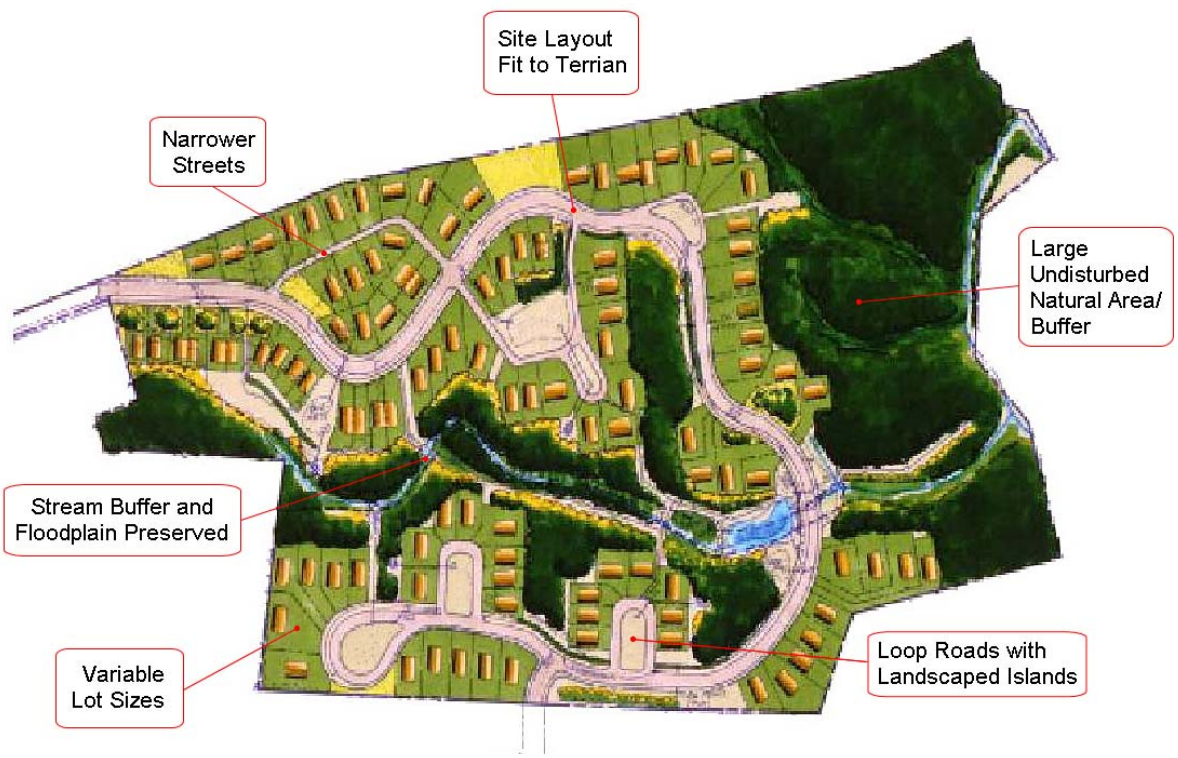


6.7.3. Example 3: Suburban Residential Subdivision B

Another typical residential subdivision design is shown in **Figure 6.117(a)**. Most of this site is cleared and mass graded, with the exception of a small riparian buffer along the large stream at the right boundary of the property. Almost no buffer was provided along the small stream that runs through the middle of the property. In fact, areas within the 100-year floodplain were cleared and filled for home sites. As is typical in many subdivision designs, this one has wide streets for on-street parking and large cul-de-sacs.

The ESD subdivision can be seen in **Figure 6.117(b)**. This subdivision layout was designed to conform to the natural terrain. The street pattern consists of a wider main thoroughfare that winds through the subdivision along the ridgeline. Narrower loop roads branch off of the main road and utilize landscaped islands. Large riparian buffers are preserved along both the small and large streams. The total undisturbed conservation area is close to one-third of the site.

Figure 6.117. Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using ESD Techniques and Practices (below)



6.7.4. Example 4: Suburban Residential Subdivision C

Still another typical residential subdivision design is shown in **Figure 6.118(a)**. Virtually all of the site is cleared and mass graded. The ESD subdivision design shown in **Figure 6.118(b)** provides exactly the same number of lots, but they are smaller and arranged in conformance with the terrain, reducing the cleared area by 40% and the amount of impervious cover by half.

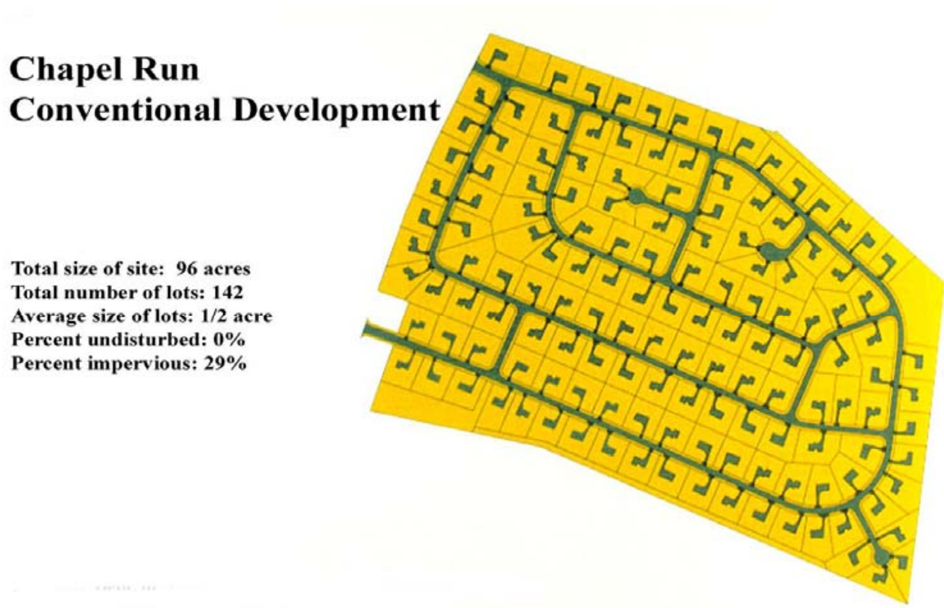
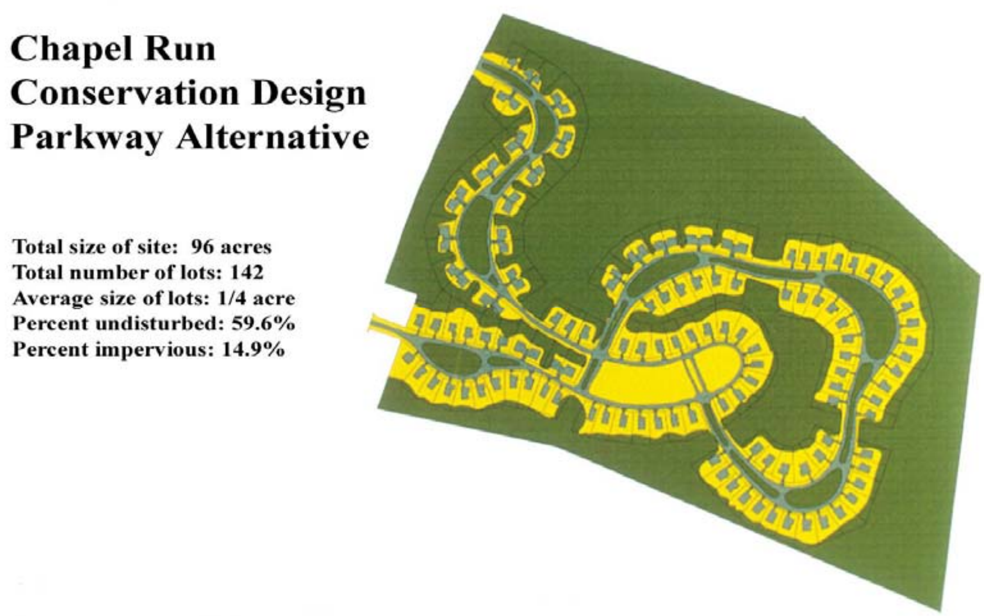


