Land Use Regulatory Control in the Tankerhoosen Watershed Material Set 1

Friends of the Hockanum River Linear Park

Vernon, Connecticut

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1 Background

1.1 Tankerhoosen River Watershed Management Plan

The Tankerhoosen River watershed is an approximately 13 square-mile subregional basin within the larger Hockanum River and Connecticut River watersheds in north-central Connecticut. Approximately 70% of the watershed is located within the Town of Vernon. The Tankerhoosen River has long been recognized as an important natural resource and a key inland watershed critical to the health of Long Island Sound. The high water quality in the upper regions of the Tankerhoosen River sustains a significant natural resource of the State of Connecticut – the Belding Wild Trout Management Area, one of only two Class I wild trout areas east of the Connecticut River. The importance of these small, high-quality watersheds to the downstream health of the larger river basins, and therefore to Long Island Sound, is well-recognized.

Development pressure in the watershed poses a threat to the long-term health of the Tankerhoosen River and other waterbodies. Water quality in the lower reaches of the Tankerhoosen has been impacted by historical development and land use activities in the watershed; this portion of the river currently does not meeting water quality standards for aquatic habitat. Uncontrolled stormwater runoff associated with future development and redevelopment activities in the Town of Vernon threatens the existing high water quality of portions of the Tankerhoosen River and threatens to further degrade the impaired segment of the river.

Friends of the Hockanum River Linear Park, in conjunction with the Town of Vernon and other local and state entities, developed a watershed management plan in 2009 to address water quality issues in the Tankerhoosen River watershed. One of the recommendations of the management plan was for the Town of Vernon to incorporate Low Impact Development (LID) into its land use regulations and policy, as an important strategy for protecting and improving water quality in the Tankerhoosen River Watershed.

The watershed management plan included an assessment of the Town of Vernon's land use regulations for the purposes of identifying potential enhancements to watershed management policy. The assessment included a review of existing land use regulations and related planning documents that pertain to stormwater management and natural resource protection issues, as well as potential approaches for developing regulatory mechanisms to incorporate improved stormwater management, including LID concepts and opportunities to reduce impervious cover, into the local land use regulations.

The previous regulatory review identified a number of strengths related to water resource protection. However, it also noted several areas where the Town's regulations, design standards, and guidance could be improved through amendments or new regulations to clarify and strengthen stormwater management requirements and better promote the use of LID approaches.

The watershed management plan identified the following specific opportunities to advance the use of LID in the Town of Vernon:

- Development of a Town stormwater design manual with LID standards
- Development of specific stormwater management standards that include LID
- Development of new or modified stormwater regulations that encourage or require LID

1.2 Low Impact Development (LID)

LID is an innovative stormwater management approach that uses the basic principle modeled after nature: manage rainfall where it lands. LID's goal is to mimic a site's pre-development hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Techniques are based on the premise that stormwater management should not be seen as stormwater disposal. Instead of conveying and managing/treating stormwater in large, costly end-of-pipe facilities located at the bottom of drainage areas, LID addresses stormwater through small, cost-effective landscape features located at the lot level. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment projects.

LID has become the preferred approach for stormwater management, both nationally and in the State of Connecticut. The U.S. Environmental Protection Agency (EPA) is promoting LID and similar approaches such as "green infrastructure" for new development and redevelopment, including in its proposed national stormwater rule. The State of Connecticut has also adopted LID as the preferred approach for stormwater management state-wide and is integrating LID into its stormwater and erosion/sediment control design guidance and stormwater general permits. Other Connecticut municipalities have either adopted or are in the process of adopting local LID design guidance and regulations. Examples of such communities include Tolland, Torrington, Plainville, Meriden, Darien, Bridgeport, Greenwich, and Avon.

1.3 Project Objectives and Approach

Since the development of the watershed management plan, Friends of the Hockanum River Linear Park applied for and secured grant funding from the National Fish and Wildlife Foundation Long Island Sound Futures Fund to implement the watershed plan recommendations relative to LID/land use regulatory controls in the Town of Vernon. The objective of this project is therefore to assist the Town of Vernon develop LID regulations and associated standards and design guidance. The general project approach consists of a review of the Town's land use regulations and policy, building on the previous review conducted during the watershed planning process, followed by development of regulatory revisions and LID standards and guidance. This technical memorandum initiates the process by discussing:

- Common impediments to LID found in local policy
- The methods used to assess the Town's existing policy
- The assessment findings
- Specific recommendations for incorporating LID into Town policy

2 Common Impediments to LID in Local Policy

Significant barriers to the implementation of LID commonly exist within municipal land use regulations and codes. Some typical examples include:

- Minimum parking space requirements that over-allocate stall size and parking needs
- General requirements for roads that are unnecessarily wide for all circumstances
- Requirements to include curb and gutter on all roadways
- Pavement type requirements that essentially prohibit use of pervious pavement
- Requirements for sidewalks that may lack flexibility for reduced foot trafic
- Prohibition of open channel conveyance
- Plumbing codes that prevent downspout disconnection

The following sections of this technical memorandum describe specific elements of land use policy related to LID. Questions that were posed to guide our assessment of existing policy are also provided. The elements are organized by the following major topics:

- Vegetation and landscaping
- Minimizing land disturbance
- Open space and cluster development
- Impervious area management
- Open vegetated channels

2.1 Vegetation and Landscaping

Developing land in a way that mimics natural landscape is a key tenet of LID. Management of both existing and proposed site vegetation can affect groundwater recharge and stormwater runoff quality and quantity.

2.1.1 Preservation of Natural Areas

To properly incorporate LID, municipal regulations should include requirements to preserve existing vegetated areas, minimize turf grass lawn areas, and use native vegetation.

- Are applicants required to provide a layout of the existing vegetated areas, and a description of the conditions in those areas?

- Does the municipality have maximum as well as minimum yard sizing requirements?

- Are residents restricted from enlarging existing turf lawn areas?

- Do the regulations provide incentives for the use of vegetation as filters for stormwater runoff?

- Do the regulations require a specific percentage of permanently preserved open space as part of the evaluation of cluster development?

2.1.2 Tree Protection

Municipalities often have tree ordinances designed to minimize the removal of trees and to replace trees that are removed. However, while tree ordinances protect the number of trees, they do not typically address the associated leaf litter or smaller vegetation that provides additional water quality and quantity benefits. The questions below are aimed at enhancing tree protection requirements and preservation of forested areas.

- Does the municipality have a tree protection regulation or ordinance?
- Can the municipality include a forest protection regulation or ordinance?
- If forested areas are present at development sites, is percentage of the stand required to be preserved?

2.1.3 Parking Lot Islands and Screening

Parking lot islands are landscaped areas within a parking lot that, traditionally have been used to physically separate parking spaces from travel lanes or sidewalks, but can also be designed to provide for groundwater recharge and treatment of parking lot runoff. Parking lot islands can also provide for visual screening. Therefore, regulations or ordinances that dictate parking lot design requirements may provide an opportunity to incorporate LID and provide stormwater quality and groundwater recharge benefits.

- Do the regulations or ordinances require landscaping islands in parking lots, or between the roadway and the sidewalk? Can the regulations or ordinances be modified to require vegetation that is more beneficial for stormwater quality, groundwater recharge, or stormwater quantity, but that does not interfere with driver vision?

- To what extent are bioretention islands and other stormwater practices within landscaped areas or setbacks allowed?

- Do the regulations or ordinances require screening from adjoining properties? Can the screening criteria require the use of vegetation to the maximum extent practicable before the use of fences, walls or berms?

2.1.4 Riparian Buffers

Many municipalities have buffer or floodplain policies that require the protection of vegetation adjacent to streams. The municipality should consider conservation restrictions and allowable maintenance to ensure the preservation of these areas.

- Is there a stream buffer or floodplain regulation or ordinance in the community?

- Does the regulation or ordinance require a conservation easement, or other permanent restrictions on buffer areas?

- Does the regulation ordinance provide detailed information on the type of maintenance and/or activities that are allowed in the buffer?

2.2 Minimizing Land Disturbance

A key goal of LID is to limit clearing, grading, and other disturbance associated with development. Limiting disturbance helps preserve the site's existing hydrologic character, as well as limiting soil compaction. Zoning requirements may limit the amount of impervious surface on building lots, but may not limit the amount of area that can be disturbed during construction.

2.2.1 Limits of Disturbance

Designing with the terrain, or site fingerprinting, requires an assessment of the site characteristics and selection of areas for development that would minimize potential impacts. This can be incorporated into the requirements for discussion of existing site conditions. Limits of disturbance should be incorporated into construction plans reviewed and approved by the municipality. Property line setbacks should be evaluated to determine whether they can be reduced.

- Does municipal policy require identification of environmentally critical and environmentally constrained areas?

- Are existing setbacks appropriate for desired LID practices?

- Does municipal policy incorporate maximum turf grass or impervious cover limits in setbacks?

- Do the regulations or ordinances inhibit or prohibit the clear cutting of the project site as part of the construction?

- Is the traffic of heavy construction vehicles limited to specific areas, such as areas of proposed roadways? Are these areas required to be identified on the plans and marked in the field?

- Do the regulations or ordinances require the identification of specific areas that provide significant hydrologic functions, such as existing surface storage areas, forested areas, riparian corridors, and areas with high groundwater recharge capabilities (i.e., well-drained or highly pervious soils)?

- Does the municipality require an as-built inspection before issuing a certificate of occupancy? If so, does the inspection include identification of compacted areas, if they exist within the site?
- Does the municipality require the restoration of compacted areas in accordance with the soil erosion and sediment control standards?

2.2.2 Open Space and Cluster Development

Since open space can have a variety of uses, municipalities should evaluate open space regulations or ordinances to evaluate whether amendments could provide for improved stormwater benefits.

- Are open-space or cluster development designs allowed in the municipality?

- Are flexible site design incentives available for developers that utilize open space or cluster design options?

- Are there limitations on the allowable disturbance of existing vegetated areas in open space?

- Are there requirements to re-establish vegetation in disturbed areas dedicated for open space?

- Is there a maximum allowable impervious cover in open space areas?

2.3 Impervious Area Management

The amount of impervious area on a site, and its relationship to adjacent vegetated areas, can significantly affect the amount of runoff that is generated and stormwater management requirements. Streets, sidewalks, driveways, and parking areas comprise a large fraction of a developed site's impervious surfaces. Continuous curb requirements may prevent runoff from reaching adjacent vegetated areas.

2.3.1 Streets and Driveways

Street widths of 18 to 22 feet are generally recommended for LID designs in low-density residential developments. Maximum driveway widths of 9 and 18 feet for one lane and two lanes, respectively, are also generally recommended. Width requirements of streets and driveways should be evaluated to demonstrate that the proposed width is the narrowest possible, consistent with safety and traffic concerns and requirements. Municipalities should evaluate which traffic calming features, such as circles, rotaries, medians, and islands, can be vegetated or landscaped. Cul-de-sacs can also be evaluated to reduce the radius area, or to provide a landscape island in the center.

- Do street designs vary by type (e.g., artery, collector, neighborhood, etc.) and context (e.g., suburban area, urban core, etc.)
- Are the street widths the minimum and maximum necessary for traffic density, emergency vehicle movement, and roadside parking while supporting pedestrian use and safety?

- Are street features, such as circles, rotaries, or landscaped islands allowed to or required to receive runoff?

- Are curb cuts or flush curbs with curb stops an allowable alternative to raised curbs?

- Can the minimum cul-de-sac radius be reduced or is a landscaped island required in the center of the cul-de-sac?

- Are alternative turn-arounds such as "hammerheads" allowed on short streets in low-density residential developments?

- Can the minimum driveway width be reduced?

- Are shared driveways permitted (and potentially accepted by homeowners) in residential developments?

2.3.2 Parking Areas and Sidewalks

A mix of uses at a development site can allow for shared parking areas, reducing total parking requirements. Municipalities require minimum parking areas, but seldom limit the total number of parking spaces.

- Can the parking ratios be reduced?
- Are parking requirements set as maximum or median rather than minimum requirements?
- Is the use of shared parking arrangements allowed to reduce the parking area?
- Are model shared parking agreements provided?
- Does the presence of mass transit allow for reduced parking ratios?
- Is a minimum stall width of 9 feet allowed?
- Is a minimum stall length of 18 feet allowed?
- Can the stall lengths be reduced to allow vehicle overhang into a vegetated area?
- Do ordinances allow for permeable material to be used in overflow parking areas?
- Are there incentives to provide parking that reduces impervious cover, rather than providing only surface parking lots?
- Are pervious materials allowed or required for surface parking lots?

Sidewalks can be made of pervious material or disconnected from the drainage system to allow runoff to infiltrate into the adjacent pervious areas.

- Are sidewalks allowed to be constructed of pervious materials?
- Can alternate pedestrian networks be substituted for sidewalks (e.g., trails through common areas)?

2.3.3 Unconnected Impervious Areas

Disconnection of impervious areas can occur in both low-density development and high-density commercial development, provided sufficient vegetated area is available to accept dispersed stormwater flows. Areas for disconnection include parking lot or cul-de-sac islands, lawn areas, and other vegetated areas.

- Are developers required to disconnect impervious surfaces to promote pollutant removal and groundwater recharge?
- Do regulations or ordinances allow the reduction of the runoff volume when runoff from impervious areas is infiltrated into vegetated areas?
- Do regulations or ordinances allow flush curb and/or curb cuts to allow runoff to discharge into adjacent vegetated areas as sheet flow?

2.4 Vegetated Open Channels

The use of vegetated channels, rather than the standard concrete curb and gutter configuration, can decrease flow velocity, and allow for stormwater filtration and infiltration. One design option is for vegetated channels that convey smaller storm events, such as the water quality design storm, and provide an overflow into a storm sewer system for larger storm events.

- Do regulations or ordinances allow or require vegetated open channel conveyance instead of the standard curb and gutter designs?
- Are there established design criteria for vegetated channels?

3 Assessment Methods

This section of the technical memorandum discusses the methods that were used to assess local policy. The following Town land use regulations, ordinances, and planning documents were reviewed:

- *Town of Vernon Zoning Regulations* (revised November 17, 2010)
- *Town of Vernon Inland Wetlands and Watercourses Regulations* (revised October 1, 2010)
- *Subdivision Regulations of the Town of Vernon* (last amended April 7, 2003)
- *Amended Subdivision Regulations of the Town of Vernon* (revisions to Section 6.1.3 and 14 as of April 14, 2006)
- *Vernon Draft Plan of Conservation and Development* (May 2011)

- *Town of Vernon Code of Ordinances*

Each of these documents was evaluated and summarized in tabular format (see *Appendix A*). The summary tables include the review topic (following the topics discussed in *Section 2*), regulatory citation, excerpted language, potential issues, and recommended revisions. The Town of Vernon Code of Ordinances does not include policy relevant to the implementation of LID; therefore, a summary of the Code of Ordinance is not included in *Appendix A* and is not discussed further in this material set. The assessment findings are presented in *Section 4,* with recommendations provided in *Section 5*.

4 Assessment Findings

This section describes the findings of our assessment, which are organized based on the categories of impediments to LID discussed in Section 2 of this technical memorandum. The assessment focuses on the four principal Town land use regulatory and planning documents – Inland Wetlands and Watercourses Regulations, Subdivision Regulations, Zoning Regulations, and Plan of Conservation and Development.

4.1 Vegetation and Landscaping

4.1.1 Preservation of Natural Areas

Inland Wetlands and Watercourses Regulations

- The regulations currently require permitting for activities in wetlands and upland review areas. This includes discharge of stormwater.

- The regulations do not specifically encourage or require the preservation and enhancement of vegetated areas in proximity to wetlands.

- The regulations do not address the use of riparian buffers (i.e., preserved natural areas along streams) for stormwater management. While Appendix C of the regulations describes standards for riparian buffers, the regulations do not appear to require buffers or specifically encourage their use.

Subdivision Regulations

- The regulations allow for designation of open spaces. This could potentially be used to preserve natural areas.

Zoning Regulations

- The regulations include open space zoning, which can be used to set aside and permanently protect areas of land for conservation.

Plan of Conservation and Development

- The plan recommends preservation of sensitive areas.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Are applicants required to provide a layout of the existing vegetated areas, and a description of the conditions in those areas?

  Both the Inland Wetlands and Watercourses Regulations and the Subdivision Regulations require that applicants provide site plans showing proposed activities and existing conditions.

- Does the municipality have maximum as well as minimum yard sizing ordinances?

  The Zoning Regulations provide minimum yard sizing requirements but not maximums. This issue is not addressed specifically by other enforceable policies.

- Are residents restricted from enlarging existing turf lawn areas?

  This issue is not addressed in enforceable policy.

- Do the ordinances provide incentives for the use of vegetation as filters for stormwater runoff?

  We found no enforceable policy that specifically discusses the use of native vegetation for stormwater treatment.

- Do the ordinances require a specific percentage of permanently preserved open space as part of the evaluation of cluster development?

  The Zoning Regulations allow for open space zoning and cluster development, but does not specify a percentage of land to be permanently preserved.

4.1.2 Tree Protection

Inland Wetlands and Watercourses Regulations

- Appendix C of the regulations discusses standards for watercourse protection buffers that include trees. The regulations do not appear to require buffers or specifically encourage their use.

Subdivision Regulations

- Site plans are required to show principal wooded areas and the approximate location of large, isolated trees at a scale of 1" = 100'; however there is no definition of principal wooded areas or of what constitutes a large tree. There is no specific requirement to show trees to be preserved.

- The regulations require installation of new trees or preservation of existing trees as part of projects.

Zoning Regulations

- The regulations establish site planning and architectural and design review standards that call for identification and preservation of existing trees.

Plan of Conservation and Development

- The plan discusses prevention of accidental tree damage and encouraging property owners to retain vegetation.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Does the municipality have a tree protection regulation or ordinance?

  The Town does not currently have a tree protection ordinance although Town regulatory policy does address some elements of tree protection.

- If forested areas are present at development sites, is there a required percentage of the stand to be preserved?

  This is not specified.

4.1.3 Parking Lot Islands and Screening

Inland Wetlands and Watercourses Regulations

- No relevant policy found.

Subdivision Regulations

- No relevant policy found.

Zoning Regulations

- The regulations establish standards for landscape buffer strips for the purposes of screening between land uses that might otherwise conflict.

- The regulations establish a requirement for parking lot islands, which appear to be for landscaping purposes.

Plan of Conservation and Development

- No relevant policy found.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Do the regulations or ordinances require landscaping islands in parking lots, or between the roadway and the sidewalk? Can the ordinance be adjusted to require vegetation that is more beneficial for stormwater quality, groundwater recharge, or stormwater quantity, but that does not interfere with driver vision?

Landscaping islands and screening are discussed in section 9 of the Zoning Regulations. The Planning and Zoning Commission (PZC) may require a landscaped buffer strip. Stormwater management is not discussed in this section of the regulations.

- To what extent are bioretention islands and other stormwater practices within landscaped areas or setbacks allowed?

  Town policy is silent on this issue.

- Do the regulations or ordinances require screening from adjoining properties? Can the screening criteria require the use of vegetation to the maximum extent practicable before the use of walls or berms?

  Screening may be required by PZC per section 9 of the Zoning Regulations.

4.1.4 Riparian Buffers

Inland Wetlands and Watercourses Regulations

- Appendix C of the regulations discusses standards for watercourse protection buffers that include trees. The regulations do not appear to require buffers or specifically encourage their use.

Subdivision Regulations

- The Town has the option of requiring a minimum 20-foot wide easement on either side of a watercourse; however, this requirement is for the purposes of providing a drainage easement in low-lying areas.

Zoning Regulations

- No relevant policy found.

Plan of Conservation and Development

- No relevant policy found.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Is there a stream buffer or floodplain regulation or ordinance in the community?

  The Town does not have a specific stream buffer or floodplain protection regulation or ordinance. Some related standards are included in the Inland Wetlands and Watercourses Regulations and the Subdivision Regulations.

- Does the ordinance require a conservation easement, or other permanent restrictions on buffer areas?

  This is not a requirement, but the Town may opt to require such easements for drainage purposes.

- Does the regulation or ordinance give detailed information on the type of maintenance and/or activities that are allowed in the buffer?

  This is not addressed.

4.2 Minimizing Land Disturbance

4.2.1 Limits of Disturbance

Inland Wetlands and Watercourses Regulations

- No relevant policy found.

Subdivision Regulations

- No relevant policy found.

Zoning Regulations

- Setbacks and lot dimensions are referenced for various use districts; however these are minimum setbacks and therefore do not limit disturbance.

Plan of Conservation and Development

- No relevant policy found.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Does municipal policy require identification of environmentally critical and environmentally constrained areas?

  Town policy does this to an extent. The Subdivision Regulations require that site development plans must show wetlands and other surface water resources, conservation areas and principal wooded areas. Use restrictions apply to certain other areas such as aquifers and riparian corridors.

- Are existing setbacks appropriate for desired LID practices?

  Current setbacks are appropriate from a dimensional standpoint; however, they are provided as minimums only. Maximum setbacks are desirable for LID.

- Does municipal policy incorporate maximum turf grass or impervious cover limits in setbacks?

  This is not addressed.

- Do the ordinances inhibit or prohibit the clear cutting of the project site as part of the construction?

  This is not addressed.

- Is the traffic of heavy construction vehicles limited to specific areas, such as areas of proposed roadway? Are these areas required to be identified on the plans and marked in the field?

  This is not addressed.

- Do the ordinances require the identification of specific areas that provide significant hydrologic functions, such as existing surface storage areas, forested areas, riparian corridors, and areas with high groundwater recharge capabilities?

  This is not addressed.

- Does the municipality require an as-built inspection before issuing a certificate of occupancy? If so, does the inspection include identification of compacted areas, if they exist within the site?

  This is not addressed.

- Does the municipality require the restoration of compacted areas in accordance with the soil erosion and sediment control standards?

  This is not addressed.

4.2.2 Open Space and Cluster Development

Inland Wetlands and Watercourses Regulations

- No relevant policy found.

Subdivision Regulations

- No relevant policy found.

Zoning Regulations

- The Town has established policy for both cluster development and open space zoning.

Plan of Conservation and Development

- The plan discusses preserving, promoting, and managing existing open space.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Are open-space or cluster development designs allowed in the municipality?

  Yes, open space zoning and cluster developments are discussed in the Town's Zoning Regulations.

- Are flexible site design incentives available for developers that utilize open space or cluster design options?

  These zones allow for reduced dimensional setbacks.

- Are there limitations on the allowable disturbance of existing vegetated areas in open space?

  This is not addressed.

- Are there requirements to re-establish vegetation in disturbed areas dedicated for open space?

  This is not addressed.

- Is there a maximum allowable impervious cover in open space areas?

  Yes, Section 4 of the Zoning Regulations actually establishes maximum allowable impervious coverages for each zoning category including cluster and open space zones.

4.3 Impervious Area Management

4.3.1 Streets and Driveways

Inland Wetlands and Watercourses Regulations

- No relevant policy found.

Subdivision Regulations

- Street and driveway dimensions and standards are provided in Section 6 of the regulations. Flexibility for LID is not discussed.

Zoning Regulations

- The Town has established a policy in its Zoning Regulations that requires site plans to include LID wherever feasible where site plans are required for PZC review. It is conceivable that this policy could conflict with the Subdivision Regulation requirements in some instances.

Plan of Conservation and Development

- The plan discusses the reduction of road widths in the context of traffic calming.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Do street designs vary by type (e.g., artery, collector, neighborhood) and context (e.g., suburban area, urban core, etc.)

  Subdivision Regulations provide for two types of streets—collector and local.

- Are the street widths the minimum and maximum necessary for traffic density, emergency vehicle movement, and roadside parking while supporting pedestrian use and safety?

  Street dimensions are limited to minimums.

- Are street features, such as circles, rotaries, or landscaped islands allowed to or required to receive runoff?

  This is appears to be allowed pursuant to Section 14.1.2.2.12 of the Zoning Regulations, but is not required.

- Are curb cuts or flush curbs with curb stops an allowable alternative to raised curbs?

  This is not specifically addressed.

- Can the minimum cul-de-sac radius be reduced or is a landscaped island required in the center of the cul-de-sac?

  This is not specifically addressed.

- Are alternative turn-arounds such as "hammerheads" allowed on short streets in low density residential developments?

  This is not specifically addressed.

- Can the minimum driveway width be reduced?

  This is not addressed.

- Are shared driveways permitted in residential developments?

  This is not specifically addressed.

4.3.2 Parking Areas and Sidewalks

Inland Wetlands and Watercourses Regulations

- No relevant policy found.

Subdivision Regulations

- No relevant policy found.

Zoning Regulations

- The Town has established policy for off-street parking by land use in Section 12 of its Zoning Regulations. The Town has established a process in its Zoning Regulations that allows for payment-in-lieu of up to 20% of required spaces. General standards and requirements are also provided in Section 12. Standards are established as minimums. It is not clear whether section 14.1.2.2.12, which indicates that LID shall be employed wherever feasible where site plans are required, would allow for reductions in minimum standards.

Plan of Conservation and Development

- Among other parking related topics, the plan discusses rethinking parking requirements to reduce the environmental and economic impacts of providing too much parking.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Can the parking ratios be reduced?

  This is not addressed per se; however, the Town does allow for buy-down of up to 20% of required parking spaces.

- Are the parking requirements set as maximum or median rather than minimum requirements?

  No, parking requirements are provided as minimums

- Is the use of shared parking arrangements allowed to reduce the parking area?

  This is not addressed.

- Are model shared parking agreements provided?

  This is not addressed.

- Does the presence of mass transit allow for reduced parking ratios?

  This is not addressed.

- Is a minimum stall width of 9 feet allowed?

  Minimum width is provided as 9 feet.

- Is a minimum stall length of 18 feet allowed?

  Minimum length is provided as 17 feet.

- Can the stall lengths be reduced to allow vehicle overhang into a vegetated area?

  This is not addressed.

- Do regulations or ordinances allow for permeable material to be used in overflow parking areas?

  This is not addressed.

- Are there incentives to provide parking that reduces impervious cover, rather than providing only surface parking lots?

  This is not addressed.

- Do ordinances allow for sidewalks constructed with pervious material?

  This is not addressed.

- Can alternate pedestrian networks be substituted for sidewalks (e.g., trails through common areas)?

  This is not addressed.

4.3.3 Unconnected Impervious Areas

Inland Wetlands and Watercourses Regulations

- No relevant policy found.

Subdivision Regulations

- No relevant policy found.

Zoning Regulations

- No relevant policy found.

Plan of Conservation and Development

- No relevant policy found.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Are developers required to disconnect impervious surfaces to promote pollutant removal and groundwater recharge?

  This is not addressed.

- Do regulations or ordinances allow the reduction of the runoff volume when runoff from impervious areas is re-infiltrated into vegetated areas?

  This is not addressed.

- Do regulations or ordinances allow flush curb and/or curb cuts to allow for runoff to discharge into adjacent vegetated areas as sheet flow?

  This is not addressed.

4.4 Vegetated Open Channels

Inland Wetlands and Watercourses Regulations

- No relevant policy found.

Subdivision Regulations

- No relevant policy found.

Zoning Regulations

- No relevant policy found.

Plan of Conservation and Development

- The plan discusses the update of zoning and subdivision regulations to require LID approaches, but does not specifically address vegetated open channels.

The following addresses the general questions posed in *Section 2*. The results of the review (i.e., answers to the questions) are shown in italics text:

- Do regulations or ordinances allow or require vegetated open channel conveyance instead of the standard curb and gutter designs?

  This is not addressed.

- Are there established design criteria for vegetated channels?

  This is not addressed.

5 Recommendations

Preliminary recommendations are presented in this section for review and discussion with the Project Steering Committee during Workshop 2. The recommendations are based on the assessment findings described in *Section 4*. The recommendations are summarized by topic in *Table 1*. Key recommendations are discussed in greater detail, following the tabular summary (see *Section 5.1.1 – Section 5.1.5*). *Section 5.2* discusses recommended approaches for updating Town ordinances, regulations and guidance to incorporate LID.

5.1 Recommended Policy Revisions

The following table summarizes recommended revisions to the Town of Vernon land use regulations to remove existing barriers to implementing LID and facilitate the use of LID by the development community.

Table 1
Recommended LID Policy Revisions by Topic

Topic	Recommendations
Preservation of Natural Areas and Riparian Buffers	• Map natural areas to be protected. Make maps available online. Alternatively or in conjunction with mapping, establish specific criteria that define natural areas to be protected in the definition sections of the Inland Wetlands, Subdivision, and Zoning regulations. In addition to wetlands and watercourses, which are already mapped, consider adding riparian buffers, special habitat, erodible soils, principal forested areas, aquifers, etc. • Establish and map protective buffers around natural areas and limit activities in these areas, but allow use of them as disconnected areas for stormwater management. • Provide buffer standards relative to composition, size, and use in a single part of the municipal regulations, such as Section 4 of the zoning regulations, or a separate document that is incorporated by reference into each regulation.

Topic	Recommendations
	• Reference maps in Inland Wetlands and Subdivision Regulations. Consider establishing an overlay zone or floating zone for these areas in Section 4 of the Zoning Regulations. • Use a LID guidance manual to standardize the use and maintenance of natural areas for stormwater management.
Tree Protection	• Establish a single part of the municipal regulations, such as a Section 5 of the Subdivision Regulations, for tree protection or develop a stand-alone tree protection ordinance in the Town's code of ordinances. • Establish standards for protection of understory, where practicable, in Section 5 and 6.1.5 of the Subdivision Regulations, Appendix A of the Zoning Regulations, or in a stand-alone tree protection ordinance. • Use a LID guidance manual to standardize the use of protected treed areas for stormwater management.
Landscaping Islands for Stormwater	• Require or strongly encourage the use of landscape strips and parking lot islands for stormwater management in Sections 9 and 21 of the Zoning Regulations.
Limits of Disturbance	• Require reduced limits of disturbance in accordance with a LID standards manual in Section 6.4 of the Subdivision Regulations. • Allow for relaxed setbacks and yard dimensions in Sections 4.1 – 4.25 of the Zoning Regulations.
Open Space and Cluster Development	• Update the cluster zoning sections of the zoning regulations to limit disturbance of vegetated areas and require reestablishment of disturbed vegetation.
Streets and Driveways	• Define "Low Impact Development" in Section 3 of the Subdivision Regulations to include reduction in road widths. • Allow roads without curbs or alternative curbs for the purpose of stormwater management in Section 6.7.2 of the Subdivision Regulations. • Allow the use of pervious pavement as an "alternate surface" (see Section 3.15 of the Zoning Regulations) in accordance with a LID standards manual. • Allow for reduced cul-de-sac radius (30 – 40 feet) in Section 6.6 of the Subdivision Regulations. This should be coordinated with the Fire and School Departments to ensure their vehicles can turn within this radius. • Require the use of LID wherever practicable in Section 6.9.4.2 of the Subdivision Regulations.
Parking Areas	• Require that parking lot islands incorporate stormwater treatment facilities wherever practicable in Section 21.4 of the Zoning Regulations. • Allow the use of pervious pavement as an "alternate surface" (see Section 3.15 of the Zoning Regulations) in accordance with a LID standards manual. • Establish maximums for off-street parking in Section 12 of the Zoning Regulations. • Revise Section 12 of the Zoning Regulations to allow the Commission

Topic	Recommendations
	to approve parking lots with more spaces than the allowed maximum provided all of the spaces above the maximum number are composed of a pervious surface, and where adequate stormwater management is provided. • Revise Section 12 of the Zoning Regulations to allow for shared parking and provide model shared parking agreements. • Revise Section 12 of the Zoning Regulations to allow parking spaces held in reserve for phased developments, thereby avoiding the situation where unnecessary parking is constructed if future phases of development do not occur. • Revise the parking stall length requirements in Section 12 of the Zoning Regulations to allow vehicle overhang into vegetated areas. • Revise Section 12 of the Zoning Regulations to specifically allow for multi-level parking.
Sidewalks	• Ensure that Appendix C of the Subdivision Regulations allows for reduced width sidewalks, grading towards front yards (i.e., pervious areas), and construction of sidewalks using pervious materials.
Unconnected Impervious Surfaces	• Add Section 6.9.4.1 to the Subdivision Regulations specifically recommending use of LID and disconnection of impervious surfaces by grading them to runoff to pervious areas.
Vegetated Open Channels	• Revise Section 6.9.4.4 to the Subdivision Regulations to allow for vegetated open channels in accordance with a LID standards manual.