Figure 6.118. Comparison of a Traditional Subdivision Design (above) with an Innovative Site Plan Developed Using ESD Techniques and Practices (below)
Source: Delaware Dept. of Natural Resources and Environmental Control



6.7.5. Example 5: Commercial Development Example

Figure 6.119(a) shows a typical commercial development containing a supermarket, drugstore, smaller shops and a restaurant on an out lot. The majority of the parcel is a concentrated parking lot area. The only pervious area is a small replanted vegetation area acting as a buffer between the shopping center and adjacent land uses. Stormwater quality and quantity control are provided by a wet extended detention pond in the corner of the parcel.

An ESD commercial development can be seen in **Figure 6.119(b)**. Here the retail buildings are dispersed on the property, providing more of an "urban village" feel with pedestrian access between the buildings. The parking is broken up, and bioretention areas for stormwater treatment are built into parking lot islands. A large bioretention area which serves as open green space is located at the main entrance to the shopping center. A larger undisturbed buffer has been preserved on the site. Because of the bioretention areas and buffer provide water quality treatment, only a dry extended detention basin is needed for water quantity control.

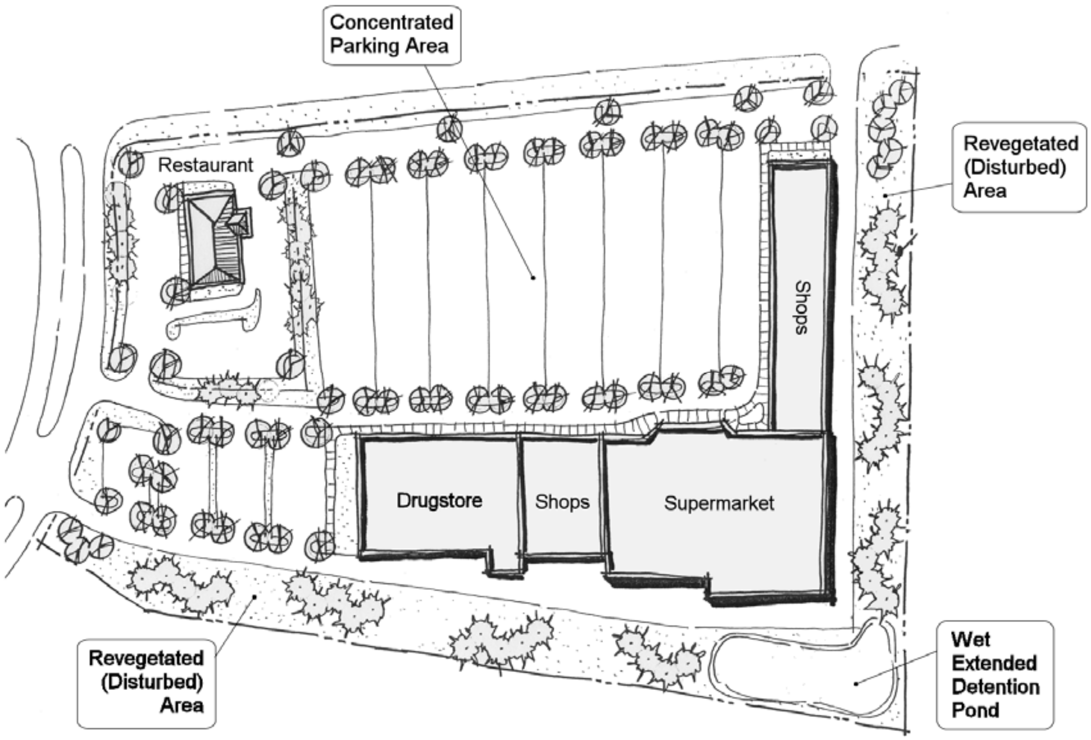
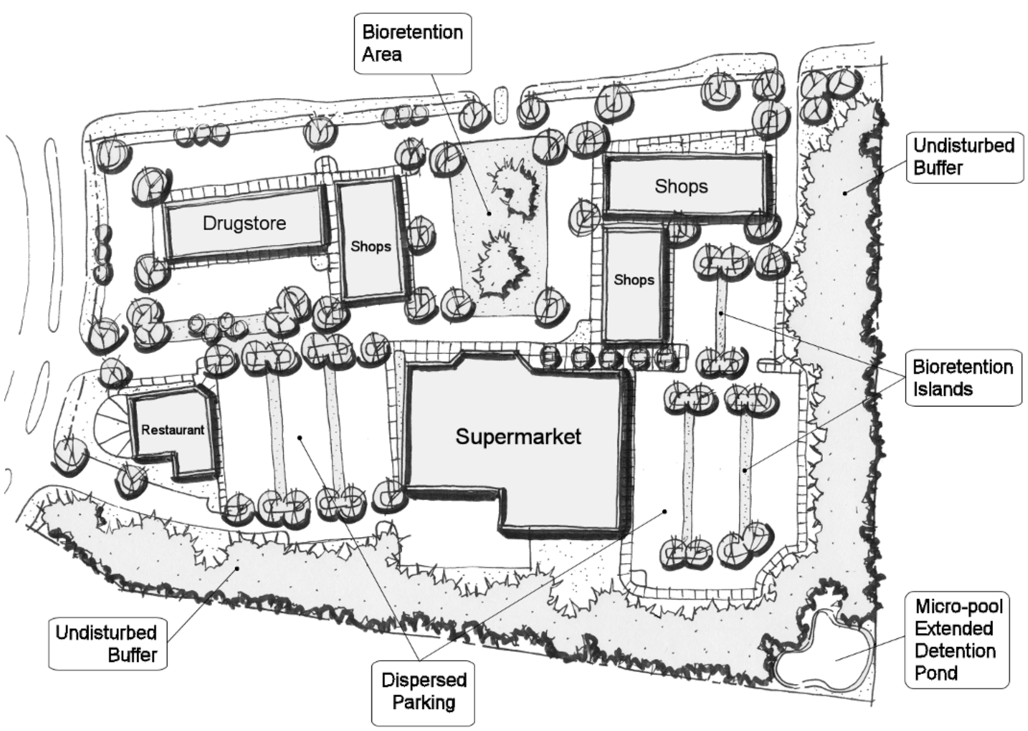


Figure 6.119. Comparison of a Traditional Commercial Development Design (above) with an Innovative Site Plan Developed Using ESD Techniques and Practices (below)



6.7.6. Example 6: Office Park Example

An office park with a conventional design is shown in **Figure 6.120(a)**. Here the site has been graded to fit the building layout and parking area. All of the vegetated areas of this site are replanted areas.

The ESD layout, presented in **Figure 6.120(b)**, preserves undisturbed vegetated buffers and open space areas on the site. Both the parking areas and buildings have been designed to fit the natural terrain of the site. In addition, a modular porous paver system is used for the overflow parking areas.