The following sections provide further explanation of the key recommendations in the summary table above.

5.1.1 Map of Natural Resources

The Town should consider developing an enhanced map of natural resources and provide the map as an online resource for convenience of Town staff and applicants. The Town currently maintains a hardcopy version of a map of wetlands resources. This map presents an excellent starting point, but could be enhanced to include other natural resources that are valuable to protect from a water resources standpoint such as aquatic habitat, soils, and forested areas.

The Town should identify criteria for the identification of such resources, map the resources, and establish buffer areas around the resources. If desired, uses allowed in the buffer areas, such as disconnection areas for stormwater treatment, could be described in the Town's Zoning Regulations. Standards for identification, use, and operation and maintenance could be developed that replace or update existing buffer and buffer yard standards in Town policy.

5.1.2 Limit "Incidental" Uses Allowed by Right

In Connecticut, municipalities must permit incidental issues by right pursuant to Section 22A-40 of the General Statutes of Connecticut:

> The following operations and uses shall be permitted in wetlands and watercourses, as of right…uses incidental to the enjoyment and maintenance of residential property, such property defined as equal to or smaller than the largest minimum residential lot site permitted anywhere in the municipality, provided in any town, where there are no zoning regulations establishing minimum residential lot sites, the largest mi9nmum lot site shall be two acres. Such incidental uses shall include maintenance of existing structures and landscaping but shall not include removal or deposition of significant amounts of material from or onto a wetland or watercourse or diversion or alteration of a watercourse.

However, watershed-based research by various groups (universities, Center for Watershed Protection, U.S. Environmental Protection Agency, etc.) indicates that gradual, cumulative change to watersheds, resulting from ongoing development and minor land alterations, can create substantial loss of wetlands and intractable impairment of water resources. In fact, small, isolated, sensitive resources (e.g., vernal pools)—existing below regulatory thresholds or outside of regulatory jurisdiction—may present some of the most valuable and productive elements of a water resource complex. They also provide valuable pollution treatment functions.

To address this environmental concern and remain in compliance with the General Statutes, the Town could continue to allow incidental uses by right, but provide specific guidance in conjunction with public outreach that provides peer-to-peer interaction. Properly designed peer-to-peer programs foster a culture of protection and can establish desired cultural norms and mores in a community. Once such a culture is established, social pressure will tend to foster desired behavior and prevent most individuals from operating outside its norms. Institutional resources to establish such programs likely exist for the Town in the form of watershed organizations and cooperative extension programs. Approaches like this have been used by a number of states and municipalities around the country. In fact, a specific environmental management approach referred to as community-based social marketing has been developed to take advantage, in part, of peer-to-peer interactions. General information on CBSM is provided in *Appendix B*.

5.1.3 Tree Protection

Large trees grow leafy canopies that intercept rain and reduce runoff. Their root systems absorb nutrients and help to provide for water treatment. In nature, trees are generally part of a vegetative ecological community that may include several levels of understory as well as a microbiological culture as part of root systems and the surrounding soil matrix.

Where this living system exists and can be maintained, it can also provide excellent water quality treatment. Tree protection policy that includes preservation of existing tree stands, replacement of damaged trees, and management of understory, forms an important element of LID-based stormwater management.

The Town has already established some elements of tree protection policy, which are embodied throughout various parts of Town regulation. We recommend that the Town establish a consolidated tree protection policy. This policy could be formed as part of an existing body of regulation. The consolidation of policy would help to make interpreting and managing the policy a simpler process.

5.1.4 Landscape Islands and Buffer Strips

From a LID perspective, the ideal way to treat stormwater is to capture it in natural landscapes as sheet flow before it concentrates into rivulets or streams. Landscape islands and buffer strips provide an excellent opportunity to collect stormwater before it can leave an impervious area or a development site.

The Town has established policy that requires vegetative buffers and landscape islands for their aesthetic and screening value. We recommend that the Town take advantage of these features for stormwater treatment as well. To do this, we suggest that the Town identify a single area within its policy documents (i.e., regulations, ordinances, or guidance) for buffer and landscape island standards, which incorporates stormwater management requirements that reviewers and applicants can readily refer to for guidance.

From a technical perspective, standards for stormwater buffers are relatively new. The science associated with these practices continues to evolve. Therefore, the standards for stormwater buffers should be located in an area of policy that is easy for Town staff to update such as a LID guidance document.

5.1.5 Standards for Impervious Surfaces and Disconnection

An important aspect of stormwater management is limiting its generation and preventing it from leaving development sites. Many of our recommendations relate to the use pervious surfaces, reduction of impervious surfaces, and disconnection of impervious surfaces. We recommend that the Town examine its existing requirements for roads, parking areas, and sidewalks to ensure that they:

- Limit the size and extent of impervious surfaces wherever practicable
- Provide flexible minimums to allow for the smallest practicable impacts
- Allow for use of alternative pervious materials
- Allow for disconnection as a method of stormwater treatment

- Allow for innovations in LID stormwater design
- Allow for the use of open vegetative channels as an alternative to hard-piped drainage systems

5.2 Recommended Implementation Approaches

Policies may be established by ordinance, regulation, or guidance. The preferred approach for a particular municipality is often determined by considering the ease or difficulty of implementing and making future changes to the policy versus the risk of misuse, misapplication, or lack of enforcement through a legal mechanism or inadequate staffing. For example, guidance documents are relatively easy to establish and change as need arises; however, they lack the weight of regulations and ordinances and at times may be pushed aside inappropriately. Promulgated policy, on the other hand, is established through a more involved process, but once in place tends to hold securely.

Table 2 summarizes preliminary recommendations for implementing the LID policy revisions that are identified in this technical memorandum. These recommendations are intended for discussion by the Project Steering Committee during Workshop 2.

Table 2
Recommended Approaches for Implementing LID Policy

Policy	Recommended Approach	Comment
Map of Natural Resources	Reference in regulations with maps that can be updated on a calendar basis	Establishment of natural resource boundaries and policy involves a complex process based largely on site-specific technical analysis. A good way to ensure that these boundaries are clearly established is to map them and reference the maps in regulation; however, criteria for developing the maps should be established in regulation to ensure its transparency. Since natural resources are dynamic, mapping should be revised on a regular basis (e.g., biennially) to ensure that it remains accurate and protective.
Limitations on Incidental Uses	Allow incidental uses in regulation with standards in guidance and a peer-to-peer compliance program	We recommend establishing guidance on incidental uses with public outreach. Ideally, this would include a peer-to-peer public outreach program as such approaches tend to establish stronger more long-lasting results.
Tree protection	Require by a new stand-alone ordinance or regulation, with standards for stormwater management in guidance	The basic tenets of tree protection are fairly well understood; however, potential for tree protection to be sidelined if it is not specifically required is fairly high. We recommend establishing a stand-alone tree protection ordinance or regulation, with related stormwater policy established in a LID guidance document.

Policy	Recommended Approach	Comment
Landscape Islands and Buffer Strips	Require by regulation with standards in guidance	The Town currently requires the use of landscape islands and buffer strips as part of its subdivision and zoning regulations. We recommend modifying the zoning and subdivision regulations stating that stormwater management should be incorporated into buffers and landscape islands whenever possible. We recommend providing the standards for incorporating stormwater management into islands and buffers as part of LID guidance to allow for their update as needed.
LID Standards including standards for impervious surface and disconnection	Guidance with reference in regulation	LID standards are relatively new to regulation. The scientific community has made substantial changes to them over recent years and they will probably continue to evolve. We recommend that the Town require LID, but plan for maximum flexibility by establishing LID standards and design criteria in a stand-alone LID guidance document that is referenced in the regulations, allowing the guidance to be updated as needed without amendments to the regulations.

We have provided a discussion of common elements in a tree protection ordinance in *Appendix C*. If the Town would like to pursue such an ordinance, then we will draft it following Workshop 2 (scheduled for July 27, 2011).

We have provided a LID standards manual in *Appendix C*. This is the manual that was developed for the Connecticut Department of Energy and Environmental Protection (CTDEEP). It includes standards for:

- Various types of buffer for stormwater management
- Landscape islands in parking lots
- Disconnection of impervious surfaces
- Minimization of impervious surfaces
- Use of pervious materials in place of traditional pavement

We recommend considering the approaches described in the draft CTDEEP manual and the standards presented therein as a starting point. Use of these or similar standards would allow the Town to remain closely consistent with state standards, which will simplify their implementation and maximize their defensibility.

Appendix A

Regulatory Review Tables for Vernon Policy Documents

Town of Vernon, CT
Inland Wetlands and Watercourses Regulations
Adopted September 22, 2009
Effective October 8, 2009
Amended to October 1, 2010

Vegetation and Landscaping

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Preservation of Natural Areas	Section 1 – Title and Authority	It is, therefore, the purpose of these regulations to protect the citizens of the state by making provisions for the protection, preservation, maintenance and use of the inland wetlands and watercourses by minimizing their disturbance and pollution; maintaining and improving water quality in accordance with the highest standards set by federal, state or local authority; preventing damage from erosion, turbidity or siltation; preventing loss of fish and other beneficial aquatic organisms, wildlife and vegetation and the destruction of the natural habitats thereof; deterring and inhibiting the danger of flood and pollution; protecting the quality of wetlands and watercourses for their conservation, economic, aesthetic, recreational and other public and private uses and values; and protecting the state's potable fresh water supplies from the dangers of drought, overdraft, pollution, misuse and mismanagement by providing an orderly process to balance the need for the economic growth of the state and the use of its land with the need to protect its environment and ecology in order to forever guarantee to the people of the state, the safety of such natural resources for their benefit and enjoyment and for the benefit and enjoyment of generations yet unborn.	The Town currently requires permitting for activities in wetlands and upland review areas. This includes discharge of stormwater. The Town may wish to encourage or require the preservation and enhancement of vegetated areas in proximity to wetlands. The Town may also wish to include the use of riparian buffers (i.e., preserved natural areas along streams) for stormwater management. While Appendix C describes standards for riparian buffers, the wetlands regulations do not appear to require buffers or specifically encourage their use.
	Section 2.1 – Definitions	2.1 "Regulated activity" means any conduct or activity within or use of a wetland or watercourse involving removal or deposition of material, or any obstruction, construction, alteration or pollution, of such wetlands or watercourses, but shall not include the specified activities in section 22a-40 of the Connecticut General Statutes. Furthermore, any clearing, grubbing, filling, grading, paving, excavating, constructing, depositing, or removing of material and discharging of storm water on the land within the following upland review areas is a regulated activity: • Within two hundred (200) feet measured horizontally from the boundary of the Hockanum River, Ogden Brook, Tankerhoosen River, Gage's Brook, Railroad Brook, Walker Reservoir West, Walker Reservoir East, and Valley Falls Pond. • Within one hundred (100) feet measured horizontally from the boundary of any other wetland, watercourse, or intermittent watercourse; • Any activity that alters the existing rate or quality of any stormwater discharge to a wetlands or watercourse, or any other activity that is likely to impact or affect wetlands or watercourses, may be considered a regulated activity by the Commission.	
	Appendix C – Design Standards Recommended for a Watercourse Protection Buffer	Retention of existing vegetation along watercourses, when in a natural state, especially when containing mature trees, is a primary consideration to protect the watercourse from erosion, siltation, pollution and temperature change. In areas where vegetated buffers do not exist, or are of limited width, consideration should be given to the creation of a buffer area. Newly created buffers should include canopy or shade trees, shrubs, and herbaceous plant species suited to the local habitat in three (3) zones of plantings. The recommended minimum width of a watercourse buffer is one hundred (100) feet measured horizontally from the banks of the watercourse and fifty (50) feet measured horizontally related to intermittent watercourses…	
	Section 2.1 – Definitions	"Watercourses" means rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, vernal or intermittent, public or private, which are contained within, flow	The Town includes definitions for wetlands and water courses, but may wish to include definitions for watersheds, vernal pools, riparian buffers and other environmental features that the Town wishes to regulate or protect.

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
		through or border upon the Town or any portion thereof not regulated pursuant to sections 22a-28 through 22a-35, inclusive, of the Connecticut General Statutes. Intermittent watercourses shall be delineated by a defined permanent channel and bank and the occurrence of two or more of the following characteristics: (a) evidence of scour or deposits of recent alluvium or detritus, (b) the presence of standing or flowing water for a duration longer than a particular storm incident, and (c) the presence of hydrophytic vegetation. A detention or retention basin created as part of a land development shall be considered a watercourse after construction of said basin and the connection of a stormwater collection system to it. "Wetlands" means land, including submerged land as defined in this section, not regulated pursuant to sections 22a-28 through 22a-35, inclusive, of the Connecticut General Statutes, which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial and floodplain by the National Cooperative Soils Survey, as it may be amended from time to time, of the Natural Resources Conservation Service of the U.S. Department of Agriculture (USDA). Such areas may include filled, graded, or excavated sites which possess an aquic (saturated) soil moisture regime as defined by the USDA Cooperative Soil Survey.	
	Section 3.1 - Inventory of Inland Wetlands and Watercourses	The map of wetlands and watercourses entitled "Inland Wetland and Watercourse Map, Town of Vernon, Connecticut" delineates the general location and boundaries of inland wetlands and the general location of watercourses. Copies of this map are available for inspection at the office of the Vernon Planning Department. In all cases, the precise location of wetlands and watercourses shall be determined by the actual character of the land, the distribution of wetland soil types and location of watercourses. The Commission may use aerial photography, remote sensing imagery, resource mapping, soils maps, site inspection observations or other information in determining the location of the boundaries of wetlands and watercourses.	The Town currently makes available mapping of inland wetlands for inspection in the Office of Planning. The Town may also wish to: • Identify and provide on-line mapping of critical wildlife habitat areas for protection • Identify and maintain comprehensive on-line mapping of critical water resources including, but not limited to, water courses, wetlands, and aquifers.
	Section 4 – Permitted uses as of Right and Nonregulated Uses	No person shall conduct or maintain a regulated activity without first obtaining a permit for such activity from the Inland Wetlands Commission of the Town of Vernon. The following operations and uses shall be permitted in inland wetlands and watercourses, as of right: d. uses incidental to the enjoyment and maintenance of residential property, such property defined as equal to or smaller than 40,000 square feet. Such incidental uses shall include maintenance of existing structures and landscaping, but shall not include removal or deposition of more than five (5) cubic yards of material from or onto a wetland or watercourse, or diversion or alteration of a watercourse	The Town currently allows incidental uses, such as lawn areas, up 40,000 square feet as a right. This is necessary for compliance with section 22a-40(4) of the Connecticut General Statutes. Notwithstanding, improperly installed incidental uses may have significant adverse impact on stormwater quality and water resources. The Town may wish to establish public education that addresses this issues.
Tree Protection	Appendix C – Design Standards Recommended for a Watercourse Protection Buffer	Retention of existing vegetation along watercourses, when in a natural state, especially when containing mature trees, is a primary consideration to protect the watercourse from erosion, siltation, pollution and temperature change. In areas where vegetated buffers do not exist, or are of limited width, consideration should be given to the creation of a buffer area. Newly created buffers should include canopy or shade trees, shrubs, and herbaceous plant species suited to the local habitat in three (3) zones of plantings. The recommended minimum width of a watercourse buffer is one hundred (100) feet measured horizontally from the banks of the watercourse and fifty (50) feet measured horizontally related to intermittent watercourses.	Appendix C of the wetlands regulations discusses standards for watercourse protection buffers that include trees. The wetlands regulations do not appear to require buffers or specifically encourage their use. The Town may wish to require vegetated/riparian buffers in areas where they do not exist.
Landscaping Islands for stormwater management		*No relevant regulations identified.*	The Town may wish to require or specifically encourage the use of stormwater islands on parking lots and other impervious surfaces.
Riparian Buffers	Appendix C - Design Standards Recommended for a Watercourse Protection Buffer	Retention of existing vegetation along watercourses, when in a natural state, especially when containing mature trees, is a primary consideration to protect the watercourse from erosion, siltation, pollution and temperature change. In areas where vegetated buffers do not exist, or are of limited width, consideration should be given to the creation of a buffer area. Newly created buffers should include canopy or shade trees, shrubs, and herbaceous plant species suited to the local habitat in three (3) zones of plantings. The recommended	• Appendix C of the wetlands regulations discusses standards for watercourse protection buffers that include trees. The wetlands regulations do not appear to require buffers or specifically encourage their use. The Town may wish to require vegetated/riparian buffers in areas where they do not exist.

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
		minimum width of a watercourse buffer is one hundred (100) feet measured horizontally from the banks of the watercourse and fifty (50) feet measured horizontally related to intermittent watercourses. The standards and specifications for these buffers are modeled after David A. Welsch, "Riparian Forest Buffers," USDA CT-RI publication NA-PR-07-91. The recommended watercourse protection area with landscape buffer may be reduced when (1) an engineered stormwater management and pollution control system employing technical best management practices (BMP) in compliance with the Connecticut Department of Environmental Protection (DEP) "Stormwater Quality Manual: is provided to treat run-off from a development site; (2) the site is served by a public sewer system; and (3) a reduction of the river protection buffer depth would not result in a significant potential adverse impact to the watercourse. If the buffer area for a watercourse is either increased or decreased, then the widths of the three (3) vegetation zones should be adjusted accordingly.	• Establish required minimum vegetated/riparian buffer dimensions. Currently dimensions are recommended. • Establish requirements for maintenance and activities allowed in vegetated/riparian buffers.

Minimizing Land Disturbance

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Limits of Disturbance		*No relevant regulations identified.*	Loss of natural vegetation reduces the natural landscapes post-construction capacity to treat stormwater. The Town may wish to specify limits of disturbance in accordance with the Connecticut Stormwater Quality Manual (in draft)
Open Space and Cluster Development		*No relevant regulations identified.*	Not appropriate for wetland regulations

Impervious Area Management

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Streets and Driveways		*No relevant regulations identified.*	Not appropriate for wetland regulations
Parking Areas and Sidewalks		*No relevant regulations identified.*	Not appropriate for wetland regulations
Unconnected Impervious Areas		*No relevant regulations identified.*	Consider establishing standards to require or encourage disconnection of new or redeveloped impervious surface.

Vegetated Open Channels

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
		No relevant regulations identified.	Consider establishing standards to require or encourage use of vegetated open channels for new or redeveloped impervious surface.

Vegetation and Landscaping

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Preservation of Natural Areas	Section 5.2.5 and 5.2.9 – Site Development Plan	Site plan should include: • Existing and proposed water courses and ponds, conservation areas, and easements and right-of-way; base flood elevation data, wetland soils, other land subject to potential flooding; the location and limits of all swamps, flood plains including those within 2001 beyond subdivision boundaries. • Principal wooded areas and the approximate location of any large, isolated trees.	The Town currently makes available mapping of inland wetlands for inspection in the Office of Planning. The Town may also wish to: • Identify and provide on-line mapping of critical wildlife habitat areas for protection • Identify and maintain comprehensive on-line mapping of critical water resources including, but not limited to, water courses, wetlands, and aquifers. • Add features to the mapping they provide such as contours, soil types, nonaquatic habitat and vegetation. • Require consideration of the preservation and enhancement of scenic points and vistas, ridgelines, and contours of the land as part of the development review process. The Town has established requirements to record easements and restriction through mapping. The Town may wish to include a requirement to establish restrictions for enlarging existing turf lawn areas. If the desired, this should be incorporated in policy, permits, and as deed restrictions.
	5.5 Record Subdivision Map	The Subdivision Map shall be prepared with an accuracy meeting, or exceeding, standards for a "Class A-2 Transit Survey" as defined by the Connecticut Technical Council, Inc. The map shall be clearly and legibly drawn and submitted in six (6) copies of blue or black line prints. The map shall be drawn to a scale of 1" = 40'. The map shall show the following…	Coordinate with 6.1.3
	Section 5.5.5	[Map] existing and proposed water courses and ponds, conservation areas, and easements and rights-of-way; the location and limits of all easement or reservation areas for the protection of swamps, flood plains, other land subject to potential flooding.	
	Section 6.1.3 – Open Spaces	The Commission may require that land be reserved for parks and recreation in locations designated in the Town of Vernon Plan of Development or otherwise where such reservation would be appropriate. Each reservation shall be of suitable size, dimension, topography and general character for the particular purpose envisioned by the Commission. A maximum of 5% of the total tract proposed for subdivision may be required as park/recreation area. The developer shall dedicate all such recreational areas to the local government as condition of final subdivision approval.	The Town allows for designation of open spaces. This could potentially be used to preserve natural areas; however, the Town may wish to be more specific about this purpose in its policy and that these spaces may be designed to allow for stormwater management provided they conform to certain standards. Policy should consider the following: • Allowing and encouraging retrofits of abandoned or underutilized public lands to serve as permanent or temporary open space and stormwater management purposes. • Considering unique species or communities in regulations for open space, alternative or traditional subdivision regulations. • Considering habitat fragmentation in regulations for open space, or for alternative/traditional subdivisions.
Tree Protection	5.2 Site Development Plan and 5.2.9 -	The Site Development Plan shall be drawn to a scale of not less than 1" = 100' on sheets 24" x 36". The plan shall show existing conditions and the proposed layout of lots, streets and improvements for the proposed subdivision and all contiguous land of the applicant that may be subdivided in the future, in order to allow the Commission to complete a general planning review of the proposed subdivision including its relationship to the future subdivision of contiguous land of the applicant. Twelve (12) black or blue line prints shall be submitted. The plan shall show at least the following information: Principal wooded areas and the approximate location of any large, isolated trees.	Site plans are required to show principal wooded areas and the approximate location of large, isolated trees at 1" = 100'; however there is no definition of principal wooded areas or of what constitutes a large tree. There is no specific requirement to preserve trees.

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
	Section 6.1.5 – Street Trees	Shade trees of varieties acceptable to the Commission shall be provided along existing and proposed streets by planting new trees or preserving existing trees. Trees shall be provided at the rate of one per 50 feet on either side of the right-of-way. Such trees shall be located between the building line and ten (10) feet inside the lot line. New Trees shall not be less than 3-3 1/2 inches in caliper and shall be guaranteed for one season's growth by the developer.	The Town requires installation of new trees or preservation of existing trees as part of projects, but may wish to consider: • Requiring diversity of tree species • Acknowledging trees as part of community infrastructure by including tree protection, management, and maintenance in planning documents and regulation. • Requiring that public trees damaged during construction are removed and replaced. • Adopt tree protection rules for public trees during construction projects.
Landscaping Islands and Screening		*No relevant regulations identified.*	The Town may wish to require or specifically encourage the use of stormwater islands on parking lots and other impervious surfaces.
Riparian Buffers	Section 6.9.2 Location of Storm Water Facilities -	6.9.2 Drainage facilities shall be located in the road right-of-way where feasible, or in perpetual unobstructed easements, where necessary. Such easements shall be at least twenty (20) feet in width. • When a proposed drainage system will carry water across private land outside the sub- division, appropriate drainage rights must be secured and indicated on the map. • The applicant may be required to dedicate either in fee or by drainage or conservation easement, land on both sides of existing watercourses to a distance to be determined by the Commission. • Low-lying lands along watercourses subject to flooding or overflowing during storm periods shall be preserved and retained in their natural state as drainage ways.	• The Town has the option of requiring an at-least 20-foot wide easement on either side of a watercourse; however, this requirement is somewhat different than the standards in the Town's Wetland Regulations. • The Town should consider establishing a clearer riparian buffer policy and standards that allows for use of the buffer as a stormwater management system within certain parameters.

Minimizing Land Disturbance

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Limits of Disturbance		*No relevant regulations identified.*	The Town may wish to establish specific limits of disturbance for buildings, roadways and other features to avoid unnecessary exposure of disturbed soil to minimize removal of naturally vegetated areas.
Open Space and Cluster Development		Open space and cluster development are not included in Town policy	The Town currently provides for dedication of open space; however, the subdivision regulations do not allow for open space, cluster, or other forms of conservation development.

Impervious Area Management

<table>
<tr><th>Topic</th><th>Source - Regulation</th><th>Language of Concern</th><th>Potential Problems and Recommended Revisions</th></tr>
<tr>
<td>Streets and Driveways</td>
<td>Section 6.5 – Streets, General

Section 6.6.6

Section 6.7 – Design Standards

Section 6.7.2 – Curbs

Section 6.7.4 - Road Pavement</td>
<td>No subdivision shall be approved unless the area to be subdivided, and each lot to be created shall have frontage on and access from another existing public street which is suitably improved and paved; or a street shown upon a map approved by the Commission and recorded in the Town Clerk's office. The Planning & Zoning Commission may require that existing roads, shown to be directly or indirectly impacted by the proposed subdivision, be improved to bring those roads up to the standards outlined in these regulations.

Cul-de-sac pavement shall be a uniform 45' radius except when an island is used then the outside radius shall be 50' and an island radius is 20'.

In order to provide for roads of suitable location, width and improvement to accommodate prospective traffic and afford satisfactory access to police, firefighting, snow removal, sanitation and road maintenance equipment, and to coordinate roads so as to compose a convenient system and avoid undue hardships to adjoining properties, the following design standards for roads shall be adhered to:

6.7.1 TABLE I
<table>
<tr><th>Road Class</th><th>Row Width</th><th>Pavement Width</th><th>Maximum Grade</th><th>Minimum Grade</th><th>Design Speed</th><th>Cross Slope</th></tr>
<tr><td>Collector</td><td>60 ft.</td><td>32 ft.</td><td>8%</td><td>2%</td><td>30 MPH</td><td>3/8"ft</td></tr>
<tr><td>Local</td><td>50 ft.</td><td>28 ft.</td><td>8%</td><td>2%</td><td>25 MPH</td><td>3/8"ft</td></tr>
</table>

Curbs shall be required on all new streets and shall conform to construction and design standards as required in Appendix of these Regulations.

All road pavement, shoulders, drainage, improvements and structures, curbs, turnarounds and sidewalks shall conform to all construction standards and specifications adopted by the Town of Vernon.</td>
<td>• Review regulations for consideration of revising design standards for streets and intersections, to reflect complete and green street designs.

• The Town's cul-de-sac standards and policy appear to be focused on their use as temporary roadways. However, the Town may wish to consider smaller cul-de-sac radius of (30 to 40 feet), or alternative designs such as hammerheads, to reduce impervious cover, such that the design allows for continuous turning movement of the largest fire fighting vehicle used by the Town of Vernon. Also consider encouraging the use of LID bioretention/rain gardens in cul-de-sac islands for stormwater management. (Previous Recommendation)

• Consider pavement widths of between 24 and 28 feet, if such a reduction will not negatively impact public safety or emergency response. Refer to the Connecticut Stormwater Quality Manual for potential variation in residential roadway widths based on terrain and development density. The Town may also wish to limit rights-of-way or make requirements that they consider use of LID stormwater management. (Previous Recommendation)

• Consider eliminating the curbing requirement for roads with grades less than 5% to encourage the use of vegetated swales and similar LID practices.</td>
</tr>
<tr>
<td>Parking Areas and Sidewalks</td>
<td>Section 6.12.1</td>
<td>Sidewalks shall be required in all subdivision on at least one side of all new streets, unless waived by a three-quarter vote of all members of the Commission, and may be required on both sides at the discretion of the commission.</td>
<td>Consider requiring sidewalks on only one side of the street and reduce sidewalk width to 3 or 4 feet. Grade sidewalks to the front yard rather than to the street. Consider using alternative materials such as pavers, stone dust, or pervious concrete.</td>
</tr>
<tr>
<td>Unconnected Impervious Areas</td>
<td></td>
<td>No relevant regulations identified.</td>
<td>Town policy is currently silent on the use of impervious surface disconnection. The Town may wish to include disconnection approaches in its policy and standards as a specifically allowable method of post-construction stormwater management.</td>
</tr>
</table>

Vegetated Open Channels

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
		No relevant regulations identified.	Town policy is currently silent on the use of vegetated open channels. The Town may wish to include vegetated open channels in its policy and standards as a specifically allowable method of post-construction stormwater management. The Town may wish to require their consideration as part of permitting.

General

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Application Requirements	Section 4.1	Application for a subdivision or resubdivision shall be made on application forms approved by the Vernon Planning & Zoning Commission and are available in the office of the Town Planner.	Require consideration of low impact development as part of the subdivision application and review process.
Grading and Drainage	Section 6.4 Section 6.4.1	Where substantial regrading of the lot is required in order to provide a buildable site, grading plans shall be submitted for Commission approval. Such plans shall demonstrate practical methods for controlling potential erosion and stabilizing areas of cuts and fills on individual lots. The plan shall employ standards and methods equal to or exceeding those set forth in Erosion and Sediment Control Handbook, USDA, SCS, Storrs, Conn., 1976. Lots shall be laid out so as to provide positive drainage away from all buildings and individual lot drainage shall be coordinated with the general storm drainage pattern for the area. Drainage shall be designed so as to avoid concentration of storm drainage water from each lot to adjacent lots.	Amend Section 6.4 to reference the Connecticut Guidelines for Soil Erosion and Sediment Control, as amended, as opposed to the outdated reference to the 1976 version of the Erosion and Sediment Control Handbook.

Vegetation and Landscaping

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Preservation of Natural Areas		4.26.1 Purpose: The purpose of the open space zone is to allow for the clear identification of land on the Town of Vernon Zoning Map that has been set aside from or permanently protected from development by legislation, dedication conservation or other legal means, which shall be used only for recreational, conservation, educational and agricultural purposes. 4.26.2 Permitted Uses: Uses permitted within this zone include recreation, conservation, education and agriculture. Under no circumstances shall a use or activity ensue on a parcel of land within this zone which is contrary and/ or detrimental to the intent and purpose of open space. There are no Special Permit Uses or Special Exceptions within the OSZ.	Town policy includes open space zoning, which can be used to set aside and permanently protect areas of land for conservation. Depending on hydrologic as well as other conditions, these may provide excellent opportunities for disconnecting impervious surfaces and treating stormwater. The Town may wish to include more explicit policy to allow for use of zoned open space to capture, treat and recharge runoff as sheetflow.
Tree Protection	Section 4.24 – Use Districts (Gerber Farm Area)	4.24.7 Landscape Buffers 4.24.7.1 Composition – Landscaped buffers shall be provided where required by this Section of the Zoning Regulations and shall conform to the standards illustrated in the "Buffer Yard" graphic (Appendix A): 4.24.7.1.1 Canopy trees shall be deciduous shade trees planted at three inches (3") in caliper with a mature height of at least thirty-five feet (35'); 4.24.7.1.2 Under-story trees shall be deciduous shade or fruit trees planted at two inches (2") in caliper with a mature height of at least twelve feet (12'); 4.24.7.1.3 Evergreens shall be coniferous species planted at six feet (6') in height; 4.24.7.1.4 Shrubs shall be either deciduous species planted at two and one-half feet (2 ½') height with a mature height of at least six feet (6') or coniferous species planted at two and one-half feet (2-½) feet in spread.	Town zoning policy establishes site planning and architectural and design review standards that call for identification and preservation of existing trees. The Town may wish to strengthen its existing policy to include items listed below. • Strengthen the landscape provisions of the Zoning Regulations by requiring maximum tree preservation, replacement and diversity of tree species. • Include tree management and maintenance in planning documents and regulation. • Require that public trees damaged during construction are removed and replaced. • Adopt tree protection rules for public trees during construction projects. • Incorporate existing treed areas into disconnection areas for stormwater treatment. • Include protection of understory such as that described in Appendix A "Buffer Yard" Alternatively the Town may wish to establish a tree protection ordinance which provides comprehensive tree protection in a single policy.
	Section 14.1 – Site Plan Requirements	14.1.2.2.19 Location of existing healthy trees larger than 18" in diameter at breast height shall be located by field survey, either singly or as groups and shall be incorporated into the site design to the maximum extent possible. Whenever possible existing trees shall be saved by "welling" or "mounding". All trees larger than 8" in diameter within the public right-of-way shall be depicted on the plan. Groups of trees may be located by a "tree line". Stands of significant (10 or more trees) of similarly species shall be located by field survey and preserved and incorporated into the site plan whenever possible, except that a site plan prepared for selective clearing within a wooded area shall show those trees or clusters of trees to be removed. Trees within areas not proposed to be disturbed need not be individually located and may be designated as "treed area not to be disturbed."	
	Section 21 – Architectural & Design Review Regulations	21.1.1 The Planning & Zoning Commission, in accordance with CGS 8-2, shall require Architectural and Design Review for all applications for Special Permits, Site Plan approval, or modifications to an already approved plan only when said modification or Special Permit or Site Plan involves significant architectural features.	
	21.4 – Landscaping and Site	21.4.5 Existing trees at four (4) inches caliper or greater shall be incorporated into the site plan wherever	

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
	Treatment	possible; 21.4.7 In locations where plants will be susceptible to injury by pedestrian or motor traffic, they shall be protected by appropriate curbs, tree guards, or other devices;	
Landscaping Islands and Screening	Section 9 – Landscape Buffer Strips	9.1 Provision. The Planning & Zoning Commission (PZC) may require a landscaped buffer strip to be provided along a property line to buffer adjacent property from the proposed development. The PZC may impose provision of the landscape buffer to address the following conditions: • To minimize potential conflict between different uses; • To assure privacy and/or the undisturbed use of property; • To lessen potential glare from light sources or reflections; • To screen motor vehicles, parking and loading areas, dumpsters, storage or display areas, heating, ventilating, air condition (HVAC) mechanical equipment, or other industrial equipment. • To provide landscape transitions; • To increase compatibility with neighboring uses, lessen the potential for nuisance, and promote the sound development of the community relative to special permit criteria of Zoning Regulations Section 17.3.1 in regard to both existing and potential development; • To prevent blight, preserve the quality of existing development, and maintain property values. 9.3 Composition – The landscape buffer strip, if required by the PZC. • Shall be designed by a licensed landscape architect; • Shall be shown on the site plan or landscaping plan in terms of the types of plants, maturities or sizes, spacing, planting schedule, and maintenance plan; • Shall be designed to retain and incorporate existing healthy mature trees whenever possible; • Shall contain a variety of interplanted evergreen, deciduous, trees and shrubs suitable in the judgment of the PZC or its designated agent to provide an adequate screen sufficient to buffer adjacent property from the proposed development, and to meet the following guidelines: o Shall contain trees and shrubs that are spaced and located as follows: ▪ Evergreen trees and large deciduous trees should be spaced using accepted landscaping practices, usually 20 feet or more on center; ▪ Flowering trees should be spaced using accepted landscaping practices, usually 10 or more feet on center; ▪ Trees shall not be planted within 20 feet of a sewer line or area of heavy ▪ equipment use; • Shall contain plantings staggered/clustered to achieve maximum screening after 5 years, and at maturity. Evergreen trees shall be a minimum of 5 feet in height at the time of plantings; deciduous shade trees shall be a minimum of 2" caliper and 10 feet in height at the time of planting; and flowering trees shall be a minimum of 6 feet in height at the time of planting and 1–½ " caliper; • May include, but shall not be limited to, the following varieties of trees and shrubs: Canada Hemlock, Scotch Pine, White Pine, Norway Spruce, Douglas Fir, Pyramidal Arborvitae, Juniper (including Red Cedar), Rhododendron, Azalea, Holly, Forsythia, Viburnum, Lilac, Yew, Flowering Crab, Dogwood, Magnolia, Hawthorn, Flowering Quince, Mountain Ash, Flowering Cherry, Sycamore (Plane Tree), and Male Ginko; • Shall be subject to modification, which may include an increase of depth or installation of a fence, wall, or barrier, as may be considered necessary by the PZC to fulfill the purpose of the landscaped buffer;	Town policy establishes standards for landscape buffer strips for the purposes of screening between land uses that might otherwise conflict. Town may wish to consider standards that require these buffers to accept stormwater whenever practicable or explicitly allowing the use of buffer strips for stormwater management.

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
	21.4 – Landscaping and Site Treatment	9.4 Maintenance ▪ Maintenance shall include, but not be limited to, watering, fertilizing, weeding, cleaning, pruning, trimming, spraying and cultivating. Vegetation that dies shall be replaced as quickly as possible and within one growing season. Replacement plantings shall conform to the original intent of the landscape design; ▪ Clear cutting/harvesting of trees within a buffer area is expressly prohibited at any time without prior Commission approval; 21.4.9 Parking areas and traffic ways shall be enhanced with landscaped spaces containing shrubs, tree or tree groupings. Parking areas shall provide a minimum of one island for every twenty (20) parking spaces. 21.4.10 For every five (5) parking spaces, a minimum of one (1) three (3) inch caliper tree shall be provided. Preferred varieties include: Pin Oaks, Norway Maples, Crimson Maples, Great Ash, Little Leaf Linden, and Black Locusts.	Town policy establishes a requirement for parking lot islands, which appear to be for landscaping purposes. Consider modifying the parking area landscaped area requirements in the zoning regulations to promote parking lot bioretention and other LID practices to manage runoff. This may include modification of landscape area requirements to specify shrubs and trees appropriate for controlling runoff.
Riparian Buffers		*No relevant regulations identified.*	Town policy establishes open space and conservation preservation; however, these policies are not specific to riparian areas. The Town may wish to establish specific zoning to protect riparian features.

Minimizing Land Disturbance

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Limits of Disturbance	Section 4.1- 4.25	Setbacks and lot dimensions are referenced for various use districts.	Review current setbacks and lot dimensions for potential to relax side yard setbacks and allow narrower frontages to reduce road length and site imperviousness, and to relax front setback requirements to reduce driveway length and lot imperviousness. This could be done with a floating zone or overlay district that is specifically intended for water resource protection.
Open Space and Cluster Development	Section 7 - Cluster Development	7.1 In order to promote the health and general welfare of the community and to preserve and make available natural open space for recreation and conservation, the Planning & Zoning Commission may grant a developer the option to vary the lot size requirements in Residential 40 and Residential 27 zoning districts, leaving a substantial area free of building lots. 7.2 The minimum parcel to be considered for variation as stated above shall be ten (10) acres. 7.3 The maximum number of building lots shall not exceed one and two-tenths (1.2) per net acre in the R-40 district, or one and nine-tenths (1.9) per net acre in the R-27 district. Net acreage shall be determined by subtracting fifteen (15) percent of the gross acreage of the parcel (for streets). The gross area of the parcel shall include only land that is not encumbered with easements or other restrictions that would prevent full use of the land. 7.4 The land area not be allocated to building lots and streets shall be permanently reserved in open space. Such areas shall be in locations designated open spaces or greenbelts on the comprehensive plan or, where the subdivider proposes open space in other areas; such proposals shall be subject to the approval of the	Town policy establishes both open space and cluster zoning. To enhance existing policy the Town may wish to: • Allow and encourage retrofits of abandoned or underutilized public lands to serve as permanent or temporary open space and for stormwater management purposes. • Consider unique species or communities in regulations for open space, alternative or traditional subdivision regulations. • Consider habitat fragmentation in regulations for open space, or for alternative/traditional subdivisions.

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
	Section 4.26 – Open Space Zone (OSZ)	Commission. 7.6 This section identifies lot dimension requirements for cluster subdivisions 7.7 The balance of the land not contained in the building lots shall be in condition, size and shape as to be readily usable for recreation or conservation… 4.26.1 Purpose: The purpose of the open space zone is to allow for the clear identification of land on the Town of Vernon Zoning Map that has been set aside from or permanently protected from development by legislation, dedication conservation or other legal means, which shall be used only for recreational, conservation, educational and agricultural purposes. 4.26.2 Permitted Uses: Uses permitted within this zone include recreation, conservation, education and agriculture. There are no Special Permit Uses or Special Exceptions within the OSZ.	

Impervious Area Management

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Streets and Driveways	Section 3 – General Provisions Section 14 - Site Plans	3.15 Surfacing: In all zones, all required parking, driveways, loading areas, motor vehicle storage, and display lots and access driveways shall have an adequate paved or alternate surface approved by the Town Engineer capable of allowing free and safe movement of all vehicles. 14.1.2.2.12 Where appropriate, existing and proposed drainage with invert and top of frame elevations; wherever feasible, drainage design for roof area, parking lots and driveways; shall employ low impact development (LID) techniques for stormwater management;	Conventional driveways are typically impervious and often connect roofs to roadway stormwater systems. Where driveways are installed or renovated, require that they are converted to pervious materials or that runoff is discharged to a disconnection area or other LID practice
Parking Areas and Sidewalks	Section 3 – General Provisions In All Zones Which Permit Single Or Two Family Dwellings, Section 4.24 – Planned Development Zone Gerber Farm Area (Similar Language In 4.25)	3.25 Sidewalks: Sidewalks shall be installed for all new developments in all areas, unless waived by a three-quarters vote of all members of the Commission. Sidewalks and granite curbs shall be installed in those areas designated as “Sidewalk Policy Areas,” which is made part of these regulations. 4.24.4.1.7 In addition to the standard site plan requirements, any development proposed within the PDZ shall provide for pedestrian and bicycle access including but not limited to: • Bike racks and or bike parking to be located as close to the building entrance as possible; • Stations for transit riders, where feasible; • Sidewalks connecting the new development to transit stops, where feasible; • Public sidewalks, unless waived by Section 3.25. 4.24.4.3.15.9.2 That where possible, these spaces are connected to sidewalks, bus stops, walking trails, bikeways; greenways; linear parks or integrated with traffic patterns, drop off and pick up points for alternate modes of transportation. 15.3 In all situations when approval is obtained for fill, excavation, or removal of material, the property owner shall be responsible and liable for any damage to public infrastructure, which includes but is not limited	Conventional sidewalks are typically impervious, generate runoff, and may in certain circumstances connect impervious surfaces. The Town may wish to revise its zoning policy to: • Consider modifying the zoning regulations to promote the use of sidewalks constructed with pervious material. • Consider requiring sidewalks on one side of the street only • Consider replacement of sidewalks with alternative materials or elimination of sidewalks if practicable • Where sidewalks are necessary, require that sidewalk runoff is discharged to a disconnection area or other LID practice

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
	Section 15 - Removal Of Earth, Sand, And Gravel Section 12 – Off Street Parking And Loading	to sidewalks, curbs, roadways, and drainage systems. 12.1 Provisions. Off-street parking shall be provided for all uses in structures hereafter constructed or enlarged or in which there is a change of use 12.2 Off street loading. Every building or structure, lot or land hereafter put into use for business or industrial purposes or for a hospital, and which has an aggregate floor area of seventy five hundred (7,500) square feet or more devoted to any such use, shall be provided with off-street truck loading spaces in accordance with the following schedule: Square Feet of Aggregate Floor Required Number of Off-Street Area Devoted to Such Use Truck Loading Spaces 7,500 to 20,000 1 20,001 to 50,000 2 50,001 to 150,000 3 Each additional 50,000 1 additional 12.3 Supplemental Regulations and Standards. 12.3.1 In all districts, a paved access drive to a garage may be located within the required setbacks. 12.3.2 No portion of a parking area shall be located closer than ten (10) feet to the boundaries of the parcel to be used or to any highway right-of-way. The parking area is taken to be that area where a vehicle is normally stored or parked and shall not be part of an access drive. 12.3.3. In all districts, required parking areas for dwellings shall be on the same lot with the main dwelling. 12.3.4 Required accessory parking and loading areas for non-residential uses shall be within three hundred (300) feet of the main building or use to be served. Any accessory parking area which is not upon the same lot as the main building or use and its necessary access-ways shall be reserved for off-street. 12.3.6 An off-street truck loading space shall have a minimum width of ten (10) feet, a minimum length of twenty-five (25) feet and a minimum clear height of fourteen (14) feet, excluding its access from the street. 12.3.7 All off-street parking spaces shall have a minimum width of nine (9) feet and a minimum length of seventeen (17) feet exclusive of access drive. 12.3.8. In all zones, all driveways, parking areas, and access aisles, automobile dealer lots, and all off-street truck loading spaces shall be suitably paved, drained and lighted, and appropriately planted and fenced for the protection of adjacent properties, and shall be arranged for convenient access, egress, snow removal and safety of vehicles and pedestrians. Such facilities shall be maintained in good condition by the owner. 12.3.8.1 Parking lot aisle widths shall conform to the following table: Parking Stall Angle Aisle Width 90° 24' 60° 16' 45° 11' 30° 8' 12.3.8.2 For parking stall angles not list, the appropriate aisle width shall be determined by the Town Engineer. 12.3.10 In the case of an expansion of a non-conforming building or the expansion of	Town policy establishes minimum parking requirements (i.e., number of spaces per unit of use). Minimums may provide more parking than is needed in many circumstances and may result in unneeded impervious surface. The Town may wish to: • Review existing parking ratios to see if lower ratios are warranted and feasible. The required parking ratio for a particular land use (other than commercial retail) should be enforced as both a maximum and minimum to limit excess parking space construction and impervious cover. • Consider allowing the Commission to approve parking lots with more spaces than the allowed maximum provided all of the spaces above the maximum number are composed of a pervious surface, and where adequate stormwater management is provided. • Allow for shared parking and provide model shared parking agreements. • Consider parking spaces held in reserve for phased developments, thereby avoiding the situation where unnecessary parking is not constructed if future phases of development do not occur. • Review current parking stall dimensions for potential reduction in maximum or median requirements. • Revise parking stall length requirements to allow vehicle overhang into vegetated areas. • Allow for multi-level parking.

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
	Section 4.24 & 4.25 – Planned Development Zone (Pdz): Gerber Farm Area & 1-84 Exit #67area	a permitted use, which does not meet the parking and loading requirements of Section 12 above, such expansion shall be subject to the following requirements: 12.3.10.2 An additional twenty-five (25) percent of the off-street parking requirements for the existing use shall be required; provided, however, that such provision does not exceed one hundred (100) percent of the requirements of Section 12. 12.3.13 In any zone, as per C.G.S. 8-2c, the Planning & Zoning Commission may reduce the number of off-street parking spaces which must be installed by the developer subject to the following conditions: 12.3.13.1 The total reduction of spaces shall not exceed twenty (20) percent of the required number of spaces. 12.3.13.2 The developer shall pay a fee of $500 for each space eliminated. This fee to be used in accordance with the guidelines established in C.G.S. 8-2c. 12.3.13.3 In granting an exemption from the required off-street parking requirements the Commission, by two-thirds vote, must find that the reduced number of spaces will not result in an increase of on-street parking. 12.3.14 The replacement, installation or addition of off-street parking or parking aisles areas, in the cumulative aggregate amount of fifteen hundred (1500) or more square feet on any lot from January 15, 1988, being the date of initial adoption of this regulation, shall require site plan approval from the Planning & Zoning Commission. 12.3.14.4 This procedure is instituted to ensure that increases in storm water run-off resulting from increases in paved parking areas are managed in such a way so as to not cause flooding of public facilities or adjoining properties. 4.24.4.1.7 & 4.25.4.1.7 In addition to the standard site plan requirements, any development proposed within the PDZ shall provide for pedestrian and bicycle access including but not limited to: • Bike racks and or bike parking to be located as close to the building entrance as possible; • Stations for transit riders, where feasible; • Sidewalks connecting the new development to transit stops, where feasible; Public sidewalks, unless waived by Section 3.25	
Unconnected Impervious Areas		*No relevant regulations identified.*	Not typically applicable to zoning

Vegetated Open Channels

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
		No relevant regulations identified.	Not typically applicable to zoning

Vegetation and Landscaping

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions

Preservation of Natural Areas	Chapter 5 – Natural Resources (pp 28 & 38)	• Make every effort possible to preserve sensitive natural resource areas.
		• Where preservation is not possible, update zoning to reduce densities/development intensity in areas with a concentration of natural resources.
		  o Consider updating zoning regulations to expand "developable acreage" to low density zones.
		• Design signs to avoid sensitive areas
		  o Update zoning regulations to allow Cluster Developments on smaller parcels, as appropriate.
		
		Protect Habitat and Minimize the Clearing of Vegetation:
		• Continue to work with applicants to minimize the amount of vegetation cleared during construction.
			• Establish restrictions for enlarging existing turf lawn areas.
			• Adopt transfer of development rights to protect natural resources and encourage infill development in densely developed areas with appropriate existing infrastructure.
			• Require consideration of the preservation and enhancement of scenic points and vistas, ridgelines, and contours of the land as part of the development review process.

Tree Protection	Chapter 5 – Natural Resources (p 38)	Protect Habitat and Minimize the Clearing of Vegetation: • Work with applicants to prevent accidental tree damage and to ensure that new trees are planted correctly and maintained. • Encourage property owners to retain vegetation, particularly mature, heritage and specimen trees.	▪ Require that public trees damaged during construction are removed and replaced. ▪ Adopt tree protection rules for public trees during construction projects.
Landscaping Islands and Screening		*No relevant regulations identified.*	• Modify the parking area landscaped area requirements in the zoning regulations to promote parking lot bioretention and other LID practices to manage runoff. This may include modification of landscape area requirements to specify shrubs and trees appropriate for controlling runoff.
Riparian Buffers	Chapter 5 – Open Space (p. 42) Chapter 5 – Natural Resources p. 31)	The goal of the Hockanum River Linear Park Plan is to bring people back to their river, increase public awareness and appreciation for the River and its surrounding environment, and to protect water quality by preserving riparian areas along the River. Tankerhoosen Watershed Management Plan, 2009: • Objectives to meet goals of this plan include protecting and restoring buffers.	• Establish riparian and wetland buffer dimensions, and regulations Town-wide on the type of maintenance and/or activities allowed in the buffer.

Minimizing Land Disturbance

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Limits of Disturbance		*No relevant regulations identified.*	
Open Space and Cluster Development	Chapter 5 – Natural Resources (p 38) Chapter 5 – Open Space and Greenways (p. 43) Chapter 5 – Open Space and Greenways (p. 45)	Protect Habitat and Minimize the Clearing of Vegetation: • Continue preserving open space in areas with critical habitat. • On existing open space, develop habitat based management plans. Promote and Manage Existing Open Space • Maintain and update the inventory of open space and greenways. • Make information on open space access and amenities easily available. • Program events to promote use of open space and parks. • Provide regular funding in the Capital Improvement Program for maintenance. Continue to Preserve Open Space: • Work with owners of managed open space to permanently preserve their land. • Focus on preserving Desired Open Space parcels identified on Open Space Plan. • Ensure that deeds for open space state that the property is to remain open space in perpetuity. • Pursue additional means of funding to purchase desirable parcels. • Encourage the creation of additional greenways.	• Consider habitat fragmentation in regulations for open space, or for alternative/traditional subdivisions. • Allow and encourage retrofits of abandoned or underutilized public lands to serve as permanent or temporary open space and stormwater management purposes.

Impervious Area Management

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Streets and Driveways	Chapter 6 – Transportation (p. 103)	Continue to Implement Traffic Calming Measures: • Implement traffic measures on a case-by-case basis as needed. • Examine road width requirements and determine if they can be reduced.	• Develop comprehensive transportation planning that includes public transportation, bicycle, and pedestrian elements as well as narrowing of streets where appropriate and use of "green street" technologies for stormwater management.
Parking Areas and Sidewalks	Chapter 6 – Transportation (p. 106)	Enhance Pedestrian and Bicycle Travel: • Continue to incorporate sidewalk improvements into road projects, where feasible. • Encourage new development to provide pedestrian and bicycle infrastructure. • Explore options for funding sidewalks, such as a sidewalk fund. Address Parking Needs: • Consider building structured parking in the municipal lost in Rockville. • Encourage landowners to share parking in Rockville. • Rethink parking requirements to reduce the environmental and economic impacts of providing too much parking. Parking Approaches: • Continue to require a minimum number of spaces, but recalibrate space requirements to better match demand (Rockville/Remainder of Town) • Reduce parking requirements by 5/8ths in areas where public parking or on-street parking is available	• Allow for shared parking Town-wide, and provide model shared parking agreements. • Allow for multi-level parking. • Review current parking stall dimensions for potential reduction in maximum or median requirements. • Consider parking spaces held in reserve for phased developments, thereby avoiding the situation where unnecessary parking is not constructed if future phases of development do not occur.

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
		(Rockville) • Set a minimum and maximum number of spaces (Rovkville/Remainder of Town) • Allow reduction in spaces if applicant can demonstrate the spaces are not needed (Rockville/Remainder of Town) • Allow reduction if other private parking spaces are available nearby and owner has a legal agreement with owner of other spaces to share (Rockville/Remainder of Town) • Allow reduction if other public parking spaces are available nearby (on-street or public lot) In this case, the fee-in-liue of parking payment should be required because a cost is born by the Town (Rockville). • Defer = Can build lesser number of spaces but must reserve an area for future parking spaces in case demand warrants a need for them (Remainder of Town). • Eliminate minimum parking requirements for some or all uses (Rockville/Remainder of Town)	
Unconnected Impervious Areas	Chapter 6 – Transportation (pp. 102 and 103)	Multiple curb cuts (driveways) in close proximity to one another impact traffic flow increase the potential for accidents and increase the number of conflict points between pedestrians and vehicles. The Planning and Zoning Commission has worked to reduce/combine curb cuts when development occurs. Continue to Require and Encourage Access Management: • Continue to work with land use applicants and the State Traffic Commission to reduce/minimize curb cuts (driveways).	Allow for downspout disconnection

Vegetated Open Channels

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
	Chapter 5 – Natural Resources (p. 37)	Reduce Stormwater Runoff: • Update zoning and subdivisions to require LID approaches • Require swales and non-piped drainage structures as appropriate, etc. • Educate property owners, developers, and other about simple LID practices they can undertake (e.g., rain gardens, directing roof runoff to vegetated areas, reducing the amount of pavement).	

General

Topic	Source - Regulation	Language of Concern	Potential Problems and Recommended Revisions
Stormwater	Section 5 – Natural Resources (p. 37)	Reduce Stormwater Flows: • Educate residents and businesses about simple LID approaches they can take to reduce stormwater flow from their properties. • Integrate LID into land use regulations (provide guidance or require). • Encourage LID techniques in the design of municipal projects. • Ensure protocols are in place for maintenance of privately owned drainage facilities.	

Appendix B

Community-Based Social Marketing

FUSS & O'NEILL

MEMORANDUM

TO: File

FROM: M. James Riordan, AICP, LEED AP
Senior Project Manager

DATE: July 15, 2011

RE: CBSM Research

This memorandum provides general information about community-based social marketing (CBSM). The information provided includes:

- A copy of a Wikipedia article on social marketing.
- An internet link to a professional CBSM text, entitled *Fostering Sustainable Behavior* (McKenzie-Mohr and Smith, 1999).
- Examples of CBSM projects.

Social Marketing and CBSM

"Social marketing" is a term used to describe the application of marketing principles to promotion of social programs (i.e., programs intended to do social good). Depending on the source consulted, CBSM may be considered a form of social marketing that focuses primarily on environmental issues or a cousin to social marketing that uses applied social-psychology to promote and institutionalize environmental programs through interventions that may include marketing but tend to focus on "environmental psychology." Environmental psychology is an area within the field of social psychology that applies the tenets of behavioral psychology at the community level in support of environmental initiatives.

Attached with this memorandum is a copy of a Wikipedia article regarding social marketing. This article provides:

- Applications of social marketing
- Types of social marketing
- Social marketing confusion
- History of social marketing
- Further reading
- External links

Fostering Sustainable Behavior

Fostering Sustainable Behavior is a very readable and complete introduction to CBSM. Doug McKenzie-Mohr, the book's principal author, is considered the founder of the CBSM approach. Fostering Sustainable Behavior provides theoretical background for the CBSM approach as well as discussion of several case studies involving CBSM. The book is available as a Google Book (i.e., at no cost) at:

http://books.google.com/books?id=2ZnKy6BMpTQC&printsec=frontcover&dq=fostering+behavior+change+doug+mckenzie-mohr&source=bl&ots=jIKcOwviO-&sig=92FFxR1dj2IjsxGZZ8axUaFmjug&hl=en&ei=zPTiTLu_Nc-p8AbKlLysDg&sa=X&oi=book_result&ct=result&resnum=3&ved=0CBsQ6AEwAg#v=onepage&q=fostering%20behavior%20change%20doug%20mckenzie-mohr&f=false

Additionally, a variety of information on CBSM can be found at:

http://www.cbsm.com/public/world.lasso

Examples of CBSM Projects
Several examples of successful CBSM projects that were completed by Action Research have been attached to this email. These include:

- Storm Water Pollution Prevention: Research, Outreach, and CBSM
  Think Blue, City of San Diego Storm Water Department

- Evaluation of Quiet Roads Outreach Campaign
  Cal Recycle; Subcontract to Katz & Associates

- Sustainable Agricultural Practices in Tennessee: CBSM
  University of Tennessee, Center for Industrial Services

- Pet Waste Pollution Prevention: Community Based Social Marketing
  City of Oceanside Water Utilities Department, Clean Water Program

Action Research has also provided cost information for four levels of services offered on an annual on-call basis (see attached). Recommended annual budgets range from $10,000 for basic on-call services to $300,000 for full CBSM services from program inception to full implementation.

Additional project summaries are available on the following website:

http://www.cbsm.com/cases/search

/ap

Attachments

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Appendix C

Common Elements of a Tree Protection Ordinance

Model Tree Protection Ordinance

KEY ELEMENTS

NOTE: Most of the following guidelines are taken from Tree Conservation Ordinances, by Christopher Duerkesen with Suzanne Richman, a publication of Scenic America and the American Planning Association, which is available in our Bookstore.

Since every community is different, every ordinance will be different as well. Communities and activists should treat these elements as a guide.

Furthermore, every community should seek the advice of its legal advisors to ensure that the ordinance is within the powers granted to communities under state law.

1. Purpose: This section should reflect the community's priorities in tree conservation. Does the community want to protect trees in order to protect its watershed, as Fairfax County, Virginia, did in stating that it adopted its ordinance ". . . to alleviate erosion, siltation, and other harmful effects of land-disturbing activities . . ."? [1] Or is it to protect historic trees? From a legal standpoint, it is most important that communities clearly state what they want the ordinance to accomplish. Scenic America strongly urges towns to prominently state the aesthetic benefits they hope to realize with their ordinance. If someone challenges the ordinance in court, the courts will look very closely at this section to determine whether or not subsequent sections serve this purpose.

2. Authority: It is also useful to cite the state enabling legislation that allows communities to protect trees. In doing so, the community acknowledges that they have the authority to do so and that they have verified that their ordinance does not exceed that authority.

3. Definitions: Depending on the scope of the ordinance, these can range from defining a "tree," which every ordinance should do (for example, does it cover large, woody plants with a height that will exceed ten feet or does it cover understory vegetation?), to defining "a heritage tree" (i.e. trees with some combination of age, historical connotations, etc., that the community finds particularly valuable), to defining more technical terms such as "mitigation," "dripline," and "afforestation." Outstanding sources of definitions include the aforementioned Tree

TREE CONSERVATION

- Tree Conservation
- Why Conserve Trees?
- Economic Benefits of Tree Conservation
- Health Benefits of Tree Conservation
- Environmental Benefits of Tree Conservation
- Strategies for Tree Conservation
- Model Ordinance
- Tree Cutting

Conservation Ordinances and U.S. Landscape Ordinances: An Annotated Reference Handbook, by Buck Abbey.

4. Inventory/Information Requirements: There are two elements to this section. First, communities can and should, regardless of whether they are developing their first ordinance or refining an existing one, conduct their own inventories of trees, including assessing species, the health of trees, and information about where the trees are in relation to other resources, such as watersheds. Second, where the ordinance protects trees on private property, the ordinance should require developers to perform an on-site tree inventory. Outstanding examples of provisions doing this are found in the ordinances of Austin, Texas [2] and Prince Georges County, Maryland. [3]

5. Identification of Protected Trees: This section clearly delineates the characteristics of trees the community wants to protect. Some communities use a simple size measure, protecting only trees, for example, with a diameter at breast height of 30 inches. Others, recognizing that an oak of that size is common while a dogwood that large would be extremely rare, set different size limits for different species. Still others use factors such as age, location and general condition. Some communities also promote the protection of durable or aesthetically pleasing trees while offering less protection to trees unusually prone to breakage during wind or ice storms or trees that drop messy fruit (such as Bradford Pears).

6. Identification of Who Must Comply with the Ordinance: This section identifies the activities that trigger the ordinance and who must and must not comply with it. Some communities do not require tree preservation measures if only small parcels are affected or if small numbers of trees are involved. Tampa, Florida, for example, exempts expansion of single and two family dwellings that do not increase the total floor area on a parcel by more than 15 percent or exceed a cost of $15,000. Gibbsboro, New Jersey, allows individual lot owners to remove fewer than two trees at any one time or six in any one year.

In addition to protecting trees from disturbance during the development process, many communities also protect trees from excessive or improper pruning. Chesapeake, Virginia [4] contains an extensive section on tree preservation and implementation in its ordinance. At the same time, San Juan Capistrano, California targets the practice of "topping," in which tree owners reduce major branches to stubs. Specifically, no property owner in certain zones may have his trees "severely trimmed," which the ordinance defines as "the cutting of the branches and/or trunk of a tree in a manner which will substantially reduce the overall size of the tree area so as to destroy the existing symmetrical appearance or natural shape of the tree in a manner which results in the removal of main lateral branches, leaving the trunk of the tree in a stub appearance." [5]

7. Administration: This section identifies the agency or individual responsible for ensuring compliance with the tree ordinance. Most communities assign the job to one of four types of agencies: planning and zoning; parks and recreation; public works; or environmental resources. Many communities also have shade tree commissions that, in addition to reviewing and updating the ordinance and related guidelines, may also review applications for permits.

At some point or at some level of discussion, communities will need a professional arborist or forester to assess compliance and provide technical expertise. While only the larger and wealthier cities tend to have such a professional on staff, most communities can retain one in their area.