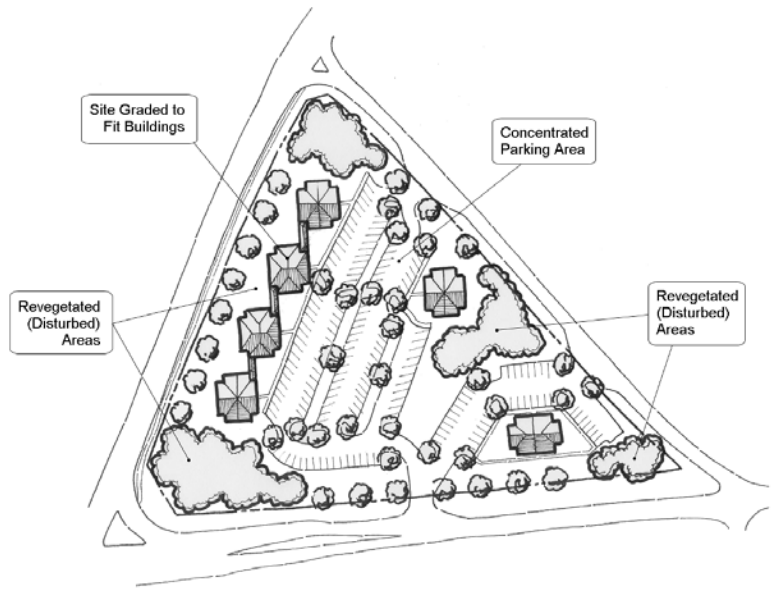


Figure 6.120. Comparison of a Traditional Office Park Design (above) with an Innovative Site Plan Developed Using ESD Techniques and Practices (below)

6.8. OTHER GOOD REFERENCE MATERIAL ON ENVIRONMENTAL SITE DESIGN

There are numerous sources of more specific information regarding Environmental Site Design. The earliest work on the specific topic was a publication by the Center for Watershed Protection entitled ***Better Site Design: A Handbook for Changing Development Rules in Your Community*** (August 1998), which is still available from the Center's website:

http://www.cwp.org/categoryblog/101-better-site-design-.html

The publication entitled ***Better Site Design: An Assessment of the Better Site Design Principles for Communities Implementing Virginia's Chesapeake Bay Preservation Act*** is available from DEQ's website:

http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

For guidance regarding use of environmental design techniques for land development in rural areas, see the book ***Rural By Design*** (Randall Arendt et al., 1994). Perhaps the seminal work on the subject of accommodating man-made structures within the existing natural order in a manner that minimizes impact and cost is Ian McHarg's ***Design with Nature*** (1969).

6.9. PLANNING STORMWATER MANAGEMENT FOR SPECIAL SITE OR CLIMATIC CONDITIONS

Certain kinds of site or climatic conditions create unique challenges regarding site design and BMP selection. Among those are karst geologic conditions, conditions unique to sites near the coastline, sites classified as pollution hotspots, sites where extremely cold winter temperatures and precipitation exist, ultra-urban settings, and sites draining to waters that have exceptional classifications, such as pristine cold water trout streams or polluted waters subject to TMDL waste load allocations. The significance of these kinds of settings for site design is discussed below. The guidance for selecting BMPs in these kinds of settings is provided in **Chapter 8,** entitled **BMP Overview and Selection.**

6.9.1. Karst Geologic Conditions

Karst topography is commonplace in portions of Virginia west of the Blue Ridge, and in small, isolated areas in the Piedmont (see **Figure 6.121**). Karst is a dynamic landscape underlain by soluble bedrock such as limestone, dolomite, and marble. Prior to urbanization, much runoff reaches the epikarst through diffuse infiltration through fractured bedrock (see **Figure 6.122**), and is released slowly into the underlying network of caves. Characteristic karst landscape features include a pinnacled, highly irregular soil-rock interface (Denton, 2008), sinkholes, sinking and disappearing streams, caves, and large springs. Together, these features comprise an interconnected karst hydrological system that is easily contaminated and able to transmit large volumes of water over long distances in a short period of time, frequently passing beneath surface watershed boundaries (Veni et al, 2001; Zokaites, 1997).

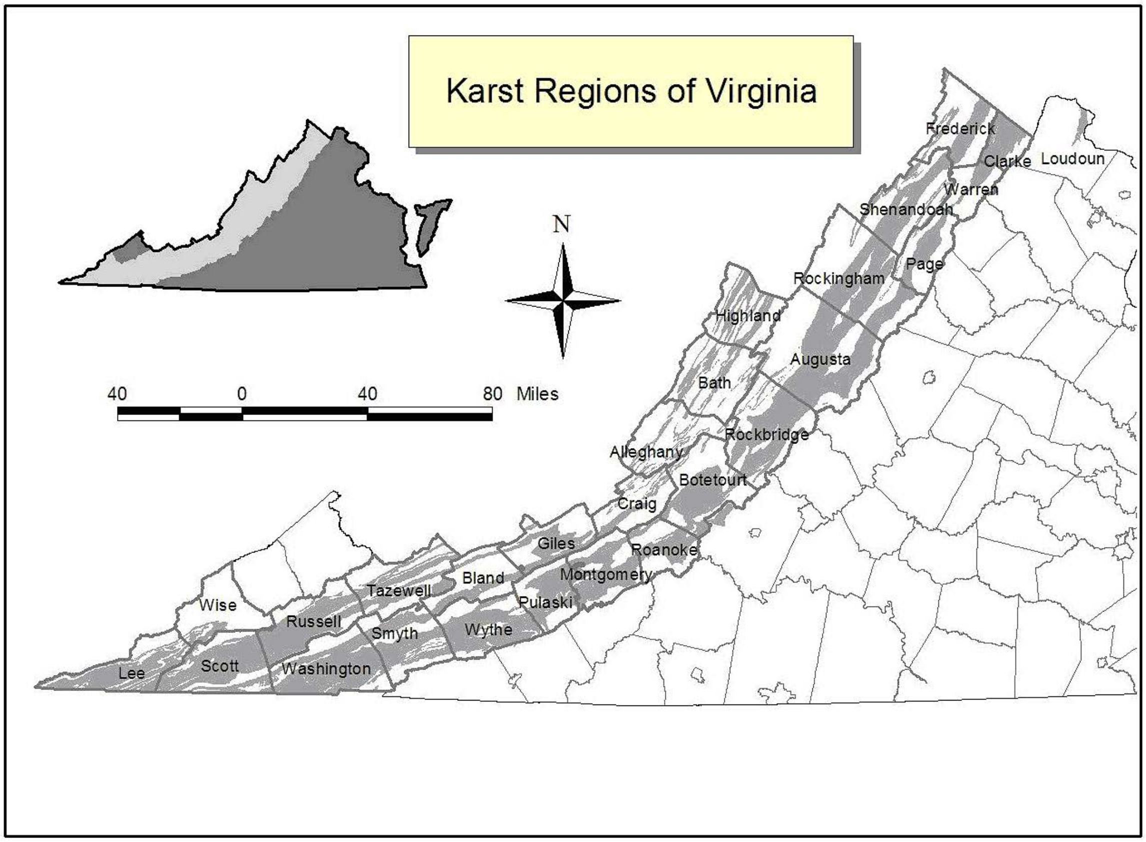


Figure 6.121. Karst Distribution in Virginia

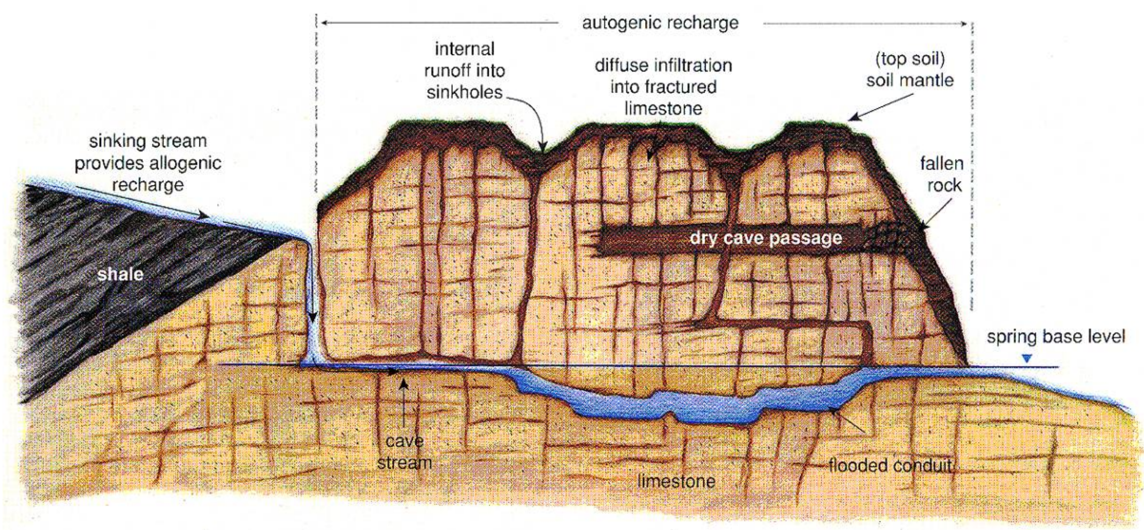


Figure 6.122. Profile Through Typical Karst Geology
Source: White et al. (1995)

The presence of active karst regions in the Ridge and Valley province of Virginia complicates the land development process and requires a unique approach to stormwater design. Some considerations include:

- Post-development runoff rates are greatly increased
- Highly variable subsurface conditions
- Surface/subsurface drainage patterns are poorly understood
- Unique rural development patterns exist in response to karst
- Much higher risk of groundwater contamination
- Risk of stimulating sinkhole formation
- Presence of endangered species

The following general principles should be considered in site layout and the design of stormwater systems in karst regions:

6.9.1.1. For Site Design

- Designers should perform the preliminary and detailed site investigations prior to site and stormwater design to fully understand subsurface conditions, assess karst vulnerability and define the actual drainage pattern present at the site. Any existing sinkholes should be surveyed and permanently recorded on the property deed. In addition, an easement, buffer or reserve area should be identified on the development plats for the project so that all future landowners are aware of the presence of active karst on their property.

- Minimize site disturbance and changes to the soil profile, including cuts, fills, excavation and drainage alteration.

- Sediment traps and basins should only be used as a last resort after all other E&S control options have been considered and rejected. In the rare instance they are employed, they should serve small drainage areas (2 acres or less), be located away from known karst features, and be equipped with impermeable liners to discourage subsidence.

- Minimize the amount of impervious cover created at the site so as to reduce the volume and velocity of stormwater runoff generated.

- Take advantage of topography when locating building pads and place foundations on sound bedrock.

6.9.1.2. For Stormwater Design

- Treat runoff as sheetflow in a series (treatment train) of small runoff reduction practices before it becomes concentrated. Practices should be designed to disperse flows over the broadest area possible to avoid ponding or soil saturation.

- Small scale LID-type practices work best in karst areas, although they should be shallow, closed and sometimes lined to prevent groundwater interaction. For example, micro-bioretention and infiltration practices are a key part of the treatment train. Distributed treatment is recommended over centralized stormwater facilities, which are defined as any practice that treats runoff from a contributing drainage area greater than 20,000 square feet of impervious cover, and/or has a surface ponding depth greater than three feet. Examples include wet ponds, dry extended detention ponds, and infiltration basins.

- The use of these centralized practices is strongly discouraged, even when liners are used. Centralized treatment practices require more costly geotechnical investigations and design features than smaller, shallower distributed LID-type practices. In addition, distributed, disconnected LID practices eliminate the need to obtain an underground injection permit from the USEPA**.**

- Any discharge to karst features should only occur downstream of other BMP's and ensure that such discharges meet all relevant criteria of the Virginia Stormwater Management Regulations. The receiving feature should be identified on the permit registration as the receiving water. Developers should check with the Virginia Karst Office in the Virginia Department of Conservation and Recreation's Division of Natural Heritage to see if the resurgence location (where water entering the sinkhole returns to the surface at a spring) has been determined. If not, the developer is encouraged to coordinate with the Karst Office to perform dye trace investigations to locate the resurgence(s). Consistent with federal environmental regulations at 40 C.F.R. parts 144-148, some karst features receiving runoff may be considered class V injection wells and would have to be registered as such with EPA Region III. To ensure compliance in cases where stormwater runoff is discharged to a karst feature, DEQ recommends coordination with EPA Groundwater & Enforcement Branch (3WP22), U.S. EPA Region 3, 1650 Arch Street , Philadelphia, PA 19103, Phone: (215) 814-5427, Fax: (215) 814-2318.

For more detail regarding the effects of karst on site and stormwater design, see **Appendix 6-B** of this chapter, entitled *Stormwater Design Guidelines for Karst Terrain in Virginia*.

6.9.2. Coastal Plain/High Groundwater Table

Most stormwater practices were originally developed in the Piedmont physiographic region and have seldom been adapted for much different conditions in the coastal plain. Consequently, guidance for stormwater design is strongly oriented toward the rolling terrain of the Piedmont with its defined headwater streams, deeper groundwater table, low wetland density, and well drained soils.

By contrast, stormwater design in the coastal plain is strongly influenced by unique physical constraints, pollutants of concern and resource sensitivity of the coastal waters. Implementation of traditional stormwater practices in the coastal plain is constrained by physical factors such as flat terrain, high water table, altered drainage, extensive groundwater interactions, poorly-drained soils, and extensive wetland complexes. The significance of these constraints is described below:

Flat Terrain. From a hydrologic standpoint, flat terrain increases surface water/groundwater interactions and reduces the hydraulic head available to treat the quality of stormwater or move floodwaters through the watershed during the intense tropical storms and hurricanes for which the region is especially prone.

High Water Table. In much of the coastal plain, the water table exists within a few feet of the surface. This strong interaction increases the movement of pollutants through shallow groundwater and diminishes the feasibility or performance of many stormwater control practices.

Highly Altered Drainage. The headwater stream network in many coastal plain watersheds no longer exists as a natural system, with most zero order, first order and second order streams replaced by ditches, canals and roadway drainage systems.

Poorly Drained Soils. Portions of the coastal plain have soils that are poorly drained and frequently do not allow infiltration to occur and, as a result, coastal plain watersheds contain have a greater density of wetlands than any other physiographic region in the country (Dahl, 2006).

Very Well-Drained Soils. In other parts of the coastal plain, particularly near the coast line, soils are sandy and extremely permeable, with infiltration rates exceeding four inches per hour or more, providing a stronger risk of stormwater pollutants rapidly migrating into groundwater. This is a particular design concern, given the strong reliance in the coastal plain on groundwater for drinking water supply.

Drinking Water Wells and Septic Systems. A notable aspect of the coastal plain is a strong reliance on public or private wells to provide drinking water (USGS, 2006). As a result, *designers need to consider groundwater protection as a first priority* when they are considering how to dispose of stormwater. At the same time, development in the coastal plain relies extensively on septic systems or land application to treat and dispose of domestic wastewater. Designers need to be careful in how they manage and dispose of stormwater so they do not reduce the effectiveness of adjacent septic systems.