8. Standards: Somewhere, either in the ordinance or in related regulations, the community should make some reference to the standards to which they intend to hold developers and property owners. Communities may either adopt comprehensive standards on their own or refer to accepted professional standards. For example, Alachua County, Florida, requires compliance with the National Arborist Association Standards for Pruning of Shade Trees when trimming trees on public or private property except in cases of emergency. [6]

9. Enforcement: Ultimately, after all the decisions of what to protect and how to protect it have been made, to be of any value the ordinance must contain some provisions for penalizing violators. Small fines might just be seen as a cost of doing business. However, such measures as linking fines and penalties to the actual value of trees destroyed, considering each tree damaged or removed a separate violation, and invoking penalties for each day the violations persist can have a significant impact on the attitudes of potential violators. [7]

With careful planning, with an ordinance containing all of the above ordinances, and most important of all, with vigorous enforcement and implementation, every community can protect its trees and enjoy the environmental, economic, and aesthetic benefits of tree conservation.

REFERENCES

The best source of information on how to draft a successful tree conservation ordinance remains Tree Conservation Ordinances, by Christopher J. Duerksen with Suzanne Richman, published in 1993 by the American Planning Association and Scenic America. This book can be ordered in our online bookstore.

The most comprehensive review of individual landscaping ordinances is *U.S. Landscape Ordinances: An Annotated Reference Handbook*, by Buck Abbey. This book can be ordered directly from the publisher, John Wiley & Sons, www.wiley.com.

Several organizations also concern themselves with community tree preservation and landscaping. National organizations include the American Society of Landscape Architects, the National Arbor Day Foundation, the National Tree Trust, and the Society of Municipal Arborists.

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1 Fairfax County, Virginia, Erosion and Sedimentation Control and Conservation Ordinance, Pt. 3, Ch. 104-1-1.
2 Austin, Texas, City Code, Chapter 13-2A (Zoning) Section 5187.
3 Prince George's County, Series No 9058201522, A Manual for Tree Preservation in Development Areas, c. 1982.
4 Chesapeake, Virginia, Land Use Code, Section 22.20-520.
5 San Juan Capistrano, California, City Code, Section 9-3.625.
6 Alachua County, Florida, Ordinance, 91-14, Section 4 (1991).
7 Duerksen, Christopher J. and Richman, Suzanne, Tree

Conservation Ordinances, American Planning Association
and Scenic America, Washington, DC 1993.

Printer-friendly version

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Appendix D

CTDEEP LID Standards Manual

Low Impact Development Appendix to *Connecticut Guidelines for Soil Erosion and Sediment Control*

Partners for the Connecticut Low Impact Development and Stormwater General Permit Evaluation

Connecticut

August 2011

FUSS & O'NEILL
Disciplines to Deliver

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Manchester, CT 06040

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Low Impact Development Appendix to *Connecticut Guidelines for Soil Erosion and Sediment Control* Partners for the Connecticut Low Impact Development and Stormwater General Permit Evaluation

1 Introduction to Low Impact Development

Traditionally, stormwater has been managed using large, structural practices installed at the low end of development sites—essentially as an afterthought—on land segments left over after subdividing property. This approach, sometimes referred to as end-of-pipe management, yields the apparent advantages of centralizing control and limiting expenditure of land. Unfortunately, end-of-pipe technology has been shown to have many economic and environmental limitations such as failure to meet receiving water protection goals, high construction, operation and maintenance costs, and certain health and safety risks. In response to these deficiencies an alternative technological approach has emerged that is generally more economical and potentially provides far better environmental protection. This new approach is referred to as low impact development (LID).

In contrast to conventional centralized end-of-pipe management, LID uses site design principles and more a number of small-scale treatment practices distributed throughout a site to manage runoff volume and water quality at the source. For new development, LID uses a planning process to employ site design techniques to first optimize conservation of natural hydrologic functions to prevent runoff and erosion. If these conservation practices are insufficient to meet required stormwater goals, engineered treatment practices are used to meet soil erosion prevention objectives.

LID is still relatively new and rapidly evolving soil management technology. It was first described in 1999 in the Prince George's County, Maryland, *Low-Impact Development Design Strategies: An Integrated Design Approach*. However, today due to LID's many economic and environmental advantages over conventional end-of-pipe technology, it has been widely and rapidly adopted throughout the country. This LID design guidance has been developed using the latest information and past lessons learned to provide the most up to date design guidance.

Much of LID focuses on post-construction runoff control; however, LID includes site planning approaches as well as impact avoidance and standards that are valuable for the purposes of controlling soil erosion and sedimentation. Therefore, this is appendix primarily addresses the aspects of LID related to soil erosion and sediment control. This appendix also provides the reader with an overall context for the use of LID so that approaches described can be more readily integrated with a LID-based approach.

The remainder of this introductory section provides discussion of the advantages of LID and the basic four basic LID principles.

1.1 Advantages of LID

Typical advantages of LID's integrated approach over the conventional end-of-pipe approach include:

- Reduced consumption of land for stormwater management – LID practices provide opportunities to integrated controls into all aspects of a site's hardscape and landscape features. This allows multifunctional use of the entire developed site for controls allowing the most cost effective use of land. Less land is needed or consumed for end-of-pipe controls often allowing for more developable space.

- LID does not dictate particular land-use controls – Since LID is a technological approach there is no need to change conventional zoning or subdivision codes accept to allow LID's use. This means LID does not reduce development potential and with less land consumed for stormwater controls lot yields may increase.

- Reduced construction costs – Traditional stormwater management requires significant storm sewering and earthwork. LID practices apply controls as close to sources of runoff as possible. Wherever practicable, conveyances incorporate natural flow paths and swales instead of pipes. Structures installed are small, thus reducing the need for excavation and construction materials.

- Ease of maintenance – LID landscape practices require limited maintenance or no increase in maintenance beyond typical landscape care. Much of the maintenance required can be accomplished by the average landowner. Further many LID site planning, conservation, and grading techniques require no maintenance.

- Takes advantage of site hydrology – Conservation of natural resources, topography, land cover, soils, and drainage features preserve the natural hydrologic functions allowing absorption of runoff from impervious surfaces. Runoff that is absorbed recharges groundwater and stream base flow and does not need to be managed or controlled by an end-of-pipe practice. Preserving and maintaining the natural hydrology also better protects streambank stability and riparian habitat.

- More aesthetically pleasing development – Traditional stormwater management tends to incorporate the use of large, unnatural looking practices such as detention ponds. When neglected, these practices may present drowning and mosquito breeding hazards. Nonstructural and upland practices optimize use of landscape features that are more aesthetically pleasing and fit well into the natural landscape.

- Multiple benefits – LID has shown to provide multiple benefits such as reducing energy cost by using green roofs and proper location of trees for shading and water conservation by using rain water as a supplemental water supply.

- Improved profit margin – The advantages of nonstructural and upland management translate into the marketplace. The value added is significant. Several studies indicate that the cost of applying these nonstructural and upland stormwater management techniques is about half that of the traditional approach. The results of one example of such a study are summarized in *Table 1.1* below (Schuler, 2000). Properties developed using nonstructural and upland stormwater practices tend to command higher sale prices.

Table 1.1
Cost Analysis for Convention and Alternative Development

Cost Categories	Conventional Development	Alternative Development[a]
Engineering	$79,600	$39,800
Road Construction	(20,250 linear ft.) $1,012,500	(9,750 linear ft.) $487,500
Sewer and Water	$25,200	$13,200
Other Costs	$111,730	$54,050
Total	$1,229,030	$594,550

Source: Center for Watershed Protection, 2000, *The Practice of Watershed Protection*, page 175.
Notes:
[a]Alternative development cost analysis was done for cluster development, which is similar to conservation development.

1.2 Four Basic LID Principles

A well-designed integrated stormwater system will minimize the volume of runoff generated and maximize the treatment capabilities of the landscape. A LID-based design controls runoff as close to the source as possible. A well-designed system should also be easy to maintain, not interfere with the typical use of the property, and be aesthetically pleasing. Most critical to soil erosion control, a well-designed development site will also minimize site disturbance. In considering the advantages and constraints of each site, these four fundamental concepts should remain preeminent:

1. **Minimizing site disturbance**
   Undisturbed lands possess a natural capacity to store runoff waters. Development sites may include areas that are relatively sensitive to impact from construction (e.g., erosion) or may encompass particularly rare or valuable environmental features. Protecting susceptible natural features provides the multiple benefits of preserving important resources, reducing development impact and providing capacity for prevention of erosion.

   Generally, developers should inventory and map natural features such as surface waters, vegetated wetlands and highly erodible soils, for preservation early in the site planning process. This helps to define a practicable development envelope. Preserved areas must be protected throughout construction and demarcated for conservation in land records.

2. **Working with site hydrology**
   Traditional stormwater management seeks to eliminate the nuisance and hazard of runoff by rapidly conveying it away from development—typically, via closed drainage systems such as storm sewers. This approach works efficiently to remove water from streets and sidewalks, but it expends significant capital for constructed systems that interrupt the recharge of groundwater resources. By contrast, LID techniques work to reduce stormwater generation or retain it in the upland where it can percolate naturally into the soil and replenish groundwater resources.

3. **Minimizing and disconnecting impervious surface**
   Runoff comes primarily from impervious surface, such rooftops, roadways or any smooth hard surface that prevents water from absorbing into the ground. Traditional developments tend to include superfluous impervious surface, which may minimized with thoughtful site planning. Techniques to limit impervious area include reducing road widths and lengths as well as the area of rooftops (e.g., preference for two-story over single-story buildings).

   To the extent possible, developers should promote contact between runoff and pervious land surface. Technically, this is done by increasing time of concentration—length of time required for runoff to concentrate and flow off site—and by reducing curve number.

4. **Applying small-scale controls at the source**
   Small-scale practices applied at the source—or as close as practicable—can offer significant advantages over conventional, engineered facilities such as ponds or concrete conveyances. They can decrease the use of typical engineering materials such as steel and concrete. By using materials such as native plants, soil and gravel these systems can be more easily integrated into the landscape and appear to be much more natural than engineered systems. The natural characteristics may also increase homeowner acceptance and willingness to adopt and maintain such systems. Small, distributed systems also offer a major technical advantage—one or more of the systems can fail without undermining the overall integrity of the site control strategy.

   Small-scale practices reduce safety concerns as they feature shallow basin depths and gentle side slopes. The integration of these facilities into the landscape throughout the site offers more opportunities to mimic the natural hydrologic functions and add aesthetic value. The adoption of these landscape features by the general public and individual property owners can result in significant maintenance and upkeep savings to the homeowners association, municipality or other management entity.

2 Site Planning and Design Process

The LID approach emphasizes the use of site design and planning techniques to conserve natural systems and hydrologic functions. LID is also a highly engineered design and management strategy, which integrates practices throughout a development.

The simplest and least costly LID technique is good site planning; and an important goal of LID is to mimic the predevelopment hydrology to the extent practicable. To accomplish this, LID projects require a thorough understanding of the site's soils, drainage patterns, and natural features.

Developers should use natural features, hydrology and soils as a design element. In order to minimize the runoff potential an understanding of site drainage patterns and soils can suggest locations both for green areas and potential building sites. Integration of natural features into the site design creates a more ecologically functional site and a more aesthetically pleasing landscape that will be a vital functioning part of the ecosystem. Outlined below is the basic LID site process.

2.1 Step 1 – Define Basic Project Objectives and Goals

Identifying the project objectives not only includes identifying regulatory needs, but also ecological needs. Ecological needs include these fundamental aspects:

- Runoff volume to match predevelopment.
- Peak runoff rate to meet regulatory needs.
- Flow frequency and duration to match predevelopment.
- Water quality to meet regulatory requirements.
- Stream or wetland base flow needs.
- Recharge areas.
- Natural resource conservation requirements.

To ensure ecological needs receive appropriate attention, the developer should prioritize and rank objectives and determine the type controls required to meet objectives such as infiltration, filtration, discharge frequency, volume of discharges and groundwater recharge. Determine the feasibility for type and proper location of LID controls to best address volume, flows, discharge frequency, discharge duration and water quality.

2.2 Step 2 – Site Evaluation and Analysis

A site evaluation will facilitate design by providing details that will help to customizing LID techniques for the sites unique constraints, regulatory requirements and receiving water goals.

1. Conduct a detailed investigation of the site using available documents such as drainage maps, utilities information, soils maps, land use plans, and aerial photographs.

2. Evaluate site constraints such as available space, soil infiltration characteristics, water table, slope, drainage patterns, sunlight and shade, wind, critical habitat, circulation and underground utilities.

3. Identify protected areas, setbacks, easements, topographic features, sub drainage divides, and other site features that should be protected such as floodplains, steep slopes, and wetlands.

4. Delineate the watershed and micro-watershed areas. Take into account previously modified drainage patterns, roads, and stormwater conveyance systems.

Many other unique site features may influence the site design including historical features, view sheds, climatic factors, energy conservation, noise, watershed goals, onsite wastewater disposal and off-site flows. All of these factors help to define the building envelop and natural features to be integrated into the LID design.

2.3 Step 3 – Optimize Conservation of Natural Features at the Larger Watershed Scale

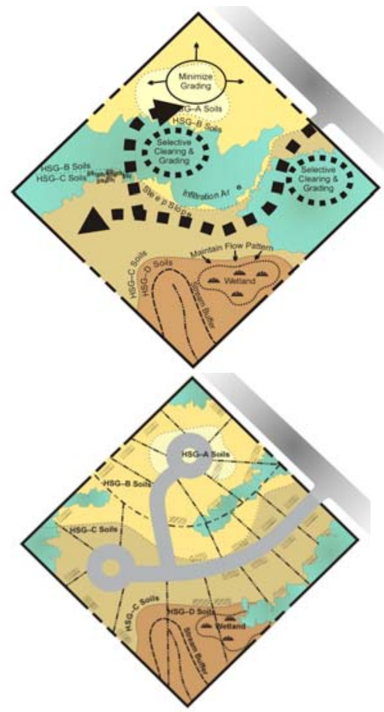

Figure 2.1 – Optimizing the use of green space.

LID does not promote the use of any particular style site development such as traditional neighborhood design, conventional grid patterns, cluster development, conservation design or new urbanism. Regardless of the development style, LID techniques can always be used throughout the site. Natural features are saved to reduce impacts and allow for greater use of natural features to treat runoff. Conserving natural features not only reduces impacts but preserves habitat and natural ecological processes.

The most successful LID design begins with understanding of the site's natural resources and how best to save these features. To the extent practicable and in accordance with current regulations, natural features (wetlands, trees/vegetation, good soils) should be conserved and integrated into the overall site plan. The conservation features should continue to be used by directing runoff to the natural features in the same manner as the predevelopment conditions. The greater use of natural features generally means reduction of clearing and grading and lower cost.

Locating infrastructure to direct runoff to buffers, vegetative filters, existing drainage features will help to reduce runoff quantity and improve water quality. This approach reduces disturbance of the natural soils and vegetation allowing more areas for infiltration and runoff contact with the landscape. To optimize the use of green space requires an ability to lay out the site infrastructure in a way that allows saving sensitive the natural features and their functions. The basic strategy is shown in *Figure 2.2*.

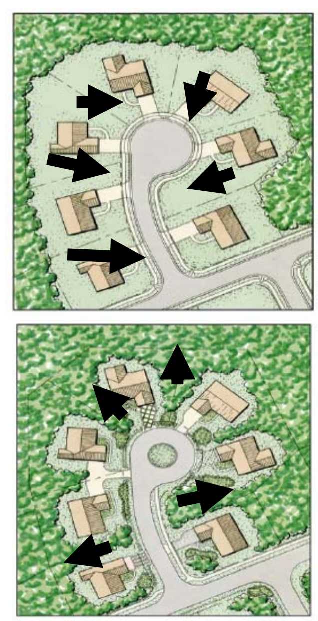

Figure 2.2 - conventional approach of draining runoff to the streets vs. a LID design using site fingerprinting.

There are many techniques that should be considered including:

- Minimizing and properly stage grading and clearing for roadways and building pads as only necessary.
- Locating, saving and utilizing pervious soils.
- Locating treatment practices in pervious hydrologic soil groups A and B.
- *Where feasible*, constructing impervious surfaces on less pervious hydrologic soils groups C and D.

- Disconnecting impervious surfaces by draining them to natural features.
- Flattening slopes where possible.
- Re-vegetating cleared and graded areas.
- Utilizing existing drainage patterns.
- Routing flow over longer distances.
- Using overland sheet flow.
- Maximizing runoff storage in natural depressions.

2.4 Step 4 – Minimize Impacts at the Lot Level

To the extent practicable, conserve trees, natural drainage patterns, pervious soils and depressions at the lot level. This often means less clearing and grading. *Figure 2.3* contrasts the conventional approach of draining runoff to the streets vs. a LID design using site fingerprinting where runoff is directed to the natural features.

The key to preventing excessive runoff from being generated is slow down velocities by directing it toward areas where it can be absorbed. The reliance on many small measures used throughout the site will serve this purpose better than a single large control measure.

There are many lot level techniques that should be considered including:

Figure 2.3 – Lot level techniques.

- Avoiding installation of roof drains.
- Directing flows to vegetated areas.
- Directing flows from paved areas to stabilized vegetated areas.
- Breaking up flow directions from large paved surfaces.
- Encouraging sheet flow through vegetated areas.
- Locating impervious areas so that they drain to permeable areas.
- Maximizing overland sheet flow.
- Lengthening flow paths and increase the number of flow paths.
- Maximizing use of open swale systems.
- Increasing (or augmenting) the amount of vegetation on the site.
- Using site fingerprinting. Restricting ground disturbance to the smallest possible area.
- Reducing paving.
- Reducing compaction or disturbance of highly permeable soils.
- Avoiding removal of existing trees.
- Using on-lot tree save areas.
- Reducing the use of turf and use more natural land cover.
- Maintaining existing topography and drainage divides.

- Locating structures, roadways on Type C soils *where feasible*.[1]

Various lot level techniques are illustrated in *Figure 2.3*.

3 Design Standards for Low Impact Development Related to Soil Erosion and Sediment Control

This section discusses design standards for LID controls related to soil erosion and sediment control. It provides a general description of each control, its advantages, general use, and standards for its application.

- Complying to Limits of Clearing and Grading
- Preserving Natural Areas
- Avoiding Disturbing Long, Steep Slopes
- Minimizing Siting on Porous and Erodible Soils

3.1 Limits of Clearing and Grading

Perhaps the most potentially destructive stage in land development is the preparation of a site for building—clearing of vegetation and soil grading (Schueler, 1995). The limits of clearing and grading refer to the part of the site where development will occur. This includes all impervious areas such as roads, sidewalks, rooftops, as well as areas such as lawn and open drainage systems.

To minimize impacts, the area of development should be located in the least sensitive areas available. At a minimum, developers should avoid streams, floodplains, wetlands, and steep slopes (see *Section 3.3*). Where practicable, developers should also avoid soils with high infiltration rates as these will aid in reducing runoff volumes (see *Section 3.4*).

Advantages

- Preserves more undisturbed natural areas on a development site.
- Uses techniques to help protect natural conservation areas and other site features.
- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- May reduce landscaping costs.

[1] Because Type C and D soils tend to be poorly suited to construction, site structures on them may be ineffective from a cost-benefit standpoint or technically impractical.

Use

Establishing a limit of disturbance based on maximum disturbance zone radii/lengths. These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as slopes or soils. Limits of disturbance may vary by type of development, size of lot or site, and by the specific development feature involved.

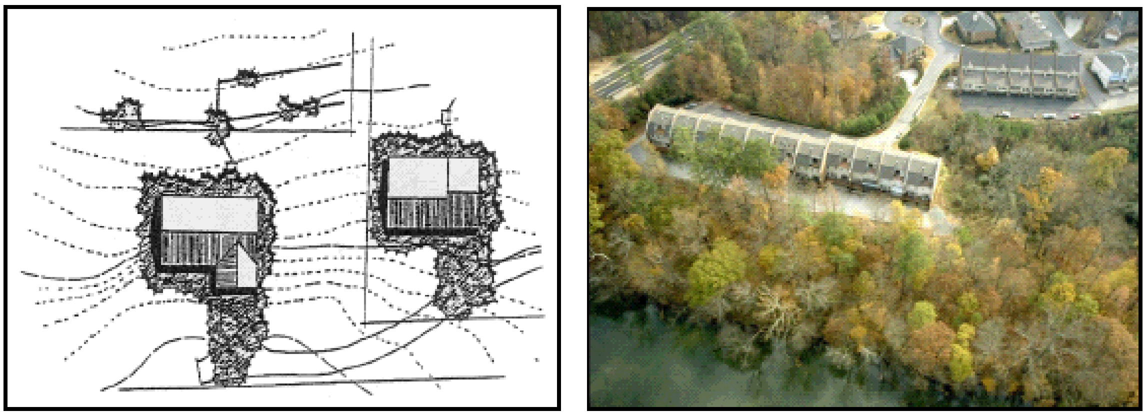

Figure 3.1 - Reduced limits of disturbance minimize water quality impacts. Source: Atlanta Regional Commission, 2001.

Standards

Generally speaking, limits of disturbance need not comprise more than:

a) Area of the building pad and utilities (including onsite wastewater treatment systems and wells) plus 25 feet.
b) Area of a roadbed and shoulder plus 9 feet. (This is not intended to limit lawn areas.)

3.2 Preserving Natural Areas

Natural areas include woodlands, riparian corridors, areas contiguous to wetlands and other hydrologically sensitive and naturally vegetated areas. To the extent practicable these areas should be preserved.

Natural areas can be one of the most important components within a development scheme, not only from a stormwater management perspective, but in reducing noise pollution and providing valuable wildlife habitat and scenic values. New development tends to fragment large tracts of undisturbed areas and displace plant and animal species; therefore it is essential to maintain these buffers in order to minimize impacts. Areas adjacent to waterbodies (both freshwater and coastal) are protected under state law and cannot be altered without a state agency permit.

Advantages

- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Reduces safety and property-damage risks where flood hazard areas are incorporated into preservation.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- Establishes and maintains open space corridors.

Use

a) Check all federal, state and local enforceable policy to ensure proper setbacks and identification of preservation areas. Identify areas for preservation through site analysis using maps and aerial or satellite photography or by conducting a site visit.
b) Delineate areas for preservation via limits of disturbance before any clearing or construction begins and should be used to set the development envelope as well as guide site layout. Clearly mark areas for preservation on all construction and grading plans to ensure that equipment is kept out of these areas and that native vegetation is kept in an undisturbed state.
c) Protect preservation areas in perpetuity by legally enforceable deed restrictions, conservation easements and maintenance agreements.

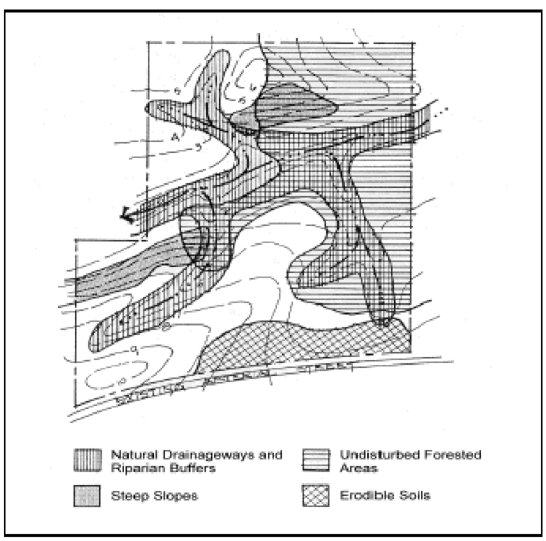

Figure 3.2 – Site map with natural areas delineated. Source: Atlanta Regional Commission, 2001.

Special Considerations

Riparian Buffers
A riparian buffer is a special type of preserved area along a watercourse where development is restricted or prohibited. Buffers protect and physically separate a watercourse from development. Riparian buffers also provide stormwater control flood storage and habitat values. An example of a riparian buffer is shown in *Figure 3.3*. Wherever possible, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and freshwater wetlands.

Figure 3.3 – Riparian buffer along the French River, in Thompson, CT. Source: Connecticut Department of Environmental Protection.

Riparian buffers consist of three zones (see *Figure 3.3*):

- The inner zone consists of the jurisdictional riverbank wetland and should be sized accordingly. In addition to runoff protection, this zone provides bank stabilization as well as shading and protection for the stream. This zone should also include wetlands and any critical habitats, and its width should be adjusted accordingly. Permits should be sought for activities in the inner zone. Generally speaking, structural best management practices (BMPs) are not allowed in the inner zone.

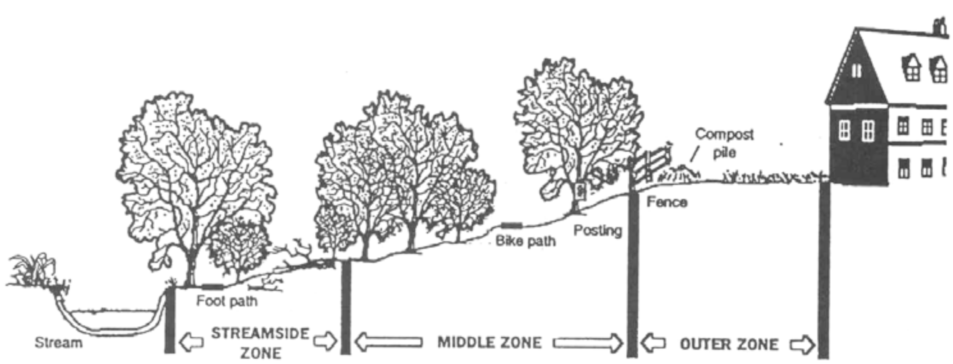

Figure 3.4 – Three-zone riparian buffer. Source: Atlanta Regional Commission, 2001.

- The middle zone provides a transition between upland development and the inner zone and should consist of managed woodland that allows for infiltration and filtration of runoff. A 25-foot width is recommended for this zone at a minimum. Forested riparian buffers should be maintained and reforestation should be encouraged where no wooded buffer exists. Proper restoration should include all layers of the forest plant community, including understory, shrubs and groundcover, not just trees.

- An outer zone allows more clearing and acts as a further setback for impervious surfaces. It also functions to prevent encroachment and filter runoff. A 25-foot width is recommended for this zone.

Ideally, all three zones of the riparian buffer should remain in their natural state. However, some maintenance is periodically necessary, such as planting to minimize concentrated flow, the removal of exotic plant species when these species are detrimental to the vegetated buffer and the removal of diseased or damaged trees.

Floodplain areas should be avoided on a development site. Ideally, the entire 100-year floodplain at full buildout should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. Maps of the 100-year floodplain can typically be obtained through the local review authority.

Standards

General

a) No disturbance shall occur to preservation areas during project construction.

b) Preserved areas shall be protected by limits of disturbance clearly shown on all construction drawings and clearly marked on site.

c) Preservation areas shall be located within an acceptable conservation easement instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked. [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management.]

d) Preservation areas are recommended have a minimum contiguous area of 10,000 square feet or in the case of stream buffers should maintain a 50-foot set back from the jurisdictional wetland edge along the entire length of stream through the property of concern. Areas of smaller size may be incorporated for disconnection of impervious surface, but will be considered as open space in good condition.

e) Level spreaders or other dispersion devices shall be incorporated, where practicable, to ensure sheet flow. See *Figure 3.5*, which depicts a level spreader. (Please note that the level spreader shown here is for dispersion of low flows only.

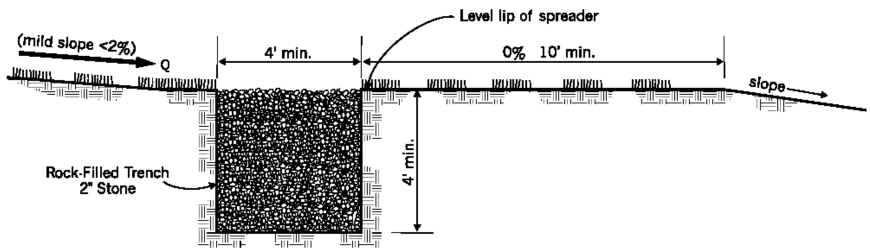

Figure 3.5 – Rock trench level spreader for low flows. Source: Prince George's County, Maryland, 2000.

f) Bypass mechanisms for higher flow events shall be included to prevent erosion or damage to a buffer or undisturbed natural area.

g) The incorporation of constructed berms around natural depressions and below undisturbed vegetated areas shall be considered to provide for additional runoff storage and infiltration. Proper use of berms is discussed in the section entitled vegetated filter strips.

h) Where no berms are provided in Hydrologic Soil Group (HSG) type A and B soils, buffers may be used to attenuate and treat flows up to the water quality volume (i.e., volume equal to one inch over the impervious surface) in the following ratios:

Table 3.1
Ratio of Forested Buffer to Impervious Surface Required to Attenuate Runoff for Precipitation between 0.5 and 1.0 Inches[a, b]

	HSG Soil Type			
Runoff (inches)	**A**	**B**	**C**	**D**
1.0	1:3	2:1	N/A	N/A
0.9	1:4	1:1	N/A	N/A
0.8	1:6	2:3	N/A	N/A
0.7	1:9	2:5	N/A	N/A
0.6	1:15	1:4	1:1	N/A
0.5	1:25	1:8	1:2	N/A

Notes:

[a]Buffer size calculations based on TR-55. Calculations for precipitation depths less than 0.5 inches are not included as the empirical equations of TR-55 become less accurate for storms less than 0.5 inches.

[b]Standards for buffer width, area and length of contributing flow path, etc. must be met regardless of soil's capacity to attenuate flow.

i) Land cover in buffers will be assumed to be woods in good condition (i.e., Curve number (CN) equal to 32 in type A soil and 55 in type B soil). Type C and D may not be used for this purpose as woods on these soil types cannot abstract the depth of rainfall associated with one inch of runoff from the impervious surface.

j) Runoff must enter the buffer as overland sheet flow. The average contributing slope should be no less than 1% and no more 3%. Maximum average slope may be increased to 5% if a flow spreader is installed across the entire contributing length followed by a flat (i.e., 0% slope) 10-foot shelf across the length.

Streambank Areas

a) The minimum undisturbed buffer width should be at least the wetland jurisdictional setback plus 50 feet.

Maintenance

Except for routine debris removal, buffers shall remain in a natural and unmanaged condition.

3.3 Avoid Disturbing Long, Steep Slopes

Disturbance of long, steep slopes tends to cause soil erosion. Studies show that soil erosion is significantly increased on slopes of 15% or greater. In addition, the geometry of steep slopes means that greater surface areas are disturbed to locate facilities on them compared to flatter slopes as demonstrated in *Figure 3.6*.

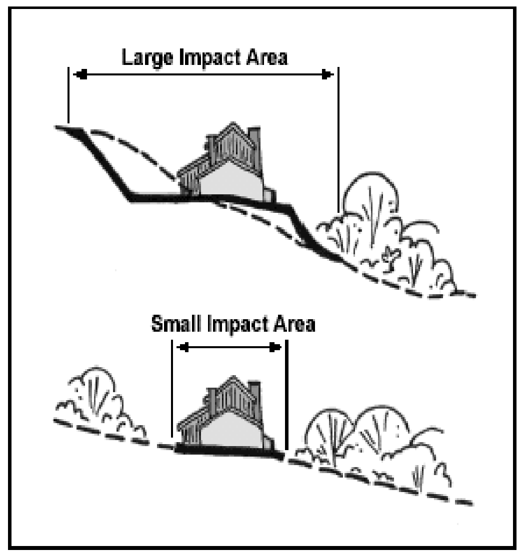

Figure 3.6 – Building on flatter slopes reduces the impact of development. Source: Atlanta Regional Commission, 2001.

Advantages

- Prevents soil erosion and sedimentation.
- Stabilizes hillsides and soils.
- Reduces the need for cut-and-fill and grading and may substantially reduce cost of development.

Standards

a) Avoid development on steep slope areas. As a general rule do not exceed the following values:

Grade	Slope Length
0% - 7%	300 feet
7% - 15%	150 feet
over 15%	75 feet

(Prince George's County, 2000)

b) On slopes greater than 25% (Georgia, 2000), no development, regarding, or stripping of vegetation should be considered unless the disturbance is for roadway crossings or utility construction. Erosion hazard risk increases as follows:

Grade	Erosion Risk
0% - 7%	Low
7% - 15%	Moderate
over 15%	High

(Prince George's County, 2000)

c) Avoid unnecessary grading on all slopes, as should the flattening of hills and ridges.

d) After cutting out soils, avoid inverting the soil horizons while filling.

3.4 Minimize Siting on Porous and Erodible Soils

This technique discusses appropriate standards for managing development in areas of erodible and porous soils.

Advantages

- Areas with highly permeable soils can be used as nonstructural stormwater infiltration zones.
- Avoiding highly erodible or unstable soils can prevent erosion and sedimentation problems and water quality degradation.
- Infiltration of stormwater into the soil reduces both the volume and peak discharge of runoff as well as groundwater recharge.
- Infiltration provides for water quality treatment.

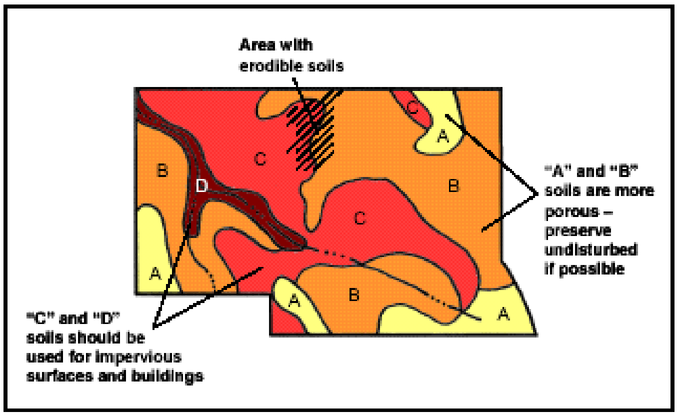

Figure 3.7 – Site plans depicting hydrologic soil groups

Use

a) Use soil surveys to determine site soil types.
b) Delineate hydrologic soil types on concept site plans to guide site layout and the placement of buildings and impervious surfaces (see *Figure 3.7*)

Standards

a) Whenever possible, leave areas of porous or highly erodible soils (hydrologic soil group A and B soils such as sandy and silty soils) as undisturbed conservation areas (see Preserve Natural Areas for more information on conservation areas).

b) Conversely, locate buildings and other impervious surfaces on those portions of the site with the *least* permeable soils. Gravel soils tend to be the least erodible. Also as clay and organic matter increase erodibility tends to decrease.

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Low Impact Development Appendix to the *Connecticut Stormwater Quality Manual*

Partners for the Connecticut Low Impact Development and Stormwater General Permit Evaluation

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1 Introduction to Low Impact Development

Traditionally, stormwater has been managed using large, structural practices installed at the low end of development sites—essentially as an afterthought—on land segments left over after subdividing property. This approach, sometimes referred to as end-of-pipe management, yields the apparent advantages of centralizing control and limiting expenditure of land. Unfortunately, end of pipe technology has been shown to have many economic and environmental limitations such as failure to meet receiving water protection goals, high construction, operation and maintenance costs, certain health and safety risks and limited use for urban retrofit. In response to these deficiencies an alternative technological approach has emerged that is generally more economical and potentially provides far better environmental protection. This new approach is referred to as LID.

In contrast to conventional centralized end-of-pipe management, LID uses numerous site design principles and small-scale treatment practices distributed throughout a site to manage runoff volume and water quality at the source. For new development, LID uses a planning process to employ site design techniques to first optimize conservation of natural hydrologic functions to prevent runoff. If these conservation practices are insufficient to meet required stormwater goals then engineered at the source treatment practices are used to meet volume and water quality objectives.

LID's distributed techniques provide retention, detention and filtration of runoff in a manner that more closely mimics the natural water balance (interception, interflow, infiltration and evapotranspiration). This is accomplished through the cumulative effects of using an array of runoff reduction techniques, small scale nonstructural or engineered practices to treat runoff. Further the uniform distribution of controls throughout a site increases runoff time of travel and concentration dramatically reducing discharge flows and increasing opportunities for infiltration and filtration within landscape features.

With appropriate selection, application and design, LID principles and practices can be used in any land planning type, soils, climate or hydrologic regime. For example, in soils with high infiltration rates LID practices may heavily rely on infiltration. For high density urban or retrofit development infiltration may not be desirable or possible; therefore, filtration, detention and runoff capture-and-use practices would be more applicable. In cold climate filtration-infiltration practices must be designed to minimize freezing allowing treatment when needed. LID principles and practices are highly adaptable and can be customized for any development scenario or receiving water goal.

The creation of LID's wide array of small-scale management principles and practices has led to the development of new tools to retrofit existing urban development. Small-scale practices can be easily integrated into existing green space, streetscapes and parking lots as part of the redevelopment process or through routine maintenance and repair of urban infrastructure. As urban areas redeveloped with integrated LID techniques, over time it will be possible to dramatically reduce pollutant loads to receiving waters to restore impaired waters.

However, the use of LID practices does not necessarily supplant the need for end-of-pipe technology. Hybrid approaches, which incorporate both types of practices, may be needed to meet stringent water quality and flood control requirements. However, as LID's decentralized practices can better reduce adverse environmental impact, Connecticut regulatory agencies will typically expect permit applicants first carefully consider all opportunities to use such practices prior to exploring end-of-pipe management. The use LID techniques alone or in combination with conventional techniques will not only reduce adverse water quality impact, but will help to restore vital ecological processes necessary to restore or sustain the ecological integrity and quality of our water resources.

LID represents an alternative approach to controlling stormwater runoff that provides effective new tools to restore or maintain a watershed's hydrologic functions for both new and existing development. LID is still relatively new and rapidly evolving stormwater management technology. It was first described in 1999 in the Prince George's County, Maryland, *Low-Impact Development Design Strategies: An Integrated Design Approach*. However, today due to LID's many economic and environmental advantages over conventional end-of-pipe technology, it has been widely and rapidly adopted throughout the country. This LID design guidance has been developed using the latest information and past lessons learned to provide the most up to date design guidance.

LID practices are commonly used on reparations made to current structures that have caused issues with stormwater runoff and the resulting water quality. However, LID practices can also be considered during new building construction and implementation. LID uses many decentralized small-scale management practices strategically located throughout a development to conserve and engineer the urban landscape in a manner that mimics predevelopment hydrologic conditions. Ideally, these LID practices are seamless in the developed environment as all traditional site features are designed to be multifunctional. Residential, commercial, and industrial properties look the same but the landscape features are designed to provide water quality and hydrologic functions to storage, detain, filter, and infiltrate runoff. Typical advantages of LID's integrated approach over the conventional end-of-pipe approach include:

- Reduced consumption of land for stormwater management – LID practices provide opportunities to integrated controls into all aspects of a site's hardscape and landscape features. This allows multifunctional use of the entire developed site for controls allowing the most cost effective use of land. Less land is needed or consumed for end-of-pipe controls often allowing for more developable space.

- LID does not dictate particular land-use controls – Since LID is a technological approach there is no need to change conventional zoning or subdivision codes accept to allow LID's use. This means LID does not reduce development potential and with less land consumed for stormwater controls lot yields may increase.

- Reduced construction costs – Traditional stormwater management requires significant storm sewering and earthwork. LID practices apply controls as close to sources of runoff as possible. Wherever practicable, conveyances incorporate natural flow paths and swales instead of pipes. Structures installed are small, thus reducing the need for excavation and construction materials.

- Ease of maintenance – LID landscape practices require limited maintenance or no increase in maintenance beyond typical landscape care. Much of the maintenance required can be accomplished by the average landowner. Further many LID site planning, conservation, and grading techniques require no maintenance.

- Takes advantage of site hydrology – Conservation of natural resources, topography, land cover, soils, and drainage features preserve the natural hydrologic functions allowing absorption of runoff from impervious surfaces. Runoff that is absorbed recharges groundwater and stream base flow and does not need to be managed or controlled by an end-of-pipe practice. Preserving and maintaining the natural hydrology also better protects streambank stability and riparian habitat.

- Better quality of discharge – Recent research indicates conventional end-of-pipe controls are unable reduce pollutant concentrations below certain thresholds, which may exceed water quality standards. However, LID techniques have shown to be far more effective in reducing the annual pollutant loads through both volume reduction and filtration of runoff. Use of natural landscape features and use of lot-level bioretention and swales may, in many cases, allow for retention all runoff from events smaller than the 2-year, 24-hour storm and significantly reduce peak discharges from larger storms.

- More aesthetically pleasing development – Traditional stormwater management tends to incorporate the use of large, unnatural looking practices such as detention ponds. When neglected, these practices may present drowning and mosquito breeding hazards. Nonstructural and upland practices optimize use of landscape features that are more aesthetically pleasing and fit well into the natural landscape.

- Multiple benefits – LID has shown to provide multiple benefits such as reducing energy cost by using green roofs and proper location of trees for shading and water conservation by using rain water as a supplemental water supply.

- Improved profit margin – The advantages of nonstructural and upland management translate into the marketplace. The value added is significant. Several studies indicate that the cost of applying these nonstructural and upland stormwater management techniques is about half that of the traditional approach. The results of one example of such a study are summarized in *Table 1.1* below (Schuler, 2000). Properties developed using nonstructural and upland stormwater practices tend to command higher sale prices.

Table 1.1
Cost Analysis for Convention and Alternative Development

Cost Categories	Conventional Development	Alternative Development[a]
Engineering	$79,600	$39,800
Road Construction	(20,250 linear ft.) $1,012,500	(9,750 linear ft.) $487,500
Sewer and Water	$25,200	$13,200
Other Costs	$111,730	$54,050
Total	$1,229,030	$594,550

Source: Center for Watershed Protection, 2000, *The Practice of Watershed Protection*, page 175.
Notes:
[a]Alternative development cost analysis was done for cluster development, which is similar to conservation development.

2 LID Planning and Design Process

LID represents a new philosophy in stormwater management. Runoff is viewed as a resource and hydrology used as an organizing principle for site design. Learning how to work with rain water in the landscape rather than just quickly disposing of it. LID is an ecologically friendly approach to site development and stormwater management that aims not just to minimize development impacts (reduce impervious surfaces), but instead restore vital watershed ecological processes (natural hydrologic regime) necessary to restore and maintain the physical and biological integrity of waters and the quality of life.

LID uses new management principles such as conservation of soils and drainage patterns; using integrated decentralized controls; uniform distribution of lot-level controls to increase runoff storage, contact time and time of travel; and, multifunction landscape features engineered to make the most cost effective use of space. The landscape is comprehensively engineered and optimized for stormwater controls. All of these principles are in direct contrast to conventional end-of-pipe treatment. *Figure 2.1* and *Figure 2.2* contrasts conventional centralized controls with a LID decentralized approach.

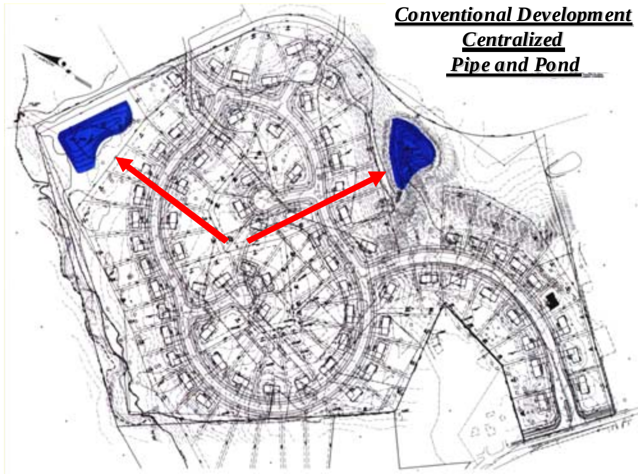

Figure 2.1 – Conventional Controls. A conventional approach requires clear cutting, mass grading and use impervious surfaces, gutters pipes and ponds to collect and treat runoff. This approach completely alters and destroys the natural hydrology and ability of the landscape to absorb rainwater and capture pollutants.

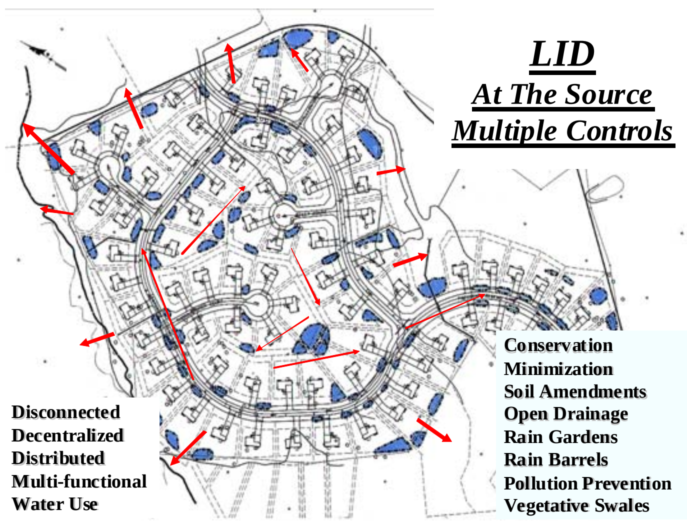

Figure 2.2 – LID Controls. A LID approach use a wide array of techniques that work with the landscape, soils, drainage patterns and vegetation to minimize impacts and integrated management controls to retain, detain, infiltrate and filter runoff. LID can provide better stormwater controls by mimicking the pre-development hydrology. Often LID designs increase lot yield and reduce infrastructure cost.

To optimize the benefits of LID, there is also a specific site planning and design process to follow. This process includes optimizing conservation at the larger project level; minimize impacts at site level, maintaining drainage features and use of engineered integrated management practices. The principles and design processes are explained in more detail below.

2.1 Basic Planning Principles

A well-designed integrated stormwater management system will minimize the volume of runoff generated and maximize the treatment capabilities of the landscape. A LID design controls runoff as close to the source as possible. A well-designed system should also be easy to maintain, not interfere with the typical use of the property, and be aesthetically pleasing. To optimize a LID design, it is important to consider a number of site planning principles and follow a systematic design processes from the very beginning. Each site has a unique set of characteristics and will require the use of a unique blend of site specific LID planning and treatment techniques. In considering the advantages and constraints of each site, four fundamental concepts should remain preeminent:

1. **Minimizing site disturbance**
   Undisturbed lands possess a natural capacity to store runoff waters. Development sites may include areas that are relatively sensitive to impact from construction (e.g., erosion) or may encompass particularly rare or valuable environmental features. Protecting susceptible natural features provides the multiple benefits of preserving important resources, reducing development impact and providing capacity for prevention of erosion.

   Generally, developers should inventory and map natural features such as surface waters, vegetated wetlands and highly erodible soils, for preservation early in the site planning process. This helps to define a practicable development envelope. Preserved areas must be protected throughout construction and demarcated for conservation in land records.

2. **Working with site hydrology**
   Traditional erosion prevention seeks to eliminate the annoyance and hazard of runoff by rapidly conveying it away from development—typically, via closed drainage systems such as storm sewers. This approach works efficiently to remove water from streets and sidewalks, but it expends significant capital for constructed systems that interrupt the recharge of groundwater resources. By contrast, LID techniques work to reduce stormwater generation or retain it in the upland where it can percolate naturally into the soil and replenish groundwater resources.

3. **Minimizing and disconnecting impervious surface**
   Runoff comes primarily from impervious surface, such rooftops, roadways or any smooth hard surface that prevents water from absorbing into the ground. Traditional developments tend to include superfluous impervious surface, which may be minimized with thoughtful site planning. Techniques to limit impervious area include reducing road widths and lengths as well as the area of rooftops (e.g., preference for multi-story over single-story buildings).

   To the extent possible, developers should promote contact between runoff and pervious land surface. Technically, this is done by increasing time of concentration—length of time required for runoff to concentrate and flow off site—and by reducing the runoff curve number.

4. **Applying small-scale controls at the source**
   Small-scale practices applied at the source—or as close as practicable—can offer significant advantages over conventional, engineered facilities such as ponds or concrete conveyances. They can decrease the use of typical engineering materials such as steel and concrete. By using materials such as native plants, soil and gravel these systems can be more easily integrated into the landscape and appear to be much more natural than

engineered systems. The natural characteristics may also increase homeowner acceptance and willingness to adopt and maintain such systems. Small, distributed systems also offer a major technical advantage—one or more of the systems can fail without undermining the overall integrity of the site control strategy.

Small-scale practices reduce safety concerns as they feature shallow basin depths and gentle side slopes. The integration of these facilities into the landscape throughout the site offers more opportunities to mimic the natural hydrologic functions and add aesthetic value. The adoption of these landscape features by the general public and individual property owners can result in significant maintenance and upkeep savings to the homeowners association, municipality or other management entity.

Another important factor in LID design is that it is best applied by a multidisciplinary team of professionals. The contributions of soils scientist, biologist, landscape architects, urban planners, and engineers are all equally important. It is not just about meeting the volume storage and flow regulatory requirements, it is about professionals using their combined knowledge and skills to create and design the most ecologically functional, economically viable, aesthetically pleasing livable community possible.

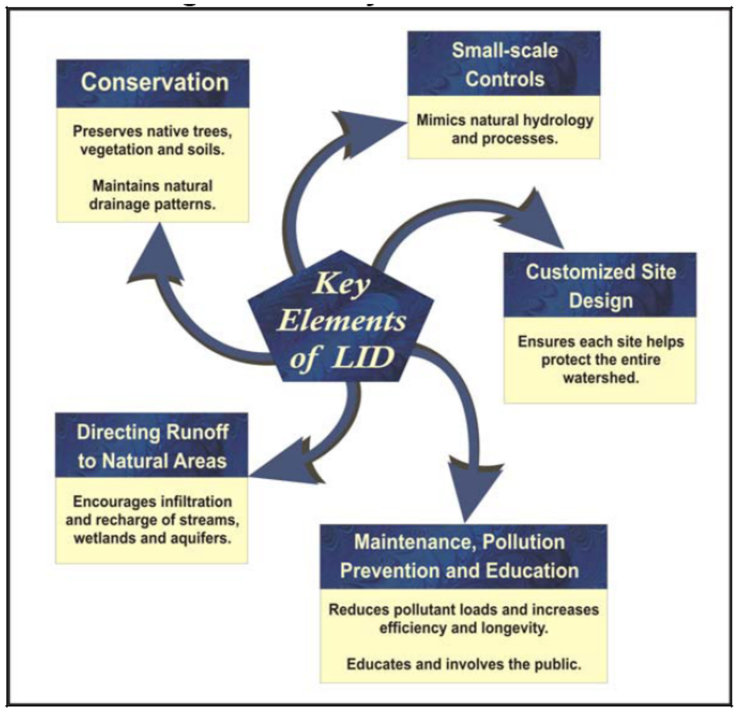

Figure 2.3 – Key elements of LID.

Several basic LID planning principles should remain in the forefront throughout the various steps of the site planning and design process. These principles require a completely different way of thinking about site design than current convention.

For example, an important LID concept is to keep water on the site as long as possible using the landscape to treat runoff, but without causing flooding problems or interfering with the typical use of the property. This is in contrast to the current practice of grading a site to quickly move water away from buildings and roadways. Until LID designs become the normal way of doing business a good design will require more time and creativity to manage runoff within the landscape effectively.

Basic LID principles include:

1. <u>Optimize conservation</u> – Save natural resource areas, vegetation and soils and wisely use them to reduce and treat runoff to maintain the site's ability to retain and detain runoff.

2. <u>Mimic the natural water balance</u> – To the extent possible continue to store detain and infiltrate water in the manner and rate as predevelopment. This requires careful evaluation of site soils in order to save sandy soils and use these areas as part of the LID

control strategy. Conserving natural drainage features and topography will help to maintain the natural frequency of discharges.

3. Disconnect Impervious Surfaces – Always disconnect impervious surfaces. The site's runoff characteristics are completely changed when impervious surfaces drain to landscape features or engineered LID practices. This approach prevents the adverse cumulative effects of collecting and concentrating flows and helps to reduce erosion problems.

4. Decentralize and Distribute Controls – The more LID techniques used and the more uniformly distributed throughout the landscape the more effective LID becomes. Increasing runoff time of travel significantly reduces flows and discharge frequencies. Increasing storage features decreases runoff volume and reduces annual pollutant loads. Utilizing all landscape features for filtration increases its capacity to capture and cycle pollutants.

5. Multifunctional/Multipurpose Landscapes – Every aspect of the urban landscape can be design to either reduce or restore hydrologic functions. Every landscape feature should be optimized to provide beneficial hydrologic and water quality functions by preventing, storing, retaining, detaining, and treating runoff.

6. Cumulative Impacts of Multiple Systems – LID relies on cumulative beneficial impacts of an array of LID planning and design principles and various treatment practices. As more LID techniques are used to store or detain runoff, the developed site also more closely replicates the natural hydrologic regime. One interesting aspect of LID--because so many techniques are used, failure of a few practices does not significantly compromise management objectives. Contrast this with using one large stormwater pond—if that one big pond fails, the entire system fails.

7. Prevention, Outreach and Education – All efforts should be made to reduce the introduction of pollutants into the environment. Therefore, a good LID program or project also includes effective public education and outreach to help ensure proper use, handling, disposal of pollutants, and maintenance of LID practices.

The first three of these principles lend themselves to development of specific design standards and are used in *Section 4* of this guidance to organized LID practices.

2.2 Site Planning and Design Process

The LID approach emphasizes the use of site design and planning techniques to conserve natural systems and hydrologic functions. LID is also a highly engineered design and management strategy, which integrates practices throughout a development.

The simplest and least costly LID technique is good site planning; and an important goal of LID is to mimic the predevelopment hydrology to the extent practicable. To accomplish this, LID projects require a thorough understanding of the site's soils, drainage patterns, and natural features.

Developers should use natural features, hydrology and soils as a design element. In order to minimize the runoff potential an understanding of site drainage patterns and soils can suggest locations both for green areas and potential building sites. Integration of natural features into the site design creates a more ecologically functional site and a more aesthetically pleasing landscape that will be a vital functioning part of the ecosystem. Outlined below is the basic LID site process.

2.2.1 Step 1 – Define Basic Project Objectives and Goals

Identifying the project objectives not only includes identifying regulatory needs, but also ecological needs. Ecological needs include these fundamental aspects:

- Runoff volume to match predevelopment.
- Peak runoff rate to meet regulatory needs.
- Flow frequency and duration to match redevelopment.
- Water quality to meet regulatory requirements.
- Stream or wetland base flow needs.
- Recharge areas.
- Natural resource conservation requirements.

To ensure ecological needs receive appropriate attention, the developer should prioritize and rank objectives and determine the type controls required to meet objectives such as infiltration, filtration, discharge frequency, volume of discharges and groundwater recharge. Determine the feasibility for type and proper location of LID controls to best address volume, flows, discharge frequency, discharge duration and water quality.

2.2.2 Step 2 – Site Evaluation and Analysis

A site evaluation will facilitate design by providing details that will help to customizing LID techniques for the sites unique constraints, regulatory requirements and receiving water goals.

1. Conduct a detailed investigation of the site using available documents such as drainage maps, utilities information, soils maps, land use plans, and aerial photographs.

2. Evaluate site constraints such as available space, soil infiltration characteristics, water table, slope, rock outcrop, drainage patterns, sunlight and shade, wind, critical habitat, existing buildings, infill opportunities, circulation and underground utilities.

3. Identify protected areas, setbacks, easements, topographic features, sub drainage divides, and other site features that should be protected such as floodplains, steep slopes, and wetlands.

4. Delineate the watershed and micro-watershed areas. Take into account previously modified drainage patterns, roads, infill opportunities, and stormwater conveyance systems.

Many other unique site features may influence the site design including historical features, view sheds, climatic factors, energy conservation, noise, watershed goals, onsite wastewater disposal and off-site flows. All of these factors help to define the development area and natural features to be integrated into the LID design.

2.2.3 Step 3 – Optimize Conservation of Natural Features at the Larger Watershed Scale

LID does not promote the use of any particular style site development such as traditional neighborhood design, conventional grid patterns, cluster development, conservation design or new urbanism. Regardless of the development style, LID techniques can always be used throughout the site. The examples to the right (*Figure 2.4*) demonstrate integration of resource conservation into a conventional design. Natural features are saved to reduce impacts and allow for greater use of natural features to treat runoff. Conserving natural features not only reduces impacts but preserves habitat and natural ecological processes to be used for stormwater controls.

The most successful LID design begins with understanding of the site's natural resources and how best to save these features and incorporate them into the stormwater management system. To the extent practicable and in accordance with current regulations, natural features (wetlands, trees/vegetation, good soils) should be conserved and integrated into the overall site plan. The conservation features should continue to be used by directing runoff to the natural features in the same manner as the predevelopment conditions. The greater use of natural features generally means reduction of clearing and grading and lower cost.

Locating infrastructure to direct runoff to buffers, vegetative filters, existing drainage features will help to reduce runoff quantity and improve water quality. This approach reduces disturbance of the natural soils and vegetation allowing more areas for infiltration and runoff contact with the landscape. To optimize the use of green space requires an ability to lay out the site infrastructure in a way that allows saving sensitive the natural features and their functions. The basic strategy is shown in *Figure 2.4*.

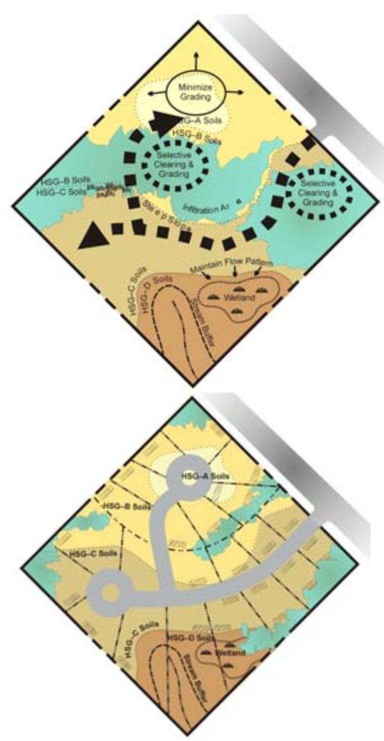

Figure 2.4 – Optimizing the use of green space.

There are many techniques that should be considered including:

- Minimizing and properly stage grading and clearing for roadways and building pads as only necessary.
- Locating, saving and utilizing pervious soils.
- Locating treatment practices in pervious hydrologic soil groups A and B.
- *Where feasible*, constructing impervious surfaces on less pervious hydrologic soils groups C and D.
- Disconnecting impervious surfaces by draining them to natural features.
- Flattening slopes where possible.
- Re-vegetating cleared and graded areas.
- Utilizing existing drainage patterns.
- Routing flow over longer distances.
- Using overland sheet flow.
- Maximizing runoff storage in natural depressions.

2.2.4 Step 4 – Minimize Impacts at the Lot Level

To the extent practicable, conserve trees, natural drainage patterns, pervious soils and depressions at the lot level. This often means less clearing and grading. *Figure 2.5* contrasts the conventional approach of draining runoff to the streets vs. a LID design using site fingerprinting where runoff is directed to the natural features.

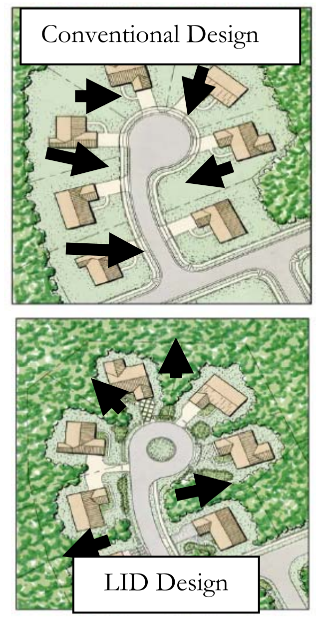

Figure 2.5 – Contrasting runoff patterns in conventional and LID design.

The key to preventing excessive runoff from being generated is slow down velocities by directing it toward areas where it can be absorbed. The reliance on many small measures used throughout the site will serve this purpose better than a single large control measure.

There are many lot level techniques that should be considered including:

Figure 2.6 – Lot level techniques.

- Avoiding installation of roof drains.
- Directing flows to vegetated areas.
- Directing flows from paved areas to stabilized vegetated areas.
- Breaking up flow directions from large paved surfaces.
- Encouraging sheet flow through vegetated areas.
- Locating impervious areas so that they drain to permeable areas.
- Maximizing overland sheet flow.
- Lengthening flow paths and increase the number of flow paths.
- Maximizing use of open swale systems.

- Increasing (or augmenting) the amount of vegetation on the site.
- Using site fingerprinting. Restricting ground disturbance to the smallest possible area.
- Reducing paving.
- Reducing compaction or disturbance of highly permeable soils.
- Avoiding removal of existing trees.
- Reducing the use of turf and use more natural land cover.
- Maintaining existing topography and drainage divides.
- Locating structures, roadways on Type C soils *where feasible*.[1]

Various lot level techniques are illustrated in *Figure 2.6*.

3 Use of Integrated Management Practices in Various Settings

IMPs are those techniques used to treat additional runoff volume needed to meet regulatory needs or receiving water goals that were not obtained during the site planning process. These practices create additional volume storage, detention and filtration opportunities to increase the treatment capacity of the landscape.

IMPs can be applied in a variety of settings. The remainder of this section focuses on the use of IMPs in several specialized settings:

- Low- to medium-density residential settings.
- Commercial, industrial and high-density residential settings.
- Roadways.
- Retrofits and redevelopment.

3.1 Integrated Management Practices in a Residential Setting

In addition to the many possible site planning techniques used, additional treatment can be provided using the following engineered practices listed below. *Figure 3.1* provides a schematic example of a combination of practices. Some potential applications of IMPs are discussed below.

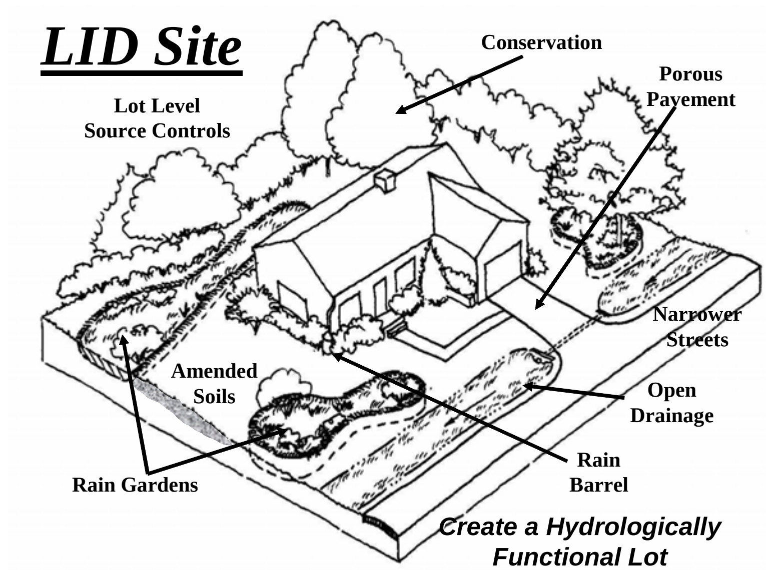

Figure 3.1 – Schematic of engineered practices.