Conversion of Croplands With Land Application. Land application of animal manure and domestic wastewater on croplands is a widespread practice across the coastal plain. When this farmland is converted to land development, there is a strong concern that infiltration through nutrient enriched soils may actually increase nutrient export from the site.

Pollutants of Concern. The key pollutants of concern in coastal plain watersheds are nitrogen, bacteria, and metals. These pollutants have greater ability to degrade the quality of unique coastal plain aquatic resources such as shellfish beds, swimming beaches, estuarine and coastal water quality, seagrass beds, migratory bird habitat, and tidal wetlands. Yet, the design of many stormwater practices is still rooted in phosphorus control.

Unique Development Patterns. The development patterns of coastal plain watersheds are also unique, with development concentrated around waterfronts, water features and golf courses rather than around an urban core. The demand for vacation rental, second homes and retirement properties also contributes to sprawl-type development.

Shoreline Buffers and Critical Areas. Chesapeake Bay Preservation Areas (CBPAs) in Virginia include special shoreline buffer and stormwater pollutant reduction requirements that strongly influence how stormwater practices are designed and located. In addition, the predominance of shoreline development often means that stormwater must be provided on small land parcels a few hundred feet from tidal waters. Consequently, many development projects within CBPAs must rely on stormwater micro-practices to comply with applicable requirements.

The Highway as the Receiving System. The stormwater conveyance system for much of the coastal plain is frequently tied to the highway ditch system, which is often the low point in the coastal plain drainage network. New upland developments often must get approvals from highway authorities to discharge to their drainage system, which may already be at or over capacity with respect to handling additional stormwater runoff from larger events. The requirement for developers to obtain both a local government and highway agency approval for their project can result in conflicting design requirements.

Sea Level Rise. Sea level is forecast to rise at least a foot over the next thirty to fifty years as a result of subsidence and climate change. This large change in average and storm elevations in the transition zone between tidal waters and the shoreline development a few feet above it has design implications for the choosing where to discharge treated stormwater.

Hurricanes and Flooding. Due to their location on the coast, coastal communities are subject to rainfall intensities that are 10-20 percent greater for the same design storm event compared to sites further inland. The flat terrain lacks enough hydraulic head to quickly move water out of the conveyance system (which may be further complicated by the backwater effects of tidal surges). Additionally, large tidal surges may cause significant flooding with no precipitation present.

Guidance for BMP selection based on a high groundwater table or the filtration rate of soils is provided in **Table 8.4** in **Chapter 8**.

6.9.2.1. General Stormwater Design Principles in the Coastal Plain

The following initial guiding principles are offered on the design of stormwater practices in the coastal plain:

- Use micro-scale and small-scale practices for development projects within 500 feet of shoreline or tidal waters.
- Keep all other practices out of the riparian buffer area, except for the use of conservation filters at their outer boundary.
- Relax some design criteria to keep practice depths shallow and respect the water table.
- Emphasize design factors that can increase bacteria removal, not exacerbate bacteria problems.
- To maximize nitrogen removal, promote denitrification by creating anaerobic and aerobic zones adjacent to one another in either the vertical or lateral direction.
- Use plant species that reflect the native coastal plain plant community and, in particular, can survive well in a high salinity environment.
- Take a linear design approach to spread treatment along the entire length of the drainage path, from the rooftop to tidal waters, maximizing the use of in-line treatment in the swale and ditch system.

- Consider the effect of sea level rise on future elevations of stormwater practices and infrastructure. In some cases, it may make more sense to use site design to "raise the bridge" by increasing the vertical elevation of building pads at coastal plain development sites.

For more detail regarding the effects of coastal settings on site and stormwater design, see **Appendix 6-C** of this chapter, entitled *Stormwater Design in the Coastal Plain of Virginia*.

6.9.3. Pollution Hot Spots

Certain classes of business, municipal and industrial operations, if not carefully managed, produce higher concentrations of certain pollutants (e.g., nutrients, hydrocarbons, metals, chlorides, pesticides, bacteria, trash, etc.) than are normally found in urban runoff. Such facilities, commonly called pollution *Hotspots*, also present a greater potential risk for spills, leaks or illicit discharges. Hotspot facilities are required to obtain discharge permits and maintain a series of pollution control practices to prevent or minimize contact of pollutants with rainfall and runoff.

Examples of business, municipal and industrial activities that may be considered hotspots and need pollution prevention permits and plans include:

- Gasoline/fueling stations (**Figure 6.123**)
- Vehicle Repair Facilities
- Vehicle washing/steam cleaning sites
- Auto recycling facilities and junk yards
- Commercial laundry and dry cleaning
- Commercial nurseries
- Golf Courses
- Swimming Pools
- Heavy manufacturing/power generation
- Metal production, plating and engraving
- Toxic chemical manufacturing/storage
- Petroleum storage and refining facilities
- Airports and deicing facilities
- Marinas and ports
- Railroads and rail yards

CERCLA-designated superfund sites

- Hazardous waste handling, transfer and disposal facilities
- Recycling and solid waste handling and transfer facilities
- Composting facilities
- Landfills
- Incinerators
- Vehicle/equipment/fleet maintenance and parking areas
- Public works yards and material storage areas (**Figure 6.124**)
- Public Buildings (e.g., Schools, Libraries, Police and Fire Stations)
- Water/Wastewater Treatment Facilities

Figure 6.123. Gasoline Station

Figure 6.124. Public Works Yard

Hotspot facilities should be evaluated to identify their potential pollution-generating activities. There are typically six categories of pollution-generating activities that commonly contribute to stormwater problems (see **Figure 6.125**):

- Outdoor materials handling
- Physical plant maintenance
- Stormwater infrastructure
- Turf/landscape management
- Vehicle operations
- Waste management

Figure 6.125. Six Categories of Pollution-Generating Activities Assessed at Stormwater Hotspot Facilities

Training of personnel at the affected area is needed to ensure that industrial and municipal managers and employees understand and implement the correct stormwater pollution prevention practices needed for their site or operation. Both industrial and municipal operations must develop detailed stormwater pollution prevention plans (SWPPPs), train employees, and submit reports to regulators.

Stormwater management implications for hot spot sites are as follows:

- The main focus regarding potential pollutants must be on shelter (from the elements – see **Figure 6.126**) and containment of potential spills and illicit discharges (**Figure 6.127**)
- Certain stormwater control measures (e.g., infiltration) should be avoided
- The practices that are applied will typically require some sort of pre-treatment (e.g., a sand filter) before runoff is allowed to be discharged to a natural channel, a storm sewer or, most important, any type of infiltration practice.

Figure 6.126. Covered Chemical Storage

Figure 6.127. Wash Water Containment

Table 8.3 in **Chapter 8** is a matrix that indicates which control measures are appropriate for use at hotspot locations.

The following are excellent sources of information related to managing stormwater and pollution at hotspot-type settings:

- ***Issue Paper H: Potential Stormwater Hotspots, Pollution Prevention, Groundwater Concerns and Related Issues, version 3 (final)***, prepared by Emons & Oliver Resources and the Center for Watershed Protection for the Minnesota Pollution Control Agency, from which the document is available online at: http://www.pca.state.mn.us/publications/wq-strm8-14bf.pdf
- ***Urban Subwatershed Restoration Manual 9, Chapter 4: Hotspot Facility Management***, available from the Center for Watershed protection online at: http://www.cwp.org/Resource_Library/Center_Docs/municipal/USRM9.pdf
- ***Stormwater Management Manual for Western Washington, Volume IV: Source Control BMPs*** (February 2005 , Publication No. 05-10-32, which is a revised portion of Publication No. 91-75) available online from the Washington State Department of Ecology's Water Quality Program at: http://www.ecy.wa.gov/pubs/0510032.pdf
- ***Development Planning for Storm Water Management: A Manual for the Standard Urban Storm Water Mitigation Plan (SUSMP)***, available from the Los Angeles County (California) Department of Public Works online at: http://ladpw.org/wmd/npdes/SUSMP_MANUAL.pdf

6.9.4. Cold Winter Climate

In parts of Virginia, colder temperatures and longer lasting snow and ice events occur during the winter. Regions that have an average daily temperature of 35 degrees Fahrenheit or less during January, and that have a growing season less than 120 days, are especially vulnerable to the effects of cold weather. While Virginia's average growing season is rarely less than 160 days, the statewide average temperature for January is just above 35ºF. This means that some areas are colder, illustrated by the typically bitterly cold temperatures of the northern Blue Ridge, which are more like January temperatures in Chicago.

Cold climates can present additional challenges to the selection, design and maintenance of stormwater management BMPs due to one or more of the factors listed in **Table 6.21** below. While there may be fewer runoff events during winter months, snow and ice may significantly impact the operation of some treatment practices during winter rain events and periods of snowmelt. Engineers and site designers in cold regions should be aware of these challenges and make provisions for them in their final designs.

Table 6.21. Cold Weather Challenges to BMP Selection and Design

Climatic Conditions	BMP Selection/Design Challenge
Cold Temperatures	• Pipe freezing • Permanent pool covered by ice • Reduced biological activity • Reduced oxygen levels during ice cover • Reduced settling velocities • Impacts of road salt/deicers/chlorides • Winter sanding impacts on facilities
Deep Frost Line	• Frost heaving • Reduced soil infiltration • Pipe freezing
Significant Snowfall	• High runoff volumes during snowmelt • High runoff during rain-on-snow • High pollutant loads during spring melt • Other impacts of road salt/deicers/chlorides • Snow management may affect BMP storage • Winter sanding impacts on facilities

Source: Adapted from Washington (State) Department of Ecology (2004)

The following describe in more detail some of the potential cold climate impacts:

Frost Heaving. Moisture in the soil expands when it freezes, causing the soil to rise or "heave." This creates the potential for damage to structural components of BMPs, such as pipes or concrete infrastructure located within the soil. Another concern is that infiltration BMPs can cause frost heave damage to other structures, particularly roads. The water infiltrated into the soil matrix can flow under a permanent structure and then re-freeze. The sudden expansion associated with this freezing can cause damage to above-ground structures.

Pipe Freezing. Most treatment practices, with the exception of vegetative filter strips, rely on some form of inlet piping and may also have an outlet or underdrain pipe. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, pipe freezing reduces the hydraulic capacity of the system, thereby limiting pollutant removal and creating the potential for flooding (CWP, 1997).

Ice Formation on a Permanent Pool. The permanent pool of a wet pond serves several purposes. First, the water in the permanent pool slows down incoming runoff, allowing for increased settling of pollutants. In addition, the biological activity in the pool can act to remove nutrients, since growing algae, plants and bacteria require these nutrients for growth. In some systems, such as sand filters, a permanent pool acts as a pre-treatment measure, settling out larger sediment particles before full treatment by the BMP.

Ice cover on a permanent pool causes two problems. First, the treatment pool's volume is reduced. Second, because the permanent pool is frozen, it acts as an impermeable surface.

Runoff entering an ice-covered pond can follow two possible routes, neither of which provides sufficient pollutant removal. In the first case, runoff is forced under the ice, causing scouring of bottom sediments. In the second case, runoff flows over the top of the ice, receiving little or no treatment. Sediment that settles on top of the ice can easily be re-suspended by subsequent runoff events (CWP, 1997).

Reduced Settling Velocities. Settling is the most important removal mechanism in many BMPs. As water becomes cooler, its viscosity increases, which reduces particle velocity by up to 50 percent and makes it more difficult for particles to settle out.

Reduced Biological Activity. Many stormwater treatment practices rely on biological mechanisms to help reduce pollutants, especially nutrients and organic matter. For example, wetland systems rely on plant uptake of nutrients and the activity of microbes at the soil/root zone interface to break down pollutants. During cold temperatures (below 40°F), photosynthetic and microbial activity is sharply reduced when plants are dormant during the non-growing season, limiting these pollutant removal pathways (CWP, 1997).

Reduced Oxygen Levels in Bottom Sediments. In cold regions, oxygen exchange between the air-water interface in ponds and lakes is restricted by ice cover. In addition, warmer water sinks to the bottom during ice cover, because it is denser than the cooler water near the surface. Although biological activity is limited in cooler temperatures, the decomposition that takes place does so at the bottom of wet ponds, sharply reducing oxygen concentrations in bottom sediments. In these anoxic conditions, positive ions retained in sediments can be released from bottom sediments, reducing the BMP’s ability to treat these nutrients or metals in runoff.

Reduced Soil Infiltration. The rate of infiltration in frozen soils is limited, especially when ice lenses form (CWP, 1997). There are two results of this reduced infiltration. First, BMPs that rely on infiltration to function can be ineffective when the soil is frozen. Second, runoff volume from snowmelt is elevated when the ground underneath the snow is frozen.

Increased Pollutant Loading During Winter or Spring Thaw Periods. Winter or spring melt events are important because of increased runoff volumes and pollutant loads. The snowpack contains high pollutant concentrations, due to the buildup of pollutants over a several-month period. Chloride loadings are highest in snowmelt events because of the use of deicing salts, such as sodium chloride and magnesium chloride. Excessive loadings can kill vegetation in swales and other vegetative BMPs. Research indicates roughly 65 percent of the annual sediment, organic, nutrient, and lead loads can be attributed to winter and spring melts.

Access Difficulties in Ice and Snow. Points of access to BMPs may be frozen shut, and BMPs and access ways may be buried under the snow.

Particular Maintenance Issues. Maintenance requirements of certain BMPS may increase during the winter months due to increased loading and debris. Pollutant loading typically increases due to leaf fall, snow plowing, sanding, salting, and accumulation of materials in snow piles. Unique cold climate pollutants include the following:

- Sand
- Salt
- Polycyclic Aromatic Hydrocarbons (PAHs) emitted from fireplaces and inefficient vehicles in the winter
- Cyanide included in deicing salt compounds to prevent clumping

BMPs that use filtration, settling, or trapping to remove contaminants require frequent inspection and maintenance. Regular maintenance of BMPs located in cold climates is suggested just prior to the first snowfall or road sanding, after the last snowfall, and during spring snowmelt to ensure the proper treatment of runoff.