- Bioretention or Rain Gardens – Vegetated depressions that collect

[1] Because Type C and D soils tend to be poorly suited to construction, site structures on them may be ineffective from a cost-benefit standpoint or technically impractical.

runoff and either filter before discharge or infiltrate it into the ground.

- Dry Wells – Gravel- or stone-filled pits that are located to catch water from roof downspouts or paved areas.
- Filter Strips – Bands of dense vegetation planted immediately downstream of a runoff source designed to filter runoff before entering a receiving structure or water body.
- Grass Swales – Shallow channels lined with grass and used to convey and store runoff.
- Infiltration Trenches – Trenches filled with porous media such as bioretention material, sand, or aggregate that collect runoff and exfiltrate it into the ground.
- Permeable Pavement – Asphalt or concrete rendered porous by the aggregate structure.
- Permeable Pavers – Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath.
- Rain Barrels and Cisterns – Containers of various sizes that store the runoff delivered through building downspouts. Rain barrels are generally smaller structures, located above ground. Cisterns are larger, are often buried underground, and may be connected to the building's plumbing or irrigation system.
- Soil amendments – Minerals and organic material added to soil to increase its capacity for infiltration, absorbing moisture and sustaining vegetation.
- Planter box filters – Curbside containers placed below grade, covered with a grate, filled with filter media and planted with a tree in the center.
- Vegetated Buffers – Natural or man-made vegetated areas adjacent to a waterbody, providing erosion control, filtering capability, and habitat.
- On-lot tree-save areas – Runoff can be directed to existing on-lot tree conservation areas to encourage stormwater retention.
- Small detention features – For example driveway culverts can be undersized to detain flow and encourage stormwater retention.
- Infiltration Swales – Swales designed with infiltration trenches.

3.2 Integrated Management Practices for High Density Industrial, Commercial and Residential Development

It is relatively easy to understand how LID principals and practices can be applied to single family residential development where there is ample space. High density development seems much more challenging with little green space available for LID practices. However, there is little difference in the application of LID site design principles nor the use of small scale engineered practices for volume and water quality control. The only difference is LID practices must be designed to accommodate building architecture, sidewalks, parking lots, streets and landscaping.

It is still important to optimize the conservation and use of natural resources and soils on the larger project level and where feasible minimize impacts internal to the site.

The examples shown in *Figure 3.2* provide general LID design strategies for office buildings, small commercial buildings and big box sites. These site designs include a variety of techniques.

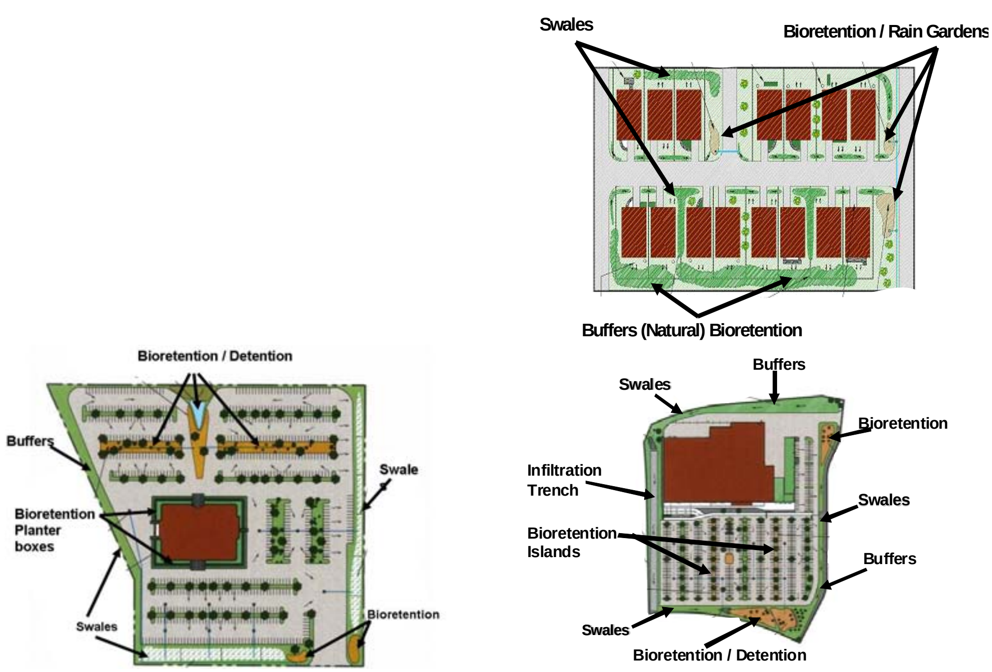

Figure 3.2 – LID design strategies for office buildings, small commercial buildings, and big box sites.

Typical LID techniques used for high-density developments include: perimeter buffers, swales and bioretention systems; parking lot bioretention/detention islands, planter boxes, green roofs, porous pavers/pavement and infiltration devices and underground storage. Runoff can be stored for use or controlled under buildings, parking lots and sidewalks using porous pavers and volume storage devices.

LID techniques can be integrated throughout the available green space using a range of bioretention techniques such as planter boxes, swales and street trees. In addition to the LID techniques previously listed, other engineered practices for high density development are included below. *Figure 3.3* provides a schematic example.

- Planter Boxes – Bioretention systems within containers designed for filtration and or infiltration.

- Green Roofs – Vegetated roofs designed for retention / detention storage and, filtration.

- Underground Storage – Use of cisterns, pipes, vaults or other storage devices for retention or detention storage.

- Porous Pavers and Surfaces – Porous surfaces design in combination gravel storage or other.

- Manufactured Devices – Numerous commercial devices are available for filtration, screening, storage and treatment that can be integrated in the high density development.

- Building Architecture – Buildings can be designed to capture hold and use more runoff with, cisterns, planter boxes and wall planting systems.

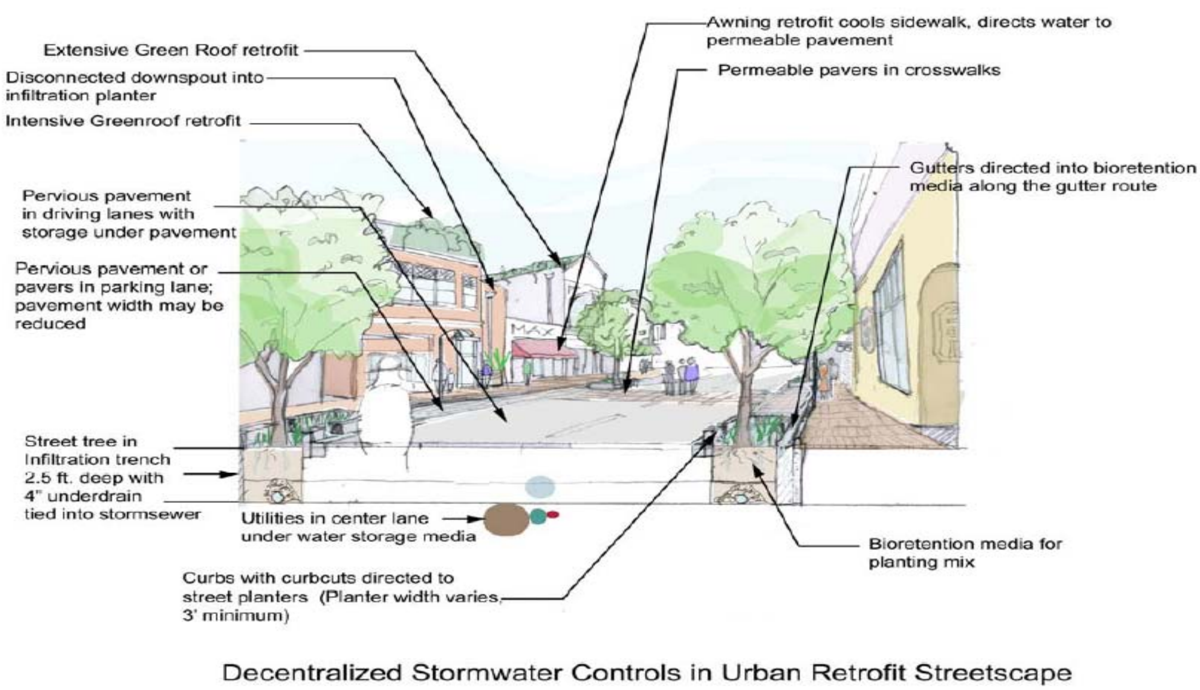

Figure 3.3 – Schematic example of engineered practices in an urban retrofit streetscape.

3.3 LID Roadway Designs

Roadways generate a major portion of runoff in urban areas and present significant engineering challenges in developing effective LID roadway controls. Despite the challenges there are effective LID design principles and engineering practices available for any roadway system to meet water quality objectives. However, use of some techniques may require modification roadway design standards. Further, in highly urbanized development, site constraints (limited space, poor soils and utility conflicts) often require more extensive engineering and use of more expensive structural LID practices.

A LID roadway design does not require reduction of impervious surface but rather optimizing the integration of LID practices by engineering the roadway itself or the surrounding landscape/streetscape to provide storage, detention or filtration as applicable. Reduction of the roadway surfaces is most useful in creating additional space for the use LID practices. Consider opportunities to hydrologically disconnect roadway surfaces by directing runoff to LID practices for storage, detention or infiltration.

3.3.1 Open Section Roadways

Open section roadways consist of a variable-width gravel or grass shoulder, usually wide enough to accommodate a parked car, and an adjoining grassed swale that conveys and treats runoff. When feasible, reducing road width provides greater opportunities to increase the width of grass shoulders and swales for treatment.

Street pavements width should be adjusted accordingly depending on off-street parking availability and shoulder requirements. Where feasible preserve existing vegetation and drainage features adjacent to the shoulder or swale. Also consider placing utilities under street pavements to eliminate conflicts with tree roots, grassed swales, and bioretention areas.

A primary goal of LID is to work with landscape hydrology and make it more functional (i.e., to use the surrounding landscape to absorb and filter water). *Figure 3.4* shows a 60-foot roadway design with sidewalks on both sides. The important LID feature is the use of wider more functional swales for treatment and control. Notice that the swales are located between the road surface and sidewalks providing greater protection to pedestrians.

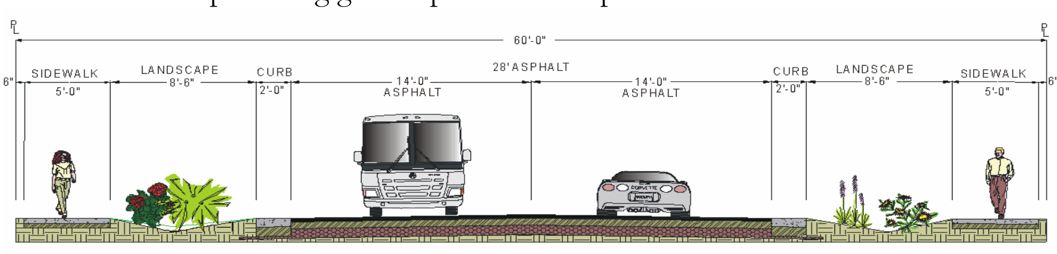

Figure 3.4 – Open section roadways.

The figure below (*Figure 3.5*) shows a narrow road section with sidewalks, shallow swale and porous pavement shoulders. The paver blocks provide a rough surface to alert drives if their tires leave the road surface. The pavers also protect the edge of the asphalt surface from breaking off. Generally, very shallow and broad swales are preferred as they provide more surface area to treat and absorb runoff. Swale performance can be greatly enhanced when you can take advantage of infiltration.

Figure 3.5 - Narrow low-volume road section with sidewalks, shallow swale and porous pavement shoulders.

The figure below (*Figure 3.6*) shows an example of how to design a swale to enhance its ability to filter and infiltrate runoff. In this case several features have been incorporated into the design including using the culvert as a weir for detention control; check dams to increase ponding time and decrease velocities; trench drain along the bottom of the swale to encourage infiltration and increase runoff storage in the engineered soil. Road water quality treatment swales should be designed to be shallow with under drains if possible to encourage good drainage and discourage standing water and associated nuisance problems.

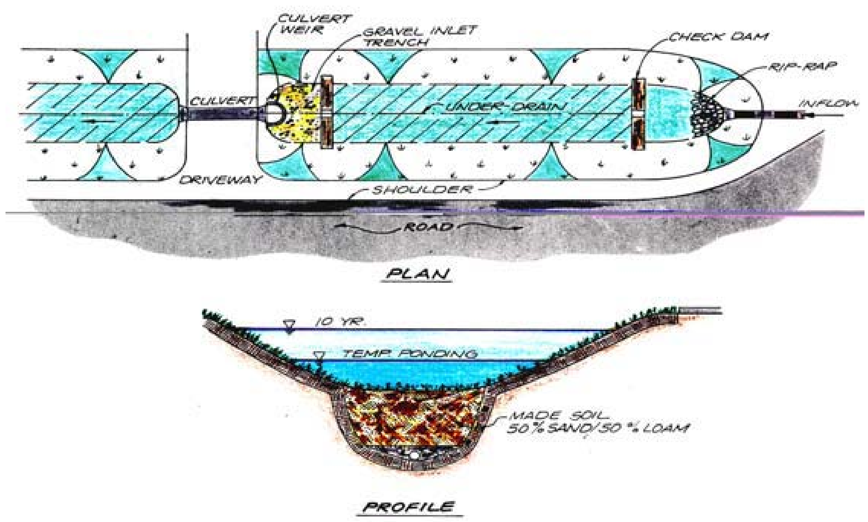

Figure 3.6 - Swale design to enhance its ability to filter and infiltrate runoff.

When it is possible to use narrower roadways the table below (*Table 3.2*) provides suggested general guidance. Even a narrow street width of 22 feet can still accommodate parking on one side of the roadway and leave ample room for a safe travel lane that is generous enough to accommodate most fire trucks, school buses, and garbage trucks.

Table 3.2
General Guidance for Narrower Roadways

Local Streets	
No On-Street Parking	18 feet
Parking on One Side	22 feet
Parking on Both Sides	28 feet

Adapted from *Designing Walkable Urban Thoroughfares (ITE, 2010).*

Local Streets are intended to provide access to individual lots. They should provide low-speed bicycle and vehicle routes and while accommodating pedestrians. In comparison to other types of streets, local streets should generally be short in total distance.

In residential areas, "yield" local streets provide the preferred cross-section to encourage equal priority among all users. These streets are characterized by a relatively narrow unstriped travelway shared by all vehicles, and also have comfortable pedestrian facilities. "Narrow" local streets may be used where most parking is handled off-street. This is typical in a traditional neighborhood design (TND) context. Where on-street parking is expected to be more heavily used, yield streets may not be appropriate.

Each local street type should feature a 14-foot minimum clear travel path so as to appropriately accommodate emergency vehicles.

3.3.2 CUL-DE-SAC Designs

Homebuyers often prefer cul-de-sac properties for many reasons, and thus cul-de-sacs have become quite common. Depending on a subdivision's lot size and street frontage requirements, five to ten houses can usually be located around a standard cul-de-sac perimeter. The bulb shape allows vehicles up to a certain turning radius to navigate the circle. To allow emergency vehicles to turn around, cul-de-sac radii can vary from as narrow as 30 feet to upwards of 60 feet, with right-of-way widths usually extending ten feet beyond these lengths. *Figure 3.7* shows an open section roadway with on lot bioretention and a cul-de-sac with a bioretention area in the center for roadway runoff.

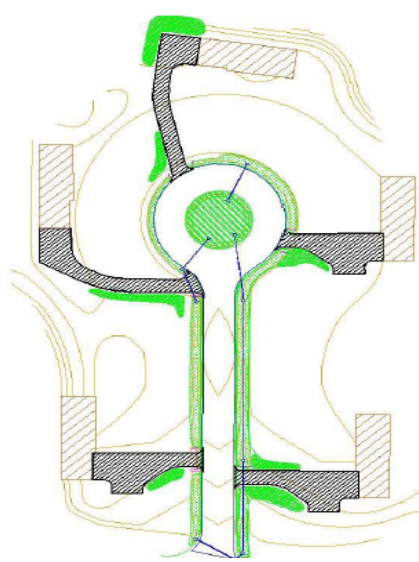

Figure 3.7 – Cul-de-sac designs.

3.3.3 Divided Highways

The wider right-of-ways of divided highways provide many opportunities for LID practices on the shoulders and in the median. *Figure 3.8* and *Figure 3.9* provides examples of these options.

Figure 3.8 – Examples of center median infiltration/filtration systems

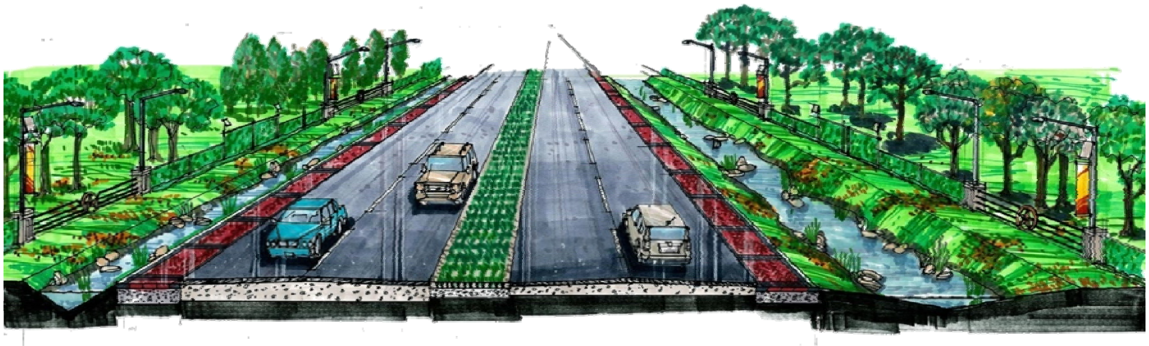

Figure 3.9 - Shoulder Treatment Systems using detention and filtration design.

3.3.4 Highly Urbanized LID Street Design

Below are two examples of planter box designs in high density development (*Figure 3.10*). The image on the left is a slow flow system that requires very large surface areas to treat the water quality volume. The image on the right is a very high flow media system that has an extremely small foot print saving space reducing overall construction and maintenance costs. However, both provide the same water quality treatment benefits. Both systems can be designed with underground storage for detention infiltration or retention to be used for irrigation. There are many devices that can be used for underground storage ranging from metal, plastic or concrete pipes to a variety of plastic prefabricated storage devices.

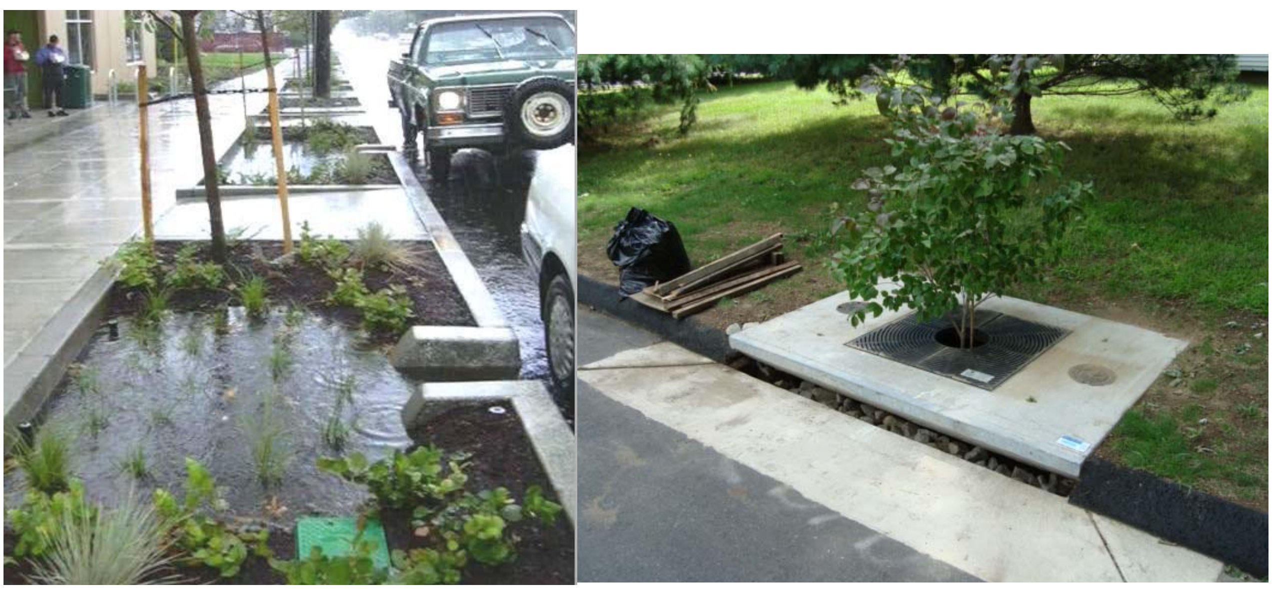

Figure 3.10 – Examples of planter box designs in high density development in Connecticut.

3.3.5 Porous Surfaces

Porous pavers, asphalt and concrete are all other design options to provide a hard surface suitable for roadways that allow runoff to percolate into underground gravel beds or other storage devices for detention or infiltration. An example is provided below as *Figure 3.11*. To reduce the cost these surfaces they should not be placed over the entire roadway but rather strategically placed and sized to allow sufficient runoff volume to enter the underlying storage device.

Figure 3.11 – Porous surfaces

.

3.3.6 Other LID Roadway Design Considerations

- Maximize natural drainage – when planning streets, consider preserving natural drainage patterns and soil permeability by preserve natural drainage patterns and avoid locating streets in low areas or highly permeable soils.

- Uncurbed roads – where feasible, build uncurbed roads using vegetated swales as an alternative.

- Urban curb/swale system – runoff runs along a curb and enters a surface swale via a curb cut, instead of entering a catch basin to the storm drain system.

- Dual drainage system – a pair of catch basins with the first sized to capture the water quality volume into a swale while the second collects the overflow into a storm drain.

- Concave medians – median is depressed below the adjacent pavement and designed to receive runoff by curb inlets or sheet flow. Can be designed as a landscaped swale or a biofilter.

- Street Length – Reduce the length of residential streets by reviewing minimum lot widths and exploring alternative street layouts.

- Access – Consider access for large vehicles, equipment, and emergency vehicles when designing alternative street layouts and widths.

- Right-of-way – should reflect the minimum required to accommodate the travel lane, parking, sidewalk, and vegetation, if present.

- Permeable materials – use in alleys and on-street parking, particularly pull out areas.

3.4 Urban Retrofit and Redevelopment

The poor state of our surface waters is the direct result of increased runoff volume and pollution loads from existing development. If impaired receiving waters are to be restored the impacts from existing development must be addressed. LID practices allow for retrofit of developed areas by integrating small-scale management techniques into the urban landscape (roads, sidewalks, parking areas, buildings, etc.). In most cases existing landscape features can simply be converted into bioretention systems for filtration, detention and infiltration. In more difficult cases storage can be provided under sidewalks and parking lots or on rooftops.

The most economical way to retrofit existing development is to ensure that all infill development, redevelopment and reconstruction projects include the LID practices. Over time as urban areas are redeveloped and rebuilt with LID practices much of the urban runoff can be treated greatly reducing water quality impacts and reducing flooding potential. The City of Portland, OR has evaluated such an urban retrofit program and has found over a 50-year period much of the City's runoff can be controlled and treated by green roofs and bioretention streetscape systems for roadway and parking lot runoff.

When selecting the most appropriate retrofit techniques it is important to select LID practices that can best address receiving water quality and volume needs. For example, where receiving waters are impaired by heavy metals or bacteria bioretention filtration and/or infiltration techniques would be most appropriate. Where volume control is necessary for detention porous surfaces or filtration devices in combination with underground storage detention and/or infiltration practices are best.

3.4.1 Retrofit Case Studies

Retrofit and redevelopment projects utilizing LID techniques have been implemented throughout the country in recent years. Multiple projects have occurred in Connecticut. For example, a traffic control project calling for access management adjacent to North Main Street in the City of Bridgeport, CT, incorporated rain gardens/bioretention and permeable pavement into project design. Specifically, North Main Street was narrowed and permeable pavement was installed alongside portions of the roadway to accommodate vehicular parking and treat storm water runoff. Additionally, series of rain gardens were installed along the sidewalk to receive and treat storm water runoff. Photographs of the LID techniques implemented along Main Street are provided as *Figure 3.12*.

Figure 3.12 – Permeable pavement (left photograph) and rain garden/bioretention (right photograph) retrofits along North Main Street in Bridgeport, CT.

Another example of green infrastructure retrofit project is the Hartford Green Capitols project. This project focused on Connecticut's capitol building in Harford, CT and included installation of porous pavement, green roofs, and rain gardens, as well as rain harvesting techniques. Such techniques served to mprove water quality and educate state residents about green infrastructure. Photographs of the LID techniques implemented as part of the Hartford Green Capitols Project are provided as *Figures 3.13-3.15*.

Figure 3.13 – Bioretention retrofit.

Figure 3.14 – Construction of a rain garden at Hartford Green Capitols Project. Source: Camp Dresser & McKee.

Figure 3.15 – Permeable pavement at Hartford Green Capitols Project. Source: Camp Dresser & McKee.

Additional examples of techniques used in Connecticut for both retrofit and redevelopment projects are provided as *Figure 3.16*.

Bioretention area at University of Connecticut Storrs Campus.

Roads are narrowed and permeable pavement is installed along roadways to provide additional parking and treat runoff.

Figure 3.16 – Retrofit and redevelopment techniques in Connecticut. Source: Connecticut Department of Environmental Protection.

4 Design Standards for Low Impact Development Controls

This section discusses design standards for LID controls. It provides a general description of each control, its advantages, general use, and standards for its application. These standards are intended to elaborate on the narrative description of LID best management practices provided in chapter 4 of the *Connecticut Stormwater Quality Manual*.

- Approaches that Optimize Conservation
  - Limits of Clearing and Grading
  - Preserving Natural Areas
  - Avoid Disturbing Long, Steep Slopes
  - Minimize Siting on Porous and Erodible Soils
- Approaches that Mimic Natural Water Balance
- Approaches that Minimize and Disconnect Impervious Surface
  - Roadways
  - Buildings
  - Parking Footprints
  - Parking Lot Islands
  - Permeable Pavement
  - Disconnecting Impervious Area
- Integrated Management Practices at the Source
  - Vegetated Filter Strips
  - Natural Drainage Ways
  - Green Roofs and Façade
  - Rain Barrels and Cisterns
  - Dry Wells
  - Bioretention and Rain Gardens
  - Infiltration

4.1 Approaches that Optimize Conservation

4.1.1 Limits of Clearing and Grading

Perhaps the most potentially destructive stage in land development is the preparation of a site for building—clearing of vegetation and soil grading (Schueler, 1995). The limits of clearing and grading refer to the part of the site where development will occur. This includes all impervious areas such as roads, sidewalks, rooftops, as well as areas such as lawn and open drainage systems.

To minimize impacts, the area of development should be located in the least sensitive areas available. At a minimum, developers should avoid streams, floodplains, wetlands, and steep slopes. Where practicable, developers should also avoid soils with high infiltration rates as these will aid in reducing runoff volumes.

Advantages

- Preserves more undisturbed natural areas on a development site.
- Uses techniques to help protect natural conservation areas and other site features.
- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- May reduce landscaping costs.

Use

Establishing a limit of disturbance based on maximum disturbance zone radii/lengths. These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as slopes or soils. Limits of disturbance may vary by type of development, size of lot or site, and by the specific development feature involved.

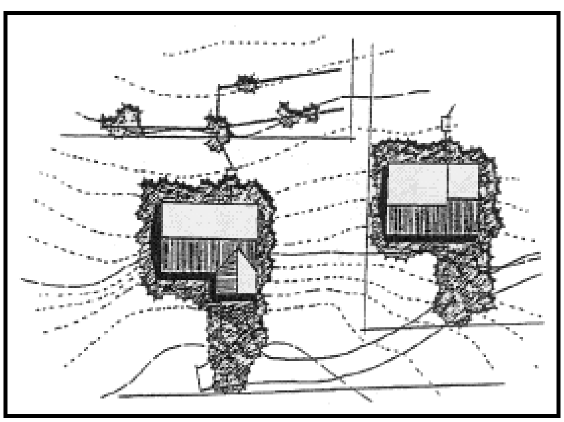

Figure 4.1 - Reduced limits of disturbance minimize water quality impacts. Source: Atlanta Regional Commission, 2001.

Standards

Generally speaking, limits of disturbance need not comprise more than:

a) Area of the building pad and utilities (e.g., onsite wastewater treatment systems and wells) plus 25 feet.
b) Area of a roadbed and shoulder plus 9 feet. (This is not intended to limit lawn areas.)

4.1.2 Preserving Natural Areas

Natural areas include woodlands, riparian corridors, areas contiguous to wetlands and other hydrologically sensitive and naturally vegetated areas. To the extent practicable these areas should be preserved.

Natural areas can be one of the most important components within a development scheme, not only from a stormwater management perspective, but in reducing noise pollution and providing valuable wildlife habitat and scenic values. New development tends to fragment large tracts of undisturbed areas and displace plant and animal species; therefore it is essential to maintain these buffers in order to minimize impacts. Areas adjacent to waterbodies (both freshwater and coastal) are protected under state law and cannot be altered without a state agency permit.

Advantages

- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Reduces safety and property-damage risks where flood hazard areas are incorporated into preservation.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- Establishes and maintains open space corridors.

Use

a) Check all federal, state and local enforceable policy to ensure proper setbacks and identification of preservation areas. Identify areas for preservation through site analysis using maps and aerial or satellite photography or by conducting a site visit.
b) Delineate areas for preservation via limits of disturbance before any clearing or construction begins and should be used to set the development envelope as well as guide site layout. Clearly mark areas for preservation on all construction and grading plans to ensure that equipment is kept out of these areas and that native vegetation is kept in an undisturbed state.
c) Protect preservation areas in perpetuity by legally enforceable deed restrictions, conservation easements and maintenance agreements.

Figure 4.2 shows a site map with undisturbed natural areas delineated.

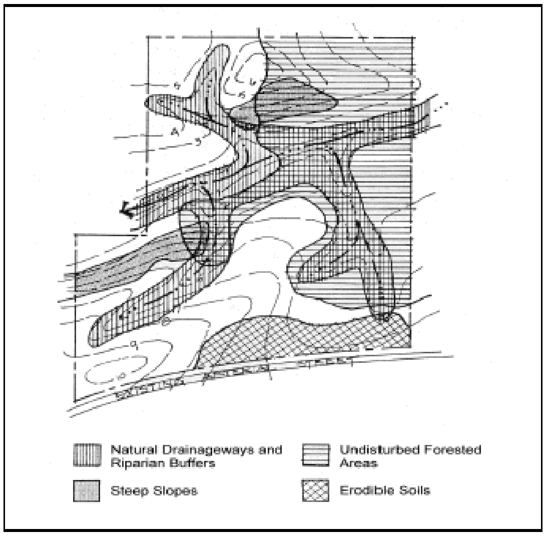

Figure 4.2 – Site map with natural areas delineated. Source: Atlanta Regional Commission, 2001.

Special Considerations

Riparian Buffers

A riparian buffer is a special type of preserved area along a watercourse where development is restricted or prohibited. Buffers protect and physically separate a watercourse from development. Riparian buffers also provide stormwater control flood storage and habitat values. An example of a riparian buffer is shown in *Figure 4.3*. Wherever possible, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and freshwater wetlands.

Figure 4.3 – Riparian buffer along the French River, in Thompson, CT. Source: Connecticut Department of Environmental Protection.