Each of the individual stormwater control measure specifications on the Virginia Stormwater BMP Clearinghouse web site includes guidance for mitigating the potential effects of cold weather on treatment practice operation and performance. Furthermore, guidance for BMP selection based tolerance for winter conditions is provided in **Table 8.5** in **Chapter 8**. The following are excellent sources of more detailed information related to managing stormwater and pollution in cold climates:

- ***Issue Paper G:. Cold Climate Considerations for Surface Water Management***, prepared by Emons & Oliver Resources and the Center for Watershed Protection for the Minnesota Pollution Control Agency, from which the document is available online at: http://www.pca.state.mn.us/publications/wq-strm8-14be.pdf
- ***Stormwater BMP Design Supplement for Cold Climates***, by D. Caraco and R. Claytor, available online from the Center for Watershed Protection at: http://www.cwp.org/Resource_Library/Center_Docs/special/ELC_coldclimates.pdf
- ***Snow, Road Salt and the Chesapeake Bay***, available online from the Center for Watershed Protection at: http://www.cwp.org/Resource_Library/Special_Resource_Management/ColdClimate/snow_roadsalt_chesbay.pdf
- ***Stormwater Management Manual for Eastern Washington***, Publication No. 04-10-076, available online from the Washington State Department of Ecology at: http://www.ecy.wa.gov/pubs/0410076.pdf .
- ***New York State Stormwater Management Design Manual, Appendix I***, available online from the New York State Department of Environmental Conservation at: http://www.dec.ny.gov/docs/water_pdf/swdmappendixi.pdf

6.9.5. Cold-Water Fisheries and Other Sensitive Receiving Waters

Cold and cool water streams have habitat qualities capable of supporting trout and other sensitive aquatic organisms. Waters of Virginia are classified in seven (7) classes in the Virginia Water Quality Standards (WQS, at 9 VAC 25-260 et seq.), administered by the State Water Control Board and the Department of Environmental Quality. Cold water fisheries fall into Classes V and VI. Class V streams are appropriate for stocking trout. Class VI streams accommodate natural trout populations. Both of these stream classes have stricter criteria for water temperature and dissolved oxygen than other classes of water in the state (9 VAC 25-260-60 and 9 VAC 25-260-70). This applies both to the typical conditions that apply to these stream classes as well as to the limit of variation in these criteria. Furthermore, § 9 VAC 25-260-370 B of the WQS describes the Virginia Department of Game and Inland Fisheries more discrete classification of trout waters and the distinctions between them. Finally, PART IX (§ 9 VAC 25-260-360 et seq.) of the WQS provides a Virginia map divided into regions and lists each named stream segment within each region, identifying for each the stream class and critical criteria that apply.

The design objective for the cold water (trout) streams is to maintain habitat quality by preventing stream warming, maintaining dissolved oxygen levels, maintaining natural recharge, preventing pollution, preventing bank and channel erosion, and preserving the natural riparian corridor. Techniques for accomplishing these objectives include the following:

- Minimizing impervious surfaces
- Minimizing surface areas of permanent pools
- Preserving existing forested areas
- Bypassing existing baseflow and/or spring flow
- Providing shade-producing landscaping

The elevated temperatures are also caused by reduced shading in developed riparian areas. Pavement and other impervious surfaces tend to absorb substantial amounts of heat in summer due to their dark coloring and typically a lack of shade. This heat is transferred to runoff passing over the surface, resulting in runoff that is dramatically warmer than natural groundwater inflow would have been under a natural hydrologic cycle. Some BMPs, such as swales, shallow ponds and large impoundments can also increase the temperature of runoff, as it is quickly warmed on hot summer days before being discharged. Traditional peak reduction outlet structures and simple spillway outlets do nothing to cool the water before discharge. Thus, their use in proximity to cold water streams should be limited. Alternative BMPs, such as buffers, infiltration or under-drained filters can be used, or, if ponds are required, under-drained outlet structures can provide effective cooling. Equally important to maintaining cool stream temperature is preservation and/or restoration of riparian trees and shrubs to provide shade, particularly for headwater streams that are the root of the local ecosystem and the base of its food chain.

Temperature changes can be stressful and even lethal to many coldwater organisms. A rise in water temperature of just a few degrees Celsius over ambient conditions can reduce or eliminate sensitive stream insects and fish species such as stoneflies, mayflies and trout (Schueler, 1987). Of note, the WQS state that temperature for Class V streams should be 21ºC and Class VI streams should be 20ºC. Furthermore the temperature may not be raised by a discharge event in excess of 2ºC for Class V streams or 0.5ºC for Class VI streams.

6.9.6. Waters Where TMDLs Have Been Established

The federal Clean Water Act and 9 VAC 25-870-10 of the Virginia Stormwater Management Regulations define *Total maximum daily load* or *TMDL* as “the sum of the individual wasteload allocations for point sources or load allocations (LAs) for nonpoint sources, natural background loading and a margin of safety. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. The TMDL process provides for point versus nonpoint source trade-offs.”

Under the Clean Water Act, water quality standards, which consist of both narrative and numeric criteria, are established to protect the physical, chemical, and biological integrity of surface waters and maintain designated uses. Under the authority of section 303(d) of the Clean Water Act, water bodies that do not meet water quality standards are considered "impaired," and a "Total Maximum Daily Load" (TMDL) study must be conducted. This study computes the maximum pollutant load the water body can receive and still meet water quality standards, and it allocates this load to various point and nonpoint pollution sources, depending on what is causing the water quality impairment. Authorized states and tribes administer the TMDL program. In Virginia, the Department of Environmental Quality (DEQ) administers the TMDL program, as delegated from the EPA. The DEQ assists with developing TMDL implementation plans for waters with impairments due to nonpoint sources.

Currently, thousands of impaired waters are listed on state 303(d) lists. The Virginia 303(d) list of impaired waters can be found on the DEQ website at the following link:

http://www.deq.virginia.gov/wqa/ir2010.html

The most common sources of impairment associated with stormwater include sediment, pathogens (bacteria), nutrients, and metals (USEPA, 2007). However, stormwater and urban and suburban runoff are also significant contributors to impairments. For this reason, EPA and relevant state agencies are increasingly motivated to create a stronger link between TMDLs and stormwater permits, such as MS4, construction site, and industrial permits (USEPA, 2007; USEPA Region 5, 2007d, 2007e). With successive rounds of MS4 permits, permitted agencies will very likely need to apply more stringent stormwater criteria in impaired watersheds and/or provide a better match between particular pollutants of concern and selected BMPs.

Reflecting this point, section 9 VAC 25-870-54 E of the Virginia Stormwater Management Regulations, with the heading *Stormwater pollution prevention plan requirements*, states the following: "In addition to the above requirements, if a specific WLA for a pollutant has been established in a TMDL and is assigned to stormwater discharges from a construction activity, additional control measures must be identified and implemented by the operator so that discharges are consistent with the assumptions and requirements of the WLA in a State Water Control Board approved TMDL."

For the local stormwater manager, this will require an effort to tailor certain stormwater criteria, watershed plans and BMPs to help meet TMDL pollutant reduction benchmarks. However, it is important to understand that efforts to (1) conserve and protect open space and sensitive resources, (2) buffer stream systems, (3) reduce runoff volume and infiltrate it or hold it for use on-site, and (4) provide treatment of runoff through other kinds of stormwater management practices, can provide significant results in addressing various kinds of urban and suburban water quality impairments.

6.9.6.1. Strategies for Local Stormwater Managers to Address TMDLs Through Special Stormwater Criteria

Depending on the nature of the TMDL and the implementation plan, local stormwater criteria can help address TMDL requirements. The following three general approaches are discussed in order of decreasing sophistication. There are other approaches that can applied, and a local program may find that a hybrid of several approaches is most applicable:

- Site-Based Load Limits
- Surrogate Measures for Sources of Impairment
- Presumptive BMP Performance Standards

A. Site-Based Load Limits

Some pollutants that are the basis for TMDLs are understood well enough that site-based load calculations can be done for each development and redevelopment site. These pollutants generally include sediment, phosphorus, and nitrogen. In some areas, other pollutants, such as ammonia, fecal coliform bacteria, and other pollutants can be added to the list if adequate local or regional studies have been conducted (MPCA, 2006). If site-based load limits are to be used, the TMDL and local stormwater program should have the following characteristics:

- The TMDL allocates a load reduction target to urban/developed land (preferably separating out existing developed land from estimates of future developed land).
- The local program uses (or plans to use) a method, such as the Simple Method (CWP and MDE, 2000), that allows for the calculation of pollutant loads for a particular site development project.
- The local, regional, or state manual (or policy document) contains a method to assign pollutant removal performance values to various structural and nonstructural BMPs. Low-Impact Development (LID) credits are another positive factor so that LID practices can be incorporated.