Riparian buffers consist of three zones (see *Figure 4.4*):

- The inner zone consists of the jurisdictional riverbank wetland and should be sized accordingly. In addition to runoff protection, this zone provides bank stabilization as well as shading and protection for the stream. This zone should also include wetlands and any critical habitats, and its width should be adjusted accordingly. Permits should be sought for activities in the inner zone. Generally speaking, structural best management practices (BMPs) are not allowed in the inner zone.

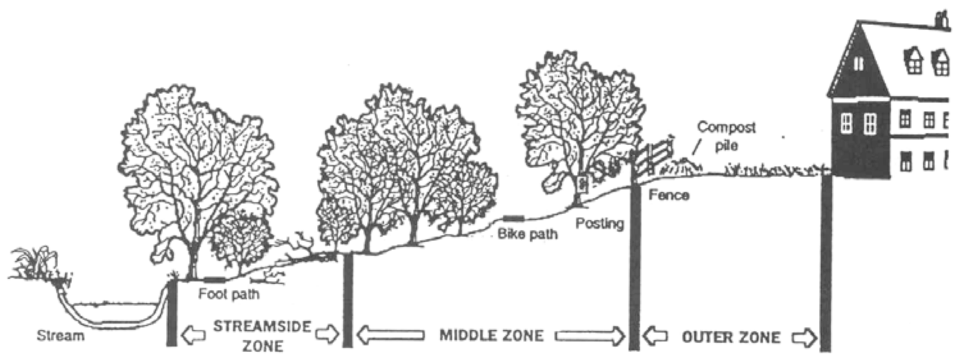

Figure 4.4 – Three-zone riparian buffer. Source: Atlanta Regional Commission, 2001.

- The middle zone provides a transition between upland development and the inner zone and should consist of managed woodland that allows for infiltration and filtration of runoff. A 25-foot width is recommended for this zone at a minimum. Forested riparian buffers should be maintained and reforestation should be encouraged where no wooded buffer exists. Proper restoration should include all layers of the forest plant community, including understory, shrubs and groundcover, not just trees.

- An outer zone allows more clearing and acts as a further setback for impervious surfaces. It also functions to prevent encroachment and filter runoff. A 25-foot width is recommended for this zone.

Ideally, all three zones of the riparian buffer should remain in their natural state. However, some maintenance is periodically necessary, such as planting to minimize concentrated flow, the removal of exotic plant species when these species are detrimental to the vegetated buffer and the removal of diseased or damaged trees.

Floodplains

Floodplains are the low-lying flatlands that border streams and rivers. When a stream reaches its capacity and overflows its channel after storm events, the floodplain provides for storage and conveyance of these excess flows. In their natural state they reduce flood velocities and peak flow rates by the passage of flows through dense vegetation. Floodplains also play an important role in reducing sedimentation and filtering runoff, and provide habitat for both aquatic and terrestrial life. Development in floodplain areas can reduce the ability of the floodplain to convey stormwater, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties.

As such, floodplain areas should be avoided on a development site. Ideally, the entire 100-year floodplain at full buildout should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. Maps of the 100-year floodplain can typically be obtained through the local review authority.

Standards

General

a) No disturbance shall occur to preservation areas during project construction.

b) Preserved areas shall be protected by limits of disturbance clearly shown on all construction drawings and clearly marked on site.

c) Preservation areas shall be located within an acceptable conservation easement instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked. [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management.]

d) Preservation areas shall have a minimum contiguous area of 10,000 square feet or in the case of stream buffers must maintain a 50-foot set back from the jurisdictional wetland edge along the entire length of stream through the property of concern. Areas of smaller size may be incorporated for disconnection of impervious surface, but will be considered as open space in good condition.

e) Incorporate level spreaders or other dispersion devices, where practicable, to ensure sheet flow. See *Figure 4.5*, which depicts a level spreader. (Please note that the level spreader shown here is for dispersion of low flows only.

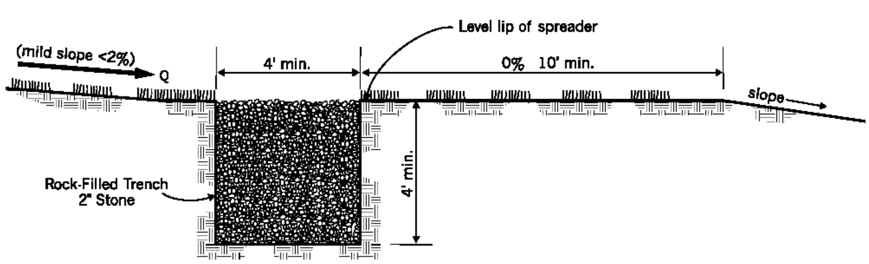

Figure 4.5 – Rock trench level spreader for low flows. Source: Prince George's County, Maryland, 2000.

f) Include bypass mechanisms for higher flow events to prevent erosion or damage to a buffer or undisturbed natural area.

g) Consider incorporating constructed berms around natural depressions and below undisturbed vegetated areas to provide for additional runoff storage and infiltration. Proper use of berms is discussed in the section entitled vegetated filter strips.

h) Where no berms are provided in Hydrologic Soil Group (HSG) type A and B soils, buffers may be used to attenuate and treat flows up to the water quality volume (i.e., volume equal to one inch over the impervious surface) in the following ratios:

Table 4.1
Ratio of Forested Buffer to Impervious Surface Required to Attenuate Runoff for Precipitation between 0.5 and 1.0 Inches[a, b]

	HSG Soil Type			
Runoff (inches)	A	B	C	D
1.0	1:3	2:1	N/A	N/A
0.9	1:4	1:1	N/A	N/A
0.8	1:6	2:3	N/A	N/A
0.7	1:9	2:5	N/A	N/A
0.6	1:15	1:4	1:1	N/A
0.5	1:25	1:8	1:2	N/A

Notes:

[a]Buffer size calculations based on TR-55. Calculations for precipitation depths less than 0.5 inches are not included as the empirical equations of TR-55 become less accurate for storms less than 0.5 inches.

[b]Standards for buffer width, area and length of contributing flow path, etc. must be met regardless of soil's capacity to attenuate flow.

i) Land cover in buffers will be assumed to be woods in good condition (i.e., Curve number (CN) equal to 32 in type A soil and 55 in type B soil). Type C and D may not be used for this purpose as woods on these soil types cannot abstract the depth of rainfall associated with one inch of runoff from the impervious surface.

j) Runoff must enter the buffer as overland sheet flow. The average contributing slope should be no less than 1% and no more 3%. Maximum average slope may be increased to 5% if a flow spreader is installed across the entire contributing length followed by a flat (i.e., 0% slope) 10-foot shelf across the length.

Streambank Areas

a) The minimum undisturbed buffer width should be at least the wetland jurisdictional setback plus 50 feet.

Maintenance
Except for routine debris removal, buffers shall remain in a natural and unmanaged condition.

4.2 Approaches that Mimic Natural Water Balance

LID controls mimic natural predevelopment hydrology in order to retain and attenuate stormwater runoff in upland areas. This reduces the amount of stormwater and intensity of flow at points of discharge. Flow attenuation prevents physical damage to waterways and reduces nonpoint source pollution. The remainder of *Section 4.2* discusses mimic natural water balance as a LID control.

Advantages

- Decreased need for constructed BMPs.
- Maintain predevelopment hydrology and thus reduces generation of stormwater and associated pollution.
- Encourage groundwater recharge.

Use

Mimicking predevelopment site hydrology involves a process of comparing and evaluating pre- and postdevelopment conditions that takes place in all stages of site planning. There are many methods of hydrologic analysis. This section of the manual relies on the use of the USDA-SCS Technical Release-55 (TR-55), entitled *Urban Hydrology for Small Watersheds* (1986).

Time of Concentration and Time of Travel
TR-55 focuses on the time of concentration (Tc) as a primary influence in the shape and peak of runoff hydrographs. TR-55 defines time of concentration as the "time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed."

Tc is calculated as follows:

$$Tc = Tt(1) + Tt(2) + \dots Tt(m)$$

Where:

Tt (travel time) = time it takes runoff to move across a segment of the watershed.
m = total number of travel segments in a watershed

Tt is mathematically defined by TR-55 as being directly influenced by two factors velocity of runoff (V) and length of runoff flow path (L). Velocity is further defined as a function of slope (s) and surface roughness (i.e., Manning's roughness coefficient for sheet flow) (n).

Tt is calculated as follows:

$$Tt = \frac{L}{3600\ V}$$

Where:

Tt = travel time in hours
L = flow length in feet
V = average velocity in feet per second
3600 = conversion factor for seconds to hours

Total Volume and Peak Discharge
TR-55 also notes that total runoff volume (Q) and peak runoff discharge (qp) tend to increase as a result of urbanization. Peak discharge is defined as a factor of Q and can be calculated using as follows:

$$qp = qu\ Am\ Q\ Fp$$

Where:

qp = peak discharge in cubic feet per second
qu = unit peak discharge
Am = drainage area in square miles
Q = runoff in inches
Fp = pond and swamp adjustment factor

Q is derived as a factor of initial abstraction (Ia) and retention (S) and is calculated as follows:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

Where:

Q = runoff in inches
P = rainfall in inches
S = retention
Ia = initial abstraction

Initial abstraction is a measure of rainfall held in surface depressions, interception by vegetation, evapotranspiration and infiltration prior to the occurrence of runoff and is calculated as follows:

$$Ia = 0.02\ S$$

Where:

Ia = initial abstraction
S = retention

Retention is a measure of total capacity for rainwater storage in a watershed during a rain event. In small agricultural watersheds retention is typically about 5 times greater than initial abstraction.

Retention is calculated as follows:

$$S = \frac{1000}{CN} - 10$$

Where:

S = retention
CN = curve number

Curve number is a coefficient ranging from 0 - 100, which is used to represent the conversion of rainfall to runoff. For example, an impervious surface such as concrete has a CN of 98, which is analogous to representing that 98% of rain that falls on concrete runs off.

Identifying Hydrologic Benefits
All nonstructural and distributed BMPs have one or more hydrologic benefits in relationship to TR-55. *Table 4.2*) summarizes key hydrologic benefits of nonstructural and distributed BMPs recommended in this manual.

Table 4.2
Hydrologic Benefits of
Nonstructural and Distributed Techniques and Controls

Techniques & Controls	Decrease Curve Number	Reduce Slope	Lengthen Flow Path	Increase Roughness	Increase Initial Abstraction	Increase Total Retention
Reduce Limits of Clearing and Grading	●[a]		◐[b]	●	●	
Preserve Natural Features	●		●	●	●	
Avoid Long, Steep Slopes		●	◖		●	
Avoid Erodible Soils				●	●	
Avoid Porous Soils	◖			●	●	
Minimize Roadways	●		◖	●	●	
Minimize Buildings	●		●	●	●	
Minimize Parking	●		●	●	●	
Disconnect Impervious Area	●		◖	◖	●	
Buffers and Undisturbed Areas	●		●	●	●	●

Techniques & Controls	Decrease Curve Number	Reduce Slope	Lengthen Flow Path	Increase Roughness	Increase Initial Abstraction	Increase Total Retention
Infiltration Swales	●	◖	◖	●	●	●
Vegetative Filter Strips	●			●	●	●
Bioretention	●				●	●
Nonstructural Conveyances	●		◖	●	●	
Drain Rooftop Runoff to Pervious Areas			●	●	●	
Rain Barrels and Cisterns					●	●
Dry Wells					●	●
Green Roofs and Walls					●	●

Notes
[a] Benefit always occurs.
[b] Benefit occurs sometimes.

Standards

Time of Concentration
The postdevelopment time of concentration (Tc) should approximate the predevelopment Tc.

Travel Time
The travel time (Tt) throughout individual lots and areas should be approximately constant.

Flow Velocity
Flow velocity in areas that are graded to natural drainage patterns should be kept as low as possible to avoid soil erosion.

Flows can be disbursed by installing a level spreader along the upland ledge of the natural drainage way buffer, and creating a flat grassy area about 30 feet wide on the upland side of the buffer where runoff can spread out. This grassy area can be incorporated into the buffer itself.

Figure 4.6– Alternative roadway design in Waterford, CT. Source: Tom Walsh, Shoreline Aerial Photography

4.3 Approaches to Minimizing and Disconnecting Impervious Surface

A key concept of LID is the minimization and disconnection of impervious surface. For the purposes of stormwater management, impervious surfaces are commonly considered to include roads, parking lots, and buildings.

4.3.1 Roadways

The greatest share of impervious cover in most communities is from paved surface such as roads and sidewalks. Roadway lengths and widths should be minimized on a development site where possible to reduce overall impervious surface.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac. These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerheads, loop roads, and pervious islands in the cul-de-sac center (see *Figures 4.7 through 4.9*).

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Reduces the costs associated with road construction and maintenance.

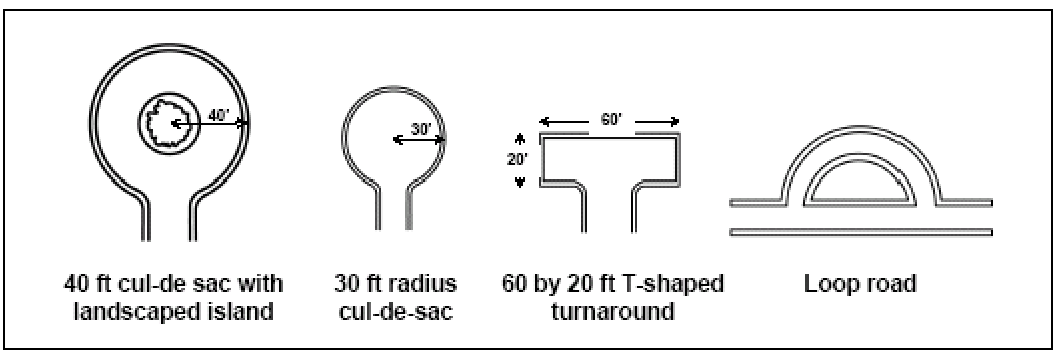

Figure 4.7 – Different styles of turnarounds. Source: Adapted from Atlanta Regional Commission, 2001.

Figure 4.8 – Cul-de-sac infiltration island accepts stormwater from surrounding pavement. Note flat curb. Source: Connecticut, 2004.

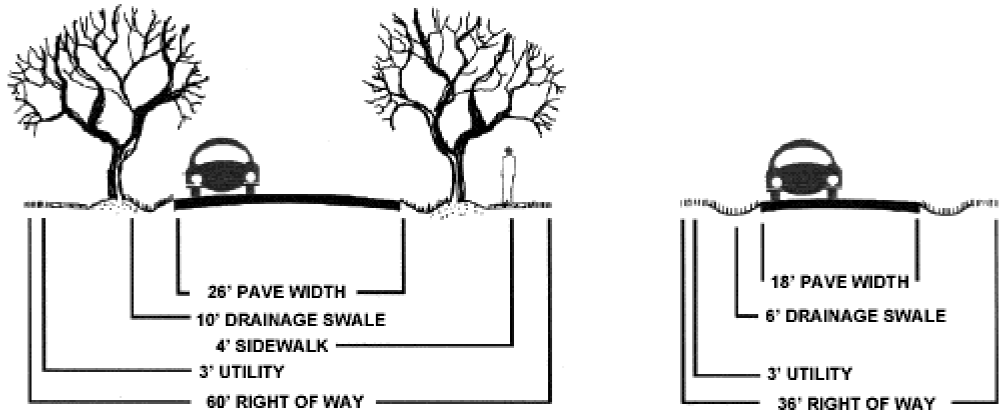

Figure 4.9 – Reduced road widths. Source: Atlanta Regional Commission, 2001.

Use

Examine local ordinances and other requirements to determine standards and degree of flexibility available. Communities may have specific standards for setbacks and frontages or criteria for cul-de-sacs and other alternative turnarounds.

Reduce Roadway Lengths and Widths

1. Consider site and road layouts that reduce overall street length.
2. Minimize street width by using narrower street designs as appropriate. Issues to consider include design speed, number of average daily trips (ADT), peak usage, need for on-street parking, sidewalks, design speed and right of way (see *Table 4.3*).

Reduce Surface Area of End-of-Street Turnarounds

1. Consider types of vehicles that may need to access a street. Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. Fire trucks, service vehicles and school buses are often cited as needing large turning radii. However, some fire trucks are designed for smaller turning radii. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and school buses usually do not enter individual cul-de-sacs.
2. Minimize pavement at end-of-street turnarounds. Incorporate landscaped areas and consider alternatives to cul-de-sacs wherever practicable.

Standards

Reduce Roadway Lengths and Widths

The table below shows a recommended standard for five categories of street. Streets are categorized based on ADT and density of dwelling units (row 1 in the table).

Table 4.3
Roadway Design Standards for Five Street Types

Design Factor	Access	Local	Collector	Arterial
ADT	0 – 500	500 – 5,000	2,500 – 10,000	7,500 – 20,000+
Number of Lanes	2	2	2	2 – 4
Turn lanes	None	None	Left (when needed)	Left and Right (when needed)
Lane Width (feet)	9 – 10	10 – 11	10 – 12	11 – 12
On-Street Parking (feet)	None	7 (parallel)	8 (parallel) 16 – 18 (angle)	None except for CBD
Drainage	Swale or curb/gutter	Swale or curb/gutter	Swale or curb/gutter	Swale or curb/gutter
Target Speed (MPH)	15 – 20	25	25 – 35	30 – 45
Bicycle Lanes	None	Shared	Shared or seperate	Yes
Sidewalks	None or one-side	Two side	Two side	One side
Frontage Lots	Yes (may be rear)	Yes	Yes	Some

Average Daily Trips
ADT = 10 x Number of Dwelling Units [7]

Peak Trips Per Hour
Peak Trips/Hour = Number of Dwelling Units [8]

Please note that local zoning may supersede these recommendations. Although, these recommended standards are intended to account for safety and snow disposal, greater widths may be appropriate in some instances.

Reduce Surface Area of End-of-Street Turnarounds
Where cul-de-sacs are necessary radii should be no more than 30 feet. Alternatives such as hammerheads, jug handles and donuts should also be considered.

4.3.2 Buildings

Imperviousness associated with buildings and accessories such as driveways can often be reduced with considerate planning in the early stages of site design. The techniques below should be considered and applied wherever practicable.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.

Discussion

Footprints
The building footprint is the surface area of ground covered by structure. The impervious footprint of commercial buildings and residences can be reduced by using multistory buildings. In comparison to single-story buildings, multistory buildings maintain floor area while covering less ground surface. Use alternate or taller building designs to reduce the impervious footprint of buildings. For example, in residential areas, consider colonial style homes instead of ranches.

Setbacks and Frontages
Driveways generally extend from a roadway to a house. Therefore, driveway length is typically determined by building setback requirements. Driveways are noted to contribute up to 30 percent of impervious cover in residential areas (Schueler, 1995). Setback requirements of up to 75 feet are not uncommon. Notwithstanding, a driveway length of 20 to 30 feet is generally adequate to meet parking needs. A driveway width of 18 feet is generally adequate for parking two cars side-by-side.

Further, reducing side-yard widths and using narrower frontages can reduce total street length, especially important in cluster and open space designs. *Figure 4.10*shows residential examples of reduced front and side yard setbacks and narrow frontages.

Figure 4.10 – Reduced side yards and frontage at a development in Connecticut.

Flexible lot shapes and setback and frontage distances allow site designers to create attractive and unique lots that provide homeowners with enough space while allowing for the preservation of natural areas in a residential subdivision. *Figure 4.11* illustrates various nontraditional lot designs.

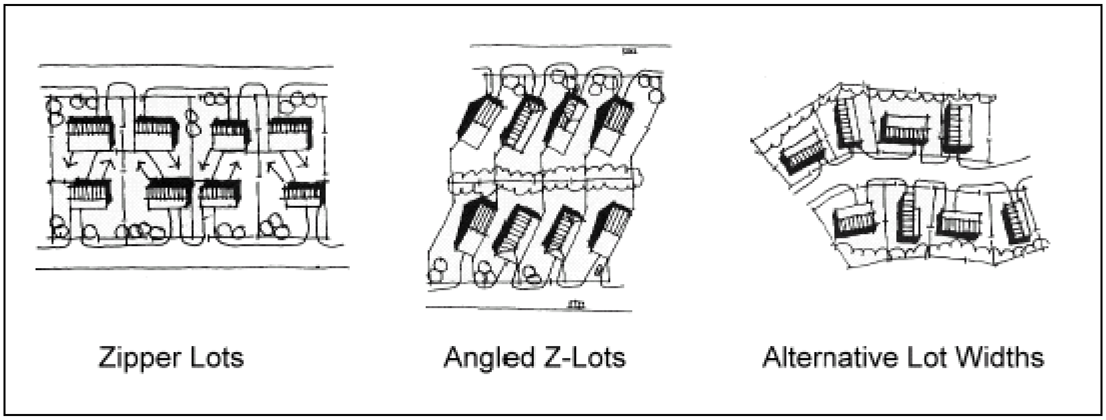

Figure 4.11 – Examples of nontraditional lot designs. Source: Adapted from Atlanta Regional Commission, 2001.

Use

Use smaller front and side setbacks and narrower frontages to reduce total road length and driveway lengths.

Reduce building and home front and side setbacks to allow for narrow frontages. Consider narrower frontages.

a) Consider alternative build styles that reduce ratio of footprint to floor area.

b) Review local regulations. Communities may have specific design criteria for setbacks and frontages.

c) Minimize setbacks and lot frontages.

Standards

a) Where practicable, reduce building setbacks to 20 - 30 feet and driveway widths to 18 feet.

b) Where practicable, reduce frontages to 60 feet.

4.3.3 Parking Footprints

Setting maximums for parking spaces, minimizing stall dimensions, using structured parking and encouraging shared parking and using alternative porous surfaces can reduce the overall parking footprint and site imperviousness.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.

Use and Standards

Apply the following approach:

Examine local ordinances and other requirements to determine standards and degree of flexibility available. Communities may have specific standards for parking stall size and number of parking spaces. There may also be prohibitions against shared parking.

Use Average Demand to Size Lots

a) Many parking lot designs result in far more spaces than actually required. This problem is exacerbated by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand.

b) If no local standards require a minimum number of spaces, apply the standards in *Table 4.4* as a maximum number of spaces.

Table 4.4
Recommended Maximum Number of Parking Spaces for Certain Land Uses

Land Use	Maximum Parking Spaces
Single Family House	2 per DU[a]
Shopping Center	5 per 1000 ft^2 GFA[b]
Convenience Store	3.3 per 1000 ft^2 GFA
Industrial	1 per 1000 ft^2 GFA
Medical Dental	5.7 per 1000 ft^2 GFA

Source: Georgia Stormwater Manual, 2002.
Notes:
[a] DU means dwelling unit.
[b] GFA means gross floor area.

Minimize Parking Stall Size

Another technique to reduce the parking footprint is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall.

Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier, stall width requirements in most local parking codes are much larger than the widest SUVs.

Figure 4.12 – Parking deck – New Haven,

Use Parking Decks
Structured parking decks can significantly reduce the overall parking footprint by minimizing surface parking. *Figure 4.12* shows a parking deck used for a commercial development.

Encourage Shared Parking
Shared parking in mixed-use areas and structured parking are techniques that can further reduce the conversion of land to impervious cover. For developments and blocks with a mix of land uses, perform a shared parking analysis in order to determine the peak demand for spaces for all uses rather than calculating each separately. Often mixed uses may be complimentary with regards to parking. For example, the peak demand for office buildings occurs during the period of minimal demand for residential buildings. The Urban Land Institute publication *Shared Parking,* Second Edition, 2005 provides a detailed methodology in order to determine the peak hour of parking demand and the overall number of spaces required for a mixed use development. This may reduce the number of spaces required by up to 20 percent.

4.3.4 Parking Lot Islands

A parking lot island is an area within a parking lot that includes one or more management practices and breaks up impervious surface (see *Figure 4.13*). Parking lot islands include small-scale management practices such as filter strips, dry swales, sand filters and bioretention.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Provides an opportunity for the siting of structural control facilities.
- Trees in parking lots provide shading for cars and are more visually appealing.

Use

- Break up expanses of parking with landscaped islands, which include shade trees and shrubs.
- Fewer large islands will sustain healthy trees better than more numerous very small islands.

Figure 4.13 – Bioretention in use as a parking lot island in Branford, CT. Source: Connecticut Department of Environmental Protection.

Structural control facilities such as filter strips, dry swales and bioretention areas can be incorporated into parking lot islands. Stormwater is directed into these landscaped areas and temporarily detained. The runoff then flows through or filters down through the bed of the facility and is infiltrated into the subsurface or collected for discharge into a stream or another stormwater facility. These facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms.

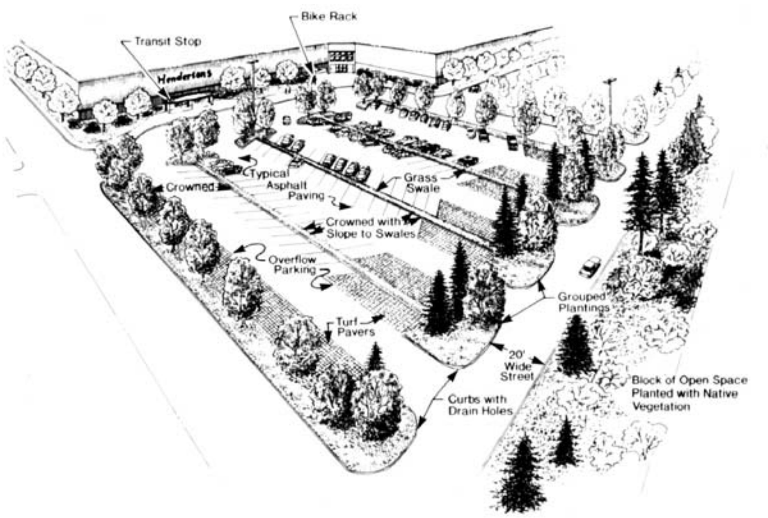

Figure 4.14 – Parking lot with islands attractively integrated. Source: Connecticut, 2004.

Standards

Parking lot islands should:

a) Be at least 8 feet wide.
b) Be constructed with sub-surface drainage.
c) Incorporate compaction resistant soil.

4.3.5 Permeable Pavement

Figure 4.15 – Permeable pavement. Source: Connecticut, 2004.

Permeable pavement is designed to allow rain and snowmelt to pass through it, thereby reducing runoff, promoting groundwater recharge, and filtering pollutants. Permeable paving materials include:

- Modular concrete paving blocks
- Modular concrete or plastic lattice
- Soil enhancement technologies
- Cast-in-place concrete grids
- Other materials such as gravel, Cobbles, wood, mulch, brick, and natural stone.

Porous asphalt or concrete (i.e., porous pavement or gap-graded pavement), which looks similar to traditional pavement but is manufactured without fine materials and incorporates additional void spaces, are only recommended for certain limited applications due to their potential for clogging and high failure rate in cold climates. Porous pavement is only recommended for sites that meet the following criteria:

- Low-traffic applications (generally 500 or fewer average daily trips or ADT).
- The underlying soils are sufficiently permeable (see Design Considerations below).
- Road sand is not applied.

Runoff from adjacent areas is directed away from the porous pavement by grading the surrounding landscape away from the site or by installing trenches to collect the runoff. Regular maintenance is performed (sweeping, vacuum cleaning).

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Reduces the costs associated with road construction and maintenance.

Use

a) Applicable to small drainage areas.

b) Low traffic (generally 500 ADT or less) areas of parking lots (i.e., overflow parking for malls and arenas), driveways for residential and light commercial use, walkways, bike paths, and patios.

c) Roadside right-of-ways and emergency access lanes.

d) Useful in stormwater retrofit applications where space is limited and where additional runoff control is required.

e) In areas where snow plowing is not required.

Standards

Chapter 11 of the current *Stormwater Quality Manual* includes specific design standards and considerations for permeable pavement, which should be followed when implementing these BMPs.

4.3.6 Disconnecting Impervious Areas

Impervious surfaces that are separated from drainage collection systems by pervious surface or infiltrating BMPs contribute less runoff and reduced pollutant loading. Isolating impervious surface promotes infiltration and filtration of stormwater runoff.

Advantages

- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.

Use

Use the following techniques to disconnect impervious surface from collection systems:

a) Direct roof runoff and runoff from paved surfaces to stabilized vegetated areas such as buffers.
b) Direct runoff from large impervious surfaces (over 5000 square feet) to more than one receiving area.
c) Encourage sheet flow through vegetated areas.

Standards

General

a) Disconnect impervious surfaces to the extent practicable.
b) Up to the first inch of runoff from an impervious surface may be disconnected to a pervious surface such as a lawn.

Table 4.5
Ratio of Open Space: Pervious Area Necessary to Attenuate Surface Runoff for Runoff Between 0.5 and 1.0 Inches[a, b]

Runoff (inches)	HSG Soil Type			
	A	B	C	D
1.0	1:2	4:1	N/A	N/A
0.9	1:3	2:1	N/A	N/A
0.8	1:4	1:1	N/A	N/A
0.7	1:8	1:2	N/A	N/A
0.6	1:8	1:3	2:1	N/A
0.5	1:8	1:6	1:1	N/A

Notes:

[a]Buffer size calculations based on TR-55. Calculations for precipitation depths less than 0.5 inches are not included as the empirical equations of TR-55 become less accurate for storms less than 0.5 inches.

[b]Standards for buffer width and length of contributing flow path, etc. must be met regardless of soil's capacity to attenuate flow.

c) Relatively permeable soils (hydrologic soil groups A and B) must be present for disconnection. Assume that the pervious surface is open space in good condition (i.e., CN of 39 for HSG A and 61 for HSG B). (If a forested buffer is being used refer to "Preserving Natural Areas" for appropriate standards.) The following impervious to pervious area ratios should be used. Type C and D may not be used for this purpose as open space on these soil types does not abstract the rainfall required to generate one inch of runoff from the impervious surface.
d) The maximum contributing impervious flow path length should be no more than 75 feet.
e) The disconnected area should drain continuously through a vegetated channel, swale, or filter strip to the property line or structural stormwater control.
f) Flow from the impervious surface must enter the downstream pervious area as sheet flow.
g) The length of the disconnected area should be equal to or greater than the contributing length.
h) The entire disconnected area should maintain a slope less than or equal to 5 percent.
i) The surface of the contributing imperviousness area should not exceed 5,000 square feet.