The general process for calculating site-based load limits is as follows:

Step 1: Based on the wasteload allocation (WLA) and load allocation (LA) in the TMDL, develop a site-based load limit for the pollutant of concern. The local program must allocate the total load reduction goal for urban/developed land to existing and future urban/developed land within the impaired watershed. The program should consider having a more flexible standard for redevelopment projects because the standard will usually be more difficult to meet for these projects.

> *Example: Site-based load limit = 0.28 pounds/acre/year for total phosphorus* (*Hirschman et al. 2008*) *That is, if each newly developed site meets the standard of 0.28 pound/acre/year, the load reduction goal for new urban/developed land can be met. In this context, other measures—such as stormwater retrofits and restoration projects—might have to be applied for existing urban/developed land (see Step 5 below and Schueler et al. 2007*).

Step 2: For each development site, the applicant should calculate the post-development load for the pollutant of concern using a recognized model or method. Most use impervious cover as the main basis for calculating loads, although other land covers (e.g., managed turf) are also important contributing sources.

Example: Post-development total phosphorus load = 0.55 pound/acre/year

Step 3: Next, the required load reduction is computed by comparing the post-development load to the site-based load limit, and an appropriate BMP is selected.

Example: Load reduction = post-development load – site-based load limit 0.55 – 0.28 = 0.27 pound/acre/year (load that must be removed to meet the load limit standard) Selected BMPs should be capable of removing the target load reduction. One way to determine this is to calculate the load leaving the BMP based on the expected effluent concentration and the effluent volume for the design storm (or on an annual basis).

Step 4: Select a combination of structural and nonstructural BMPs that can be documented to meet the required load reduction. If the local program and/or TMDL implementation plan encourages LID, then these practices should be assigned load reduction credits.

If the entire load reduction cannot be achieved (or is impractical) on the particular site, the applicant might be eligible to implement equivalent off-site BMPs within the impaired watershed. These off-site BMP may be implemented by the applicant on developed land that is currently not served by stormwater BMPs. As and alternative, the applicant can pay an appropriate fee (fee in lieu) to the local program to implement stormwater retrofits within the impaired watershed. In either case, full on-site compliance is being “traded” to implement other BMPs that can help achieve TMDL goals.

The local program would have to apply this technique to a variety of local plans to gauge achievability and feasibility across a range of development scenarios. A good real-world example of this approach (although not specific to impaired watersheds) is Maine’s *Phosphorus Control in Lake Watersheds: A Guide to Evaluating New Development*, which can be found at:

http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterbmps

B. Surrogate Measures for Sources of Impairment

If site-based load limits cannot be used because of the type of impairment (e.g., aquatic life) or limited data, surrogates that have a strong link to the cause of impairment can be used. For instance, various TMDLs have used impervious cover and stormwater flow as surrogates for stormwater impacts on aquatic life, stream channel stability, and habitat (USEPA, 2007). In these cases, the surrogates are relatively easy to measure and track through time. The TMDL might have a goal to reduce impervious cover and/or to apply BMP treatment to a certain percentage of impervious cover within the impaired watershed.

A local stormwater program could apply the surrogate approach through a tiered implementation strategy for new development and redevelopment:

- FIRST, minimize the creation of new impervious cover at the site through site design techniques. Preserve sensitive site features, such as riparian areas, wetlands, and important forest stands.
- SECOND, disconnect impervious cover by using LID and nonstructural BMPs.
- THIRD, install structural BMPs to reduce the impact of impervious cover on receiving waters.

C. Presumptive BMP Performance Standards

Perhaps the most widespread and simplest method to link TMDL goals with stormwater criteria is to presume that implementation of a certain suite of BMPs will lead to load reductions, and that monitoring and adaptive management can help adjust the appropriate template of BMPs over time (USEPA, 2007; USEPA Region 5, 2007d). This strategy acknowledges that data are often too limited to draw a conclusive link between particular pollutant sources and in-stream impairments. However, as more data becomes available and TMDL implementation strategies are refined, a more quantitative method, such as the two noted above, should be pursued.

There are a wide variety of "presumptive" BMPs that can be included in local stormwater criteria for an impaired watershed, and these should be adapted based on the pollutant(s) of concern:

- Stream/wetland/lake setbacks and buffers
- Site reforestation
- Soil enhancements
- Incentives for redevelopment

Requirements for runoff reduction:

- Implementation of LID
- Requirements for BMPs with filter media and/or vegetative cover
- Enhanced sizing and/or pre-treatment requirements
- Required BMPs at stormwater hotspots or particular land use categories (e.g., marinas, industrial operations)
- Contribution to stormwater retrofit projects within the watershed

The "providing channel protection" criterion is highly recommended for receiving waters that are impaired by sediment or sediment-related pollutants. Given the importance of channel erosion in the sediment budget of urban streams, it is critical to control erosive flows from development projects.

For more information on linking TMDLs to stormwater permits, see the following:

Total Maximum Daily Loads with Stormwater Sources: A Summary of 17 TMDLs, EPA 841-R-07-002, at:

http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/17_TMDLs_Stormwater_Sources.pdf

Total Maximum Daily Loads and National Pollutant Discharge Elimination System Stormwater Permits for Impaired Waterbodies: A Summary of State Practices, USEPA, at:

http://www.epa.gov/r5water/wshednps/pdf/state_practices_report_final_09_07.pdf

Incorporating Green Infrastructure Concepts into Total Maximum Daily Loads (TMDLs), USEPA at:

http://water.epa.gov/aboutow/owow/upload/tmdl_lid_final.pdf

For a comprehensive primer on stormwater retrofitting in existing urban/developed land, see: ***Urban Stormwater Retrofit Practices, Manual 3***, 2008, *Urban Subwatershed Restoration Manual Series*, Center for Watershed Protection, at:

http://www.cwp.org/documents/cat_view/68-urban-subwatershed-restoration-manual-series/89-manual-3-urban-stormwater-retrofit-practices-manual.html

To obtain even more information on creating a stronger link between stormwater criteria and TMDLs, refer to Chapter 4 of the Center for Watershed Protection's ***Post-Construction SWMP Program Guidance Manual,* at:**

http://www.cwp.org/documents/doc_details/200-managing-stormwater-in-your-community-a-guide-for-building-an-effective-post-construction-program.html?tmpl=component

6.9.7. Ultra Urban Settings

Accomplishing Environmental Site Design at ultra-urban development and redevelopment sites is challenging, since population is dense and space is extremely limited, land is expensive, soils are disturbed, and runoff volumes and pollutant loadings are great, and there is a wide range of potential pollutants. These sites do, however, present a great opportunity for making progress in stormwater management where it has not previously existed. Much of the opportunity is focused on BMP selection and design, as well as cohesive integration of the BMP treatment train into the development scheme. BMP selection for ultra-urban sites is addressed in **Section 8.6.1 and Table 8.3 of Chapter 8** of this Handbook. BMP designs aimed specifically at ultra-urban settings can be found in Attachment D of the *Baltimore City Stormwater Management Manual.* Such designs may be considered for approval by local plan review authorities as innovative/alternative designs, provided sufficient design/routing information is included.

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