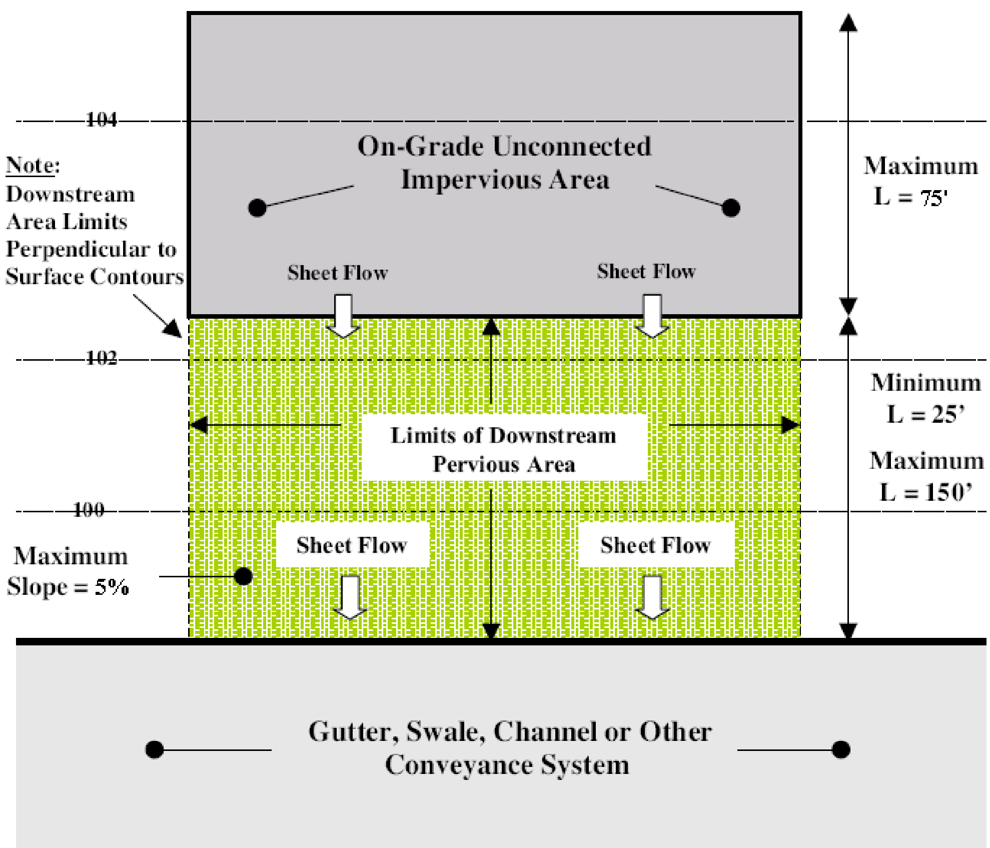

Figure 4.16 – Standards for disconnecting impervious surface via sheet flow. Source: New Jersey Department of Environmental Protection, 2004.

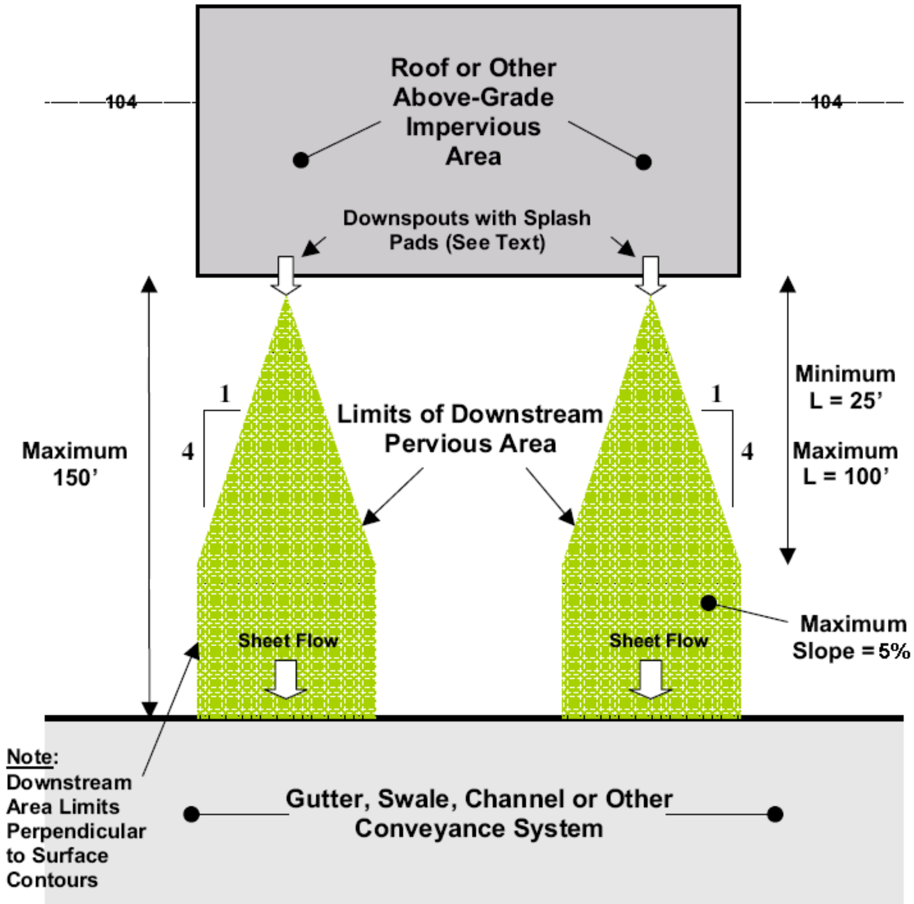

Figure 4.17 – Standards for disconnecting impervious surface via downspouts. Source: New Jersey Department of Environmental Protection, 2004.

Downspouts

a) Downspout outfall expands in width at a rate of 1:4 for a maximum length of 100 feet and a minimum length of 25 feet.
b) No downspout may drain more than 600 square feet of roof.
c) Downspouts should be at least 10 feet away from the nearest impervious surface (e.g., driveways) to discourage reconnections to those surfaces.
d) Downspouts must be equipped with splash pads, level spreaders, or dispersion trenches that reduce flow velocity and induce sheet flow in the downstream pervious area.

4.4 Integrated Management Practices at the Source

4.4.1 Vegetated Filter Strips

A vegetated filter strip is an undisturbed densely vegetated area (e.g., well-tended lawn) contiguous with a developed area. These filter strips are most often located between a water resource and the developed portion of a site (see *Figure 4.18*).

Figure 4.18 – Vegetative filter strip. Source: Connecticut, 2004.

Advantages

Filter strips serve to improve runoff water quality, add or maintain wildlife habitat, and provide a screening effect for homeowners. This type of BMP is best suited for complementing other structural methods utilized on-site for stormwater management.

Use

Filter strips can be composed of an undisturbed-forested area or created from disturbed land by proper seeding and plantings. Where grass is being used, the most effective pollutant removal filter strip is composed of dense grassy vegetation that is properly maintained

Channelization of runoff within the filter strip significantly reduces the amount of infiltration and subsequent pollutant removal. Filter strips must have a level-spreading device incorporated into the design. Caution must be used when installing level spreaders to ensure long-term even flow and distribution of runoff to the filter strip. See *Figure 4.5* for an example of a level spreader. Low volume pedestrian pathways may be constructed through a buffer strip, provided they are no greater than 5 feet wide and take a winding course to reduce the potential for channelized runoff flow. Pesticides should not be applied in these areas, although minimal, fertilizer use is acceptable to help seeded areas become more quickly established. Incorporating organic material, such as mulch, into the topsoil is encouraged to promote better filter strip performance.

Soils with a high content of organic material will attenuate greater amounts of pollutants from stormwater runoff.

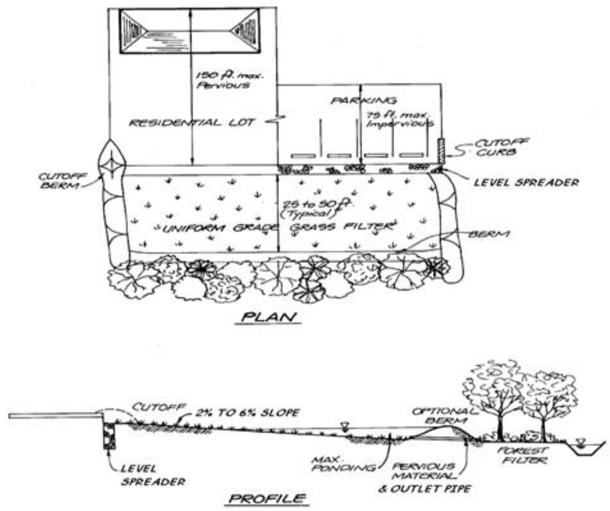

Figure 4.19 – Drawing of a vegetative filter strip. Source: Atlanta Regional Commission, 2001.

Standards

Chapter 11 of the current *Stormwater Quality Manual* includes specific design standards and considerations for vegetative filter strips, which should be followed when implementing these BMPs.

4.4.2 Natural and Vegetated Drainage Ways

Structural drainage systems and storm sewers are designed to be hydraulically efficient for removing stormwater from a site. However, in doing so these systems tend to increase peak runoff discharges, flow velocities and the delivery of pollutants to downstream waters. An alternative is the use of natural drainage ways such as grass natural drainage systems (see *Figure 4.20*).

Figures 4.20 – Vegetated drainage way. Photograph courtesy of the University of Connecticut NEMO program, Kara Bonsack

The use of natural open channels allows for more storage of stormwater flows on-site, lower stormwater peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of stormwater pollutants.

Advantages

- Reduces or eliminates the cost of constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading.
- Increases travel times and lower peak discharges.
- Can be combined with buffer systems to enhance stormwater filtration and infiltration.

Use

a) Use vegetated open channels in the street right-of-way to convey and treat stormwater runoff from roadways, particularly for low-density development and residential subdivisions where density, topography, soils, slope, and safety issues permit.

b) Use vegetated open channels in place of curb and gutter to convey and treat stormwater runoff.

c) Design drainage systems and open channels to:
   i. Increase surface roughness to retard velocity.
   ii. Include wide and flat channels to reduce velocity of flow and encourage sheet flow if possible.
   iii. Increase channel flow path to increase time of concentration and travel time.

Standards

Chapter 11 of the current *Stormwater Quality Manual* includes specific design standards and considerations for grass drainage channels, which should be followed when implementing these BMPs.

4.4.3 Green Roofs and Facades

Figure 4.21 – Aetna Building, Hartford, CT. Source: Connecticut Department of Environmental Protection.

Rooftop runoff management structures are modifications to conventional building design that retard runoff originating from roofs. The modifications include:

- Vegetated roof covers
- Roof gardens
- Vegetated building facades
- Roof ponding areas

Roofs are significant sources of concentrated runoff from developed sites. If runoff is controlled at the source, the size of other BMPs throughout the site can be minimal. Rooftop runoff management practices influence the runoff hydrograph in two ways:

- Intercept rainfall during the early part of a storm.
- Limit the maximum release rate.

In addition to achieving specific storm water runoff management objectives, rooftop runoff management can also be aesthetically and socially beneficial.

Advantages

- Rooftop runoff management techniques can be retrofitted to most conventionally constructed buildings.
- Reduces energy consumption for heating and cooling.
- Conserves space.
- Reduces wear on roofs caused by UV damage, wind, and extremes of temperature. Vegetative roof covers can reduce bare roof temperatures in summer by as much as 40 percent.
- Roof gardens, vegetated roof covers, and vegetated facades add aesthetic value to residential and commercial property that attract songbirds, bees, and butterflies.
- Benefit water quality by reducing the acidity of runoff and trapping airborne particulates.
- May reduce the size of onsite runoff attenuation BMPs.

Use

a) Use vegetative roofs on residential, commercial and light industrial buildings.
b) Vegetative roof systems are most appropriate on roofs with slopes of 12:1 to 4:1.
c) Vegetative roofs may be used on flatter slopes if an underdrain is installed.

Design Variations

- <u>Vegetated roof cover</u> – Vegetated roof covers, also called green roofs and extensive roof gardens, involve blanketing roofs with a veneer of living vegetation. Vegetative roof covers are particularly effective when applied to extensive roofs, such as those that typify commercial and institutional buildings. The filtering effect of vegetated roof covers results in a roof discharge that is free of leaves and roof litter. Therefore, it is recommended where roof runoff will be directed to infiltration devices (see Standards for Infiltration Practices and Dry Wells.)

Because of recent advances in synthetic drainage materials, vegetated covers now are feasible on most conventional flat roofs. An efficient drainage layer is placed between the growth media and the roof surface. This layer rapidly conveys water off of the roof surface and prevents water from "lying" on the roof. In fact, vegetated roof covers can be expected to protect roof materials and prolong their life.

If materials are selected carefully to reduce the weight of the system, vegetated roof covers generally can be created on existing flat roofs without additional structural support. Drainage nets or sheet drains constructed from lightweight synthetic materials can be used as underlayments to carry away water and prevent ponding. The total load of a fully vegetated and saturated roof cover system can be less than the design load computed for gravel ballast on conventional tar roofs.

Although vegetative roof covers are most effective during the growing season, they also are beneficial during the winter months as additional insulation if the vegetative matter from the dead or dormant plants is left in place and intact.

- Roof Gardens – Vegetated roof covers blanket an entire roof area and, although presenting an attractive vista, generally are not intended to accommodate routine traffic by people. Roof gardens, on the other hand, are landscaped environments, which may include planters and potted shrubs and trees. Roof gardens can be tailor-made natural areas, designed for outdoor recreation, and perched above congested city streets. Because of the special requirements for access, structural support, and drainage, roof gardens are found most frequently in new construction.

  Roof gardens generally are designed to achieve specific architectural objectives. The load and hydraulic requirements for roof gardens will vary according to the intended use of the space. Intensive roof gardens typically include design elements such as planters filled with topsoil, decorative gravel or stone, and containers for trees and shrubs. Complete designs also may detain runoff ponding in the form of water gardens or storage in gravel beds. A wide range of hydrologic principles may be exploited to achieve storm water management objectives, including runoff peak attenuation and runoff volume control.

- Vegetated Building Facades – Vegetated facades provide many of the same benefits as vegetated roof covers and roof gardens, including the interception of precipitation and the retardation of runoff. However, their effectiveness is limited to small rainfall events.

  Vertical facades and walls of houses can be covered with the foliage of self-climbing plants that are rooted in the ground and reach heights in excess of 80 feet. Vines can be evergreen or prolific deciduous flowering plants. As for roof gardens, the designer must be judicial in selecting plant species that will prosper in the constructed environment. Planters and trellises can be installed so that vegetation can be placed strategically.

- Roof Ponding – Roof ponding is applicable where the increased load of impounded water on a roof will not increase the building costs significantly or require extensive reinforcement. Roof ponding generally is not viable for large-area commercial buildings where clear spans are required. Special consideration must be given to ensuring that the roof will remain watertight under a range of adverse weather conditions. Low-cost plastic membranes can be used to construct an impermeable lining for the containment area.

Flat roofs can be converted to ponding areas by restricting the flow to downspouts. Even small ponding depths of 1 or 2 inches can attenuate storm water-runoff peaks effectively for most storms.

Design Considerations

Rooftop measures are primarily peak runoff attenuation measures. The methods for evaluating the peak attenuation properties of these measures are based on approaches used for other peak runoff attenuation BMPs. The emphasis of the design should be promoting rapid roof drainage and minimizing the weight of the system. By using appropriate materials, the total weight of fully saturated vegetated roof covers can readily be maintained below 20 pounds per square foot (psf). Because of the many factors that may influence the design of vegetated roof covers, it is advisable to obtain the services of installers that specialize in this area.

Rainfall retention properties are related to field capacity and wilting point. Appropriate media for this application should be capable of retaining water at the rate of 40 percent by weight, or greater. The media must be uniformly screened and blended to achieve its rainfall retention potential. During the early phases of a storm, the media and root systems of the cover will intercept and retain most of the rainfall, up to the retention capacity. For instance, 3-inch cover with 40 percent retention potential will effectively control the first 1.2 inches of rainfall. Although some water will percolate through the cover during this period, this quantity generally will be negligible compared to the direct runoff rate without the cover in place.

Once the field capacity of the cover is attained, water will drain freely through the media at a rate that is approximately equal to the saturated hydraulic conductivity for the media. Through the selection of the media, the maximum release rate from the roof can be controlled. The media is a mechanism for "buffering" or attenuating the peak runoff rates from roofed areas. Rooftop runoff management measures generally are more effective in controlling storms that generate 1 inch or less of runoff (i.e., 1.2-inch storm). However, because storms of this size constitute the majority of rainfall events, rooftop runoff measures can be important in planning for comprehensive storm water management. These measures are particularly useful when linked to groundwater recharge BMPs such as infiltration trenches, dry wells, and permeable pavements. By retaining rainfall for evaporation or plant transpiration, some rooftop runoff management measures, such as vegetated roof covers, can also achieve significant reductions in total annual runoff. This attenuation of runoff peaks from larger storms should be taken into account when sizing related runoff peak attenuation at the site.

By using specific information about the hydraulic properties of the cover media, the effect of the roof cover system on the runoff hydrograph can be approximated with numerical modeling techniques. As appropriate, the predicted hydrographs can be added into site-wide runoff models to evaluate the effect of the vegetative roof covers on site runoff. The hydraulic analysis of roof covers will require the services of a professional engineer who is experienced with drainage design.

Impermeable Lining

a) In some instances, the impermeable lining can be the watertight tar surface, which is conventional for flat roof construction. However, where added protection is desired, a layer of plastic or rubber membrane can be installed immediately beneath the drainage net or sheet drain. This liner needs to be designed by a professional engineer to ensure proper function.

b) If membranes are used, their resistance to ultraviolet (UV) radiation, extremes of temperature, and puncture must be known. In most cases, covering the sealing material with a protective layer of gravel or geotextile is advisable.

Drainage

a) The drainage net or sheet drain is a continuous layer that underlies the entire cover system. A variety of lightweight, high-performance drainage products will function well in this environment. The product selected should be capable of conveying the discharge associated with the runoff peak attenuation storm without ponding water on top of the roof cover. When evaluating a drainage layer design, the roof topography should be evaluated to establish where the longest travel distances to a roof gutter, drain, or downspout occur. If flow converges near drains and gutters, the design unit-flow rate should be increased accordingly.

b) Drainage nets or sheet drains with transmissivities of 15 gallons per minute per foot, or larger, are recommended.

c) The drainage layer should be able to convey the design unit flow rate at the roof grade without water ponding on top of the cover media. For larger storms, direct roof runoff is permitted to occur. The design flow rates should be based on the largest runoff peak attenuation design storm considered in the design.

d) To prevent the growth media from penetrating and clogging the drainage layer and to prevent roots from penetrating the roof surface, a geotextile should be installed immediately over the drainage net or sheet drain. Many vendors will bond the geotextile to the upper surface of the drainage material.

e) Effective roof garden designs will ensure that all direct rainfall is cycled through one or more devices before being discharged to downspouts as runoff. For instance, rainfall collected on a raised tile patio can be directed to a media-filled planter where some water is retained in the root zone and some is detained and gradually discharged through an overflow to the downspout.

f) In the case of roof ponding, devices such as the one shown in *Figure 4.22*, are easily fabricated. However, some form of emergency overflow also is advisable. Emergency overflow can be as simple as a free overfall through a notch in the roof parapet wall.

g) In roof ponding systems, because the roof is impermeable, the runoff hydrograph is simply the rainfall distribution for the design storm multiplied by the area of the roof.

The depth to storage relationship can be computed from the topography of the roof. For perfectly flat roofs, the storage volume of a ponding level is equal to the roof area times the ponding level. The depth-discharge relationship in will be unique to the outlet device used. For simple ponding rings on flat roofs, the discharge rate will approximately equal:

$$q = 3.141\ CD\ (d - H)^{3/2}$$

Where:

q = outflow rate
C = discharge coefficient (Varies based on design) Typical: C = 3.0
D = diameter of the ring
d = depth of ponding
H = height of the ring

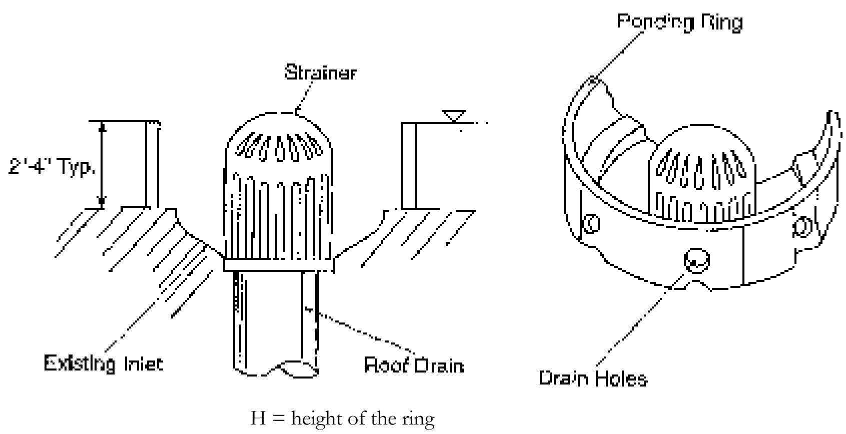

Figure 4.22 – Roof ponding rings. Source: Tourbier, 1974.

Roof Loading

The net weight of the fully vegetated roof cover should be compared against the design loads for the roof.

Lightweight Growth Media

a) The depth of the growth media should be kept as small as the cover vegetation will allow. Typically, a depth of 3 to 4 inches will be sufficient. Low-density substrate materials with good water-retention capacity should be specified. Examples are mixtures containing crushed pumice and terra cotta. Media that are appropriate for this application will retain 40 to 60 percent water by weight and have bulk dry densities of between 35 and 50 lb/cubic foot. Earth and topsoil are too heavy for most applications.

b) Hydrologic properties are specific to the growth medium. If the supplier does not provide information, prospective media should be laboratory tested to establish porosity, moisture content at field capacity, moisture content at the wilting point (nominally 0.33 bar), and saturated hydraulic conductivity.

Adapted Plants and Grasses

a) A limited number of plants can thrive in the roof environment where periodic rainfall alternates with periods that are hot and dry. Effective plant species must:

   i. Tolerate mildly acidic conditions and poor soil;
   ii. Prefer very-well-drained conditions and full sun;
   iii. Tolerate dry soil;
   iv. Be vigorous colonizers.

   Both annual and perennial plants can be used. Dozens of species have been successfully field-tested. Among these, some species of sedum (Sedum) have been shown to be particularly well adapted. Other candidates include hardy species of sedge (Carex), fescue (Festuca), feather grass (Stipa), and yarrow (Achillea).

b) Vegetative roof covers may include provisions for occasional watering during extended dry periods. Conventional lawn sprinklers work well.

c) The key to developing an effective vegetated facade is selecting plants that are well adapted to the conditions in which they must grow. For instance, depending on the location, plants may encounter shade or full sun. Plants that will provide thick foliage should be selected. Some plants with good climbing and foliage characteristics are ivy (Hedera), honeysuckle (Loniciera), wisteria (Wisteria), Virginia creeper (Part henocissus), trumpet creeper (Campsis), and hardy cultivars of clematis (e.g., Cleinatis paniculata). Some of these plants will require a trellis or lattice to firmly support the vines.

Inspection and Maintenance

a) Plans for water quality swales should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

b) All rooftop runoff management measures must be inspected and maintained periodically. Furthermore, the vegetative measures require the same normal care and maintenance that a planted area does. The maintenance includes attending to plant nutritional needs, irrigating as required during dry periods, and occasionally weeding.

c) The cost of maintenance can be significantly reduced by judiciously selecting hardy plants that will outcompete weeds.

d) In general, fertilizers must be applied periodically. Fertilizing usually is not a problem on flat or gently sloping roofs where access is unimpeded and fertilizers can be uniformly broadcast.

e) Properly designed vegetated roof covers should not be damaged by treading on the cover system.

f) When retrofitting existing roofs, preserve easy access to gutters, drains, spouts, and other components of the roof drainage system.

g) It is good practice to thoroughly inspect the roof drainage system quarterly. Foreign matter, including leaves and litter, should be removed.

Table 4.6
Typical Maintenance Activities for Rooftop Runoff Structures

Activity	Schedule
• Inspect to ensure vegetative cover is established • Remove foreign matter, leaves, and litter	Quarterly
• Irrigate/Water • Weed	As necessary
• Apply fertilizers to flat or gently sloped roofs	As necessary
• Repair erosion on side slopes with seed or sod	As necessary

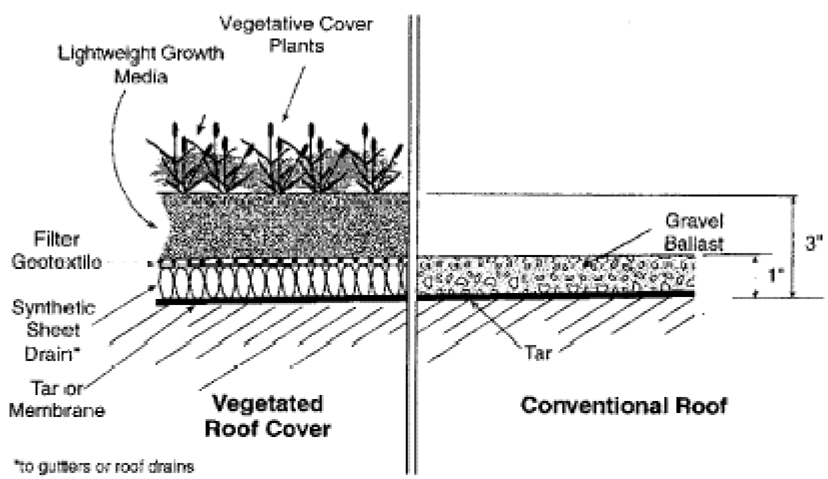

Figure 4.23 – Example Vegetated Rooftop Cross-Section

4.4.4 Rain Barrels and Cisterns

Rain barrels and cisterns are rainwater collection and storage devices (see *Figure 4.24*). They are generally low-cost and easily maintainable. They are applicable, for purposes of retrofit, to residential, commercial and industrial sites to manage rooftop runoff. Rain barrels and cisterns are not generally given stormwater management credit on new development.

Cisterns are generally larger than rain barrels, with some underground cisterns having the capacity of 10,000 gallons or more. Water collected in cisterns is typically used for irrigation or in some instances as a potable supply.

Figure 4.24 – Example of a rain barrel. Source: Connecticut Department of Environmental Protection.

Advantages

- Low cost.
- Applicable to a wide range of sites (e.g., residential, commercial industrial, etc.).
- Provide retention and detention of runoff from roofs.
- Can provide reuse of water for landscape irrigation.

Use

a) Use rain barrels and cisterns in commercial, industrial and domestic settings.
b) Incorporate rain barrels and cisterns when a building is being designed so that they can be blended into the landscape. They can also be retrofitted.
c) Size rain barrels and cisterns based on roof area. The required capacity of a rain barrel is a function of the rooftop surface evaporative water losses and initial abstraction.

Rain barrel volume can be determined by calculating the roof top water yield for any given rainfall, using Equation 10. A general rule of thumb to utilize in the sizing of rain barrels is that 1 inch of rainfall on a 1000-square-foot roof will yield approximately 600 gallons.

$V = A^2 \times R \times 0.90 \times 7.5 \; gals/ft^3$

where:

V = volume of rain barrel (gallons)
A^2 = surface area roof (square feet)
R = rainfall (feet)
0.9 = losses to system (no units)
7.5 = conversion factor (gallons per cubic foot)

Example: one 60-gallon barrel would provide runoff storage from a rooftop area of approximately 215 square feet for a 0.5 inch (0.042 ft.) of rainfall.

$60\ gallons = 215\ ft.^2 \times 0.042\ ft. \times 0.90 \times 7.5\ gallons/ft.^3$

d) If collected water will be used as a drinking source, the system will generally require local authority review and approval.

e) Assure long-term function by establishing maintenance agreements.

Standards

Chapter 4 of the current *Stormwater Quality Manual* includes specific design standards and considerations for rain barrels and cisterns, which should be followed when implementing these BMPs.

4.4.5 Dry Wells

A dry well is a small, excavated pit, backfilled with stone aggregate. Dry wells function like infiltration systems to control roof runoff and are applicable for most types of buildings (see *Figure 4.25*).

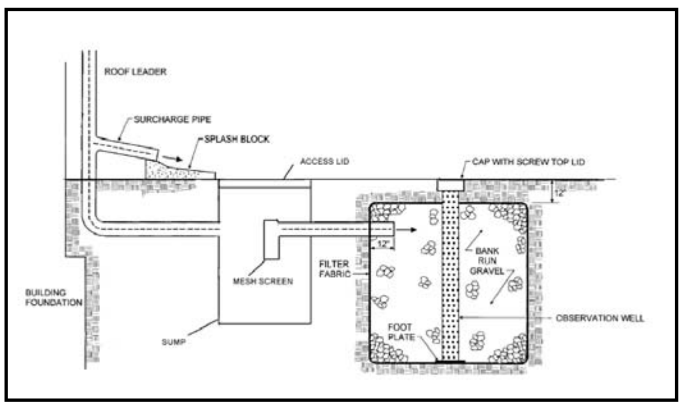

Figure 4.25 – Schematic of a drywell with optional sump to facilitate cleanout. Source: Adapted from New York, 2001.

Advantages

- Low cost.
- Applicable to a wide range of sites (e.g., residential, commercial industrial, etc.).
- Provides retention of runoff from roofs.
- Recharges groundwater.
- Reduces need for end-of-pipe treatment.

Use

a) Dry wells can be useful for disposing of roof runoff and reducing the overall runoff volume from a variety of building sites.
b) Infiltration of rooftop runoff from commercial or industrial buildings with pollution control, heating, cooling, or venting equipment may require UIC review and approval.

Standards

Chapter 4 and 11 of the current *Stormwater Quality Manual* include specific design standards and considerations for dry wells, which should be followed when implementing these BMPs.

4.4.6 Bioretention and Rain Gardens

Figure 4.26 – Bioretention at University of Connecticut Storrs Campus –Mansfield. Source: Connecticut Department of Environmental Protection.

Bioretention and rain gardens are shallow landscaped depressions designed to manage and treat storm water runoff. Bioretention systems are a variation of a surface sand filter, where the sand filtration media is replaced with a planted soil bed designed to remove pollutants through physical and biological processes (EPA, 2002). The concept of bioretention originated with the Prince Gorge's County, Maryland, Department of Environmental Resources in the early 1990s as an alternative to more traditional management practices. Storm water flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Treated water is allowed to infiltrate into the surrounding soils or is collected by an underdrain system and discharged to the storm drain system or receiving waters. Small-scale bioretention applications (i.e., residential yards, median strips, parking lot islands) are commonly referred to as rain gardens (*Figure 4.27*).

Figure 4.27 – Rain garden. Source: Connecticut Department of Environmental Protection.

Advantages

- Applicable to small drainage areas, storm water retrofits and highly developed sites.
- Can be applied to most sites due to relatively few constraints and many design variations (i.e., highly versatile).
- High solids, metals, and bacteria removal efficiency.
- Infiltrating bioretention can provide groundwater recharge.
- Helps to mimic predevelopment runoff conditions.
- Reduces need for end-of-pipe treatment.

Use

a) Bioretention may be used in a wide variety of settings including residential, commercial, and industrial areas.
b) May be decentralized (e.g., as rain gardens on individual lots) or centralized in common areas to manage multiple properties.
c) May be lined and underdrained; or designed to infiltrate and recharge groundwater.

Standards

Chapter 4 and 11 of the current *Stormwater Quality Manual* include specific design standards and considerations for bioretention, which should be followed when implementing these BMPs.

4.4.7 Infiltration Trenches

An infiltration trench is an excavated trench that has been back-filled with stone to form a subsurface basin. Stormwater runoff is diverted into the trench and is stored until it can be infiltrated into the soil, unusually over a period of 1 – 2 days.

Figure 4.28 – Infiltration trench. Source: Connecticut Department of Environmental Protection.

Advantages

- Applicable to small drainage areas, storm water retrofits and highly developed sites.
- High bacteria removal efficiency.

- Infiltration provides groundwater recharge.
- Helps to mimic predevelopment runoff conditions.
- Reduces need for end-of-pipe treatment.

Use

a) Infiltration may be useful for disposing of roof runoff (e.g., dry wells), or runoff from parking lots and roadways.
b) Infiltration trenches generally have a longer life cycle when hydrologically proceeded by pretreatment such as a vegetated filter strip.
c) Infiltration generally requires UIC review and approval.

Standards

Chapter 11 of the current *Stormwater Quality Manual* includes specific design standards and considerations for infiltration, which should be followed when implementing infiltration BMPs.

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