CHAPTER

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CHAPTER

1

STORM WATER MANAGEMENT SYSTEM PLANNING AND DESIGN

Section 1.1
Storm Water Site Planning

1.1.1 Overview

1.1.1.1 Introduction

In order to most effectively and efficiently manage storm water on new development and redevelopment sites, consideration of storm water runoff needs to be fully integrated into the site planning and design process. This involves a more comprehensive approach to site planning and a thorough understanding of the physical characteristics and natural resources of the site. In addition, the management of the quantity and the quality of storm water should be addressed in an integrated approach. The purpose of this manual is to provide design guidance and a framework for incorporating effective and environmentally sensitive storm water management into the site development process and to encourage a greater uniformity in developing plans for storm water management systems that meet the following goals:

- Control conveyance of runoff within and from the site to minimize flood risk to people and properties;
- Assess discharges from the site to minimize downstream bank and channel erosion; and
- Reduce pollutants in storm water runoff to protect water quality;

When designing the storm water management system for a site, a number of questions need to be answered by the site planners and design engineers, including:

- How can the storm water management system be designed to most effectively address the quality of runoff from the site, protect against increased streambank erosion, and meet flood control objectives?
- What are the opportunities for utilizing site design practices to minimize the need for and the size of structural storm water controls?
- What are the development site constraints that preclude the use of certain structural controls?
- What structural controls are most suitable and cost-effective for the site?

1.1.1.2 Five (5) Principles of Storm Water Management Site Planning

The following Five (5) Principles of Storm Water Management Site Planning should be kept in mind in preparing an iSWM Site Plan for a development or redevelopment site:

1. **The site design should utilize an integrated approach to deal with storm water quality protection, streambank protection, and flood control requirements.**

   The storm water management infrastructure for a site should be designed to integrate drainage and flood control, water quality protection, and downstream streambank protection. Site design should be done in unison with the design and layout of storm water infrastructure to better attain storm water management goals. Together, the combination of site design practices and effective infrastructure layout and design can mitigate the worst storm water impacts of most urban developments while preserving stream integrity and aesthetic attractiveness.

2. **Storm water management practices should strive to utilize the natural drainage system and require as little maintenance as possible.**

   Almost all sites contain natural features which can be used to help manage and mitigate runoff from development. Features on a development site might include natural drainage patterns, depressions, permeable soils, wetlands, floodplains, and undisturbed vegetated areas that can be used to reduce runoff; provide infiltration, and storm water filtering of pollutants and sediment; recycle nutrients; and maximize on-site storage of storm water.

   Site design should seek to supplement the effectiveness of natural systems rather than to ignore or replace them. Further, natural systems typically require low or no maintenance, and will continue to function many years into the future.

3. **Structural storm water controls should be implemented only after all site design and nonstructural options have been exhausted.**

   Operationally, economically, and aesthetically, storm water sensitive site design and the use of natural techniques offer significant benefits over structural storm water controls. Therefore, all opportunities for utilizing these methods should be explored before implementing structural storm water controls such as wet ponds.

4. **Structural storm water solutions should attempt to be multi-purpose and be aesthetically integrated into a site's design.**

   A structural storm water facility need not be an afterthought or ugly nuisance on a development site. A parking lot, soccer field, or city plaza can serve as a temporary storage facility for storm water. In addition, water features such as ponds and lakes, when correctly designed and integrated into a site, can increase the aesthetic value of a development.

5. **"One size does not fit all" in terms of storm water management solutions.**

   Although the basic problems of storm water runoff and the need for its management remain the same, each site, project, and watershed presents different challenges and opportunities. For instance, an infill development in a highly urbanized town center or downtown area will require a much different set of storm water management solutions than a low-density residential subdivision in a largely undeveloped watershed. Therefore, local storm water management needs to take into account differences between development sites, different types of development and land use, various watershed conditions and priorities, the nature of downstream lands and waters, and community desires and preferences.

1.1.2 *integrated* Storm Water Management (iSWM) Site Plans

1.1.2.1 Introduction

To encourage and ensure that the storm water management goals are addressed and that local storm water guidelines and requirements are implemented, communities adopting this manual shall implement a formal *integrated* Storm Water Management Site Plan or iSWM Site Plan preparation, submittal, and review process that facilitates open communication and understanding between the involved parties.

An iSWM Site Plan is a comprehensive report that contains the technical information and analysis to allow a community to determine whether the storm water management system of a proposed new development or redevelopment project meets the general storm water management goals and the local storm water regulatory requirements. This section discusses the typical contents of an iSWM Site Plan, the steps for a site developer to follow in preparing an iSWM Site Plan, and the recommended review and consultation checkpoints between the local government staff and the site developer.

The procedures and guidelines for the preparation of an iSWM Site Plan should be explicitly stated in a local ordinance. The ordinance, in turn, should refer to this Manual for additional detail. Ideally, site storm water plans are developed with open lines of communication between the developer (and developer's engineer) and the plan reviewer. iSWM Site Plans are an enhanced version of traditional drainage plans, and are more than just the preparation of a document and maps. Instead, iSWM Site Plans should be thought of as a subset of the overall development process that occurs throughout the planning and development cycle of a project and then continues after construction is completed via regular inspection and maintenance of the storm water management system.

1.1.2.2 Applicability

iSWM Site Planning is applicable to land disturbing activity of 1 acre or more where total impervious area is increased by more than 5% above the current land development conditions. The Local Criteria section may provide additional definition, restrictions, or exceptions to the applicability of iSWM Site Plans based on the size of the development, specific watershed conditions, or identified hotspots of concern within the local jurisdiction. (Hotspots are land uses or activities that produce higher concentrations of trace metals, hydrocarbons, or other priority pollutants. See page 5.1-8 for examples.)

New development or redevelopment in critical or sensitive areas, or as identified through a watershed study or plan, may be subject to additional performance and/or regulatory criteria. Furthermore, these sites may need to utilize certain structural controls in order to protect a special resource or address certain water quality or drainage problems identified for a drainage area or watershed.

All iSWM Site Plans shall be prepared and sealed by a Licensed Professional Engineer with a valid license from the State of Texas. The Engineer shall attest that the design was conducted in accordance with this integrated Storm Water Management Design Manual.

1.1.2.3 Contents of an iSWM Site Plan

The following elements are typical components of an iSWM Site Plan. Projects could be requested by the local jurisdiction to prepare a site plan that includes a defined subset of the elements outlined below.

1. **Existing Conditions Hydrologic Analysis**
2. **Project Description and Design Considerations**
3. **Post-Development Hydrologic Analysis**
4. **Storm Water Management System Design**
5. **Construction Storm Water Pollution Prevention Plan (SWPPP)**
6. **Landscaping Plan**

7. **Operations and Maintenance Plan**
8. **Evidence of Acquisition of Applicable Federal, State, and Local Permits**
9. **Waiver Requests**

The typical contents of each element are described further in the following sections.

1.1.3 Developer Steps to Prepare an iSWM Site Plan

1.1.3.1 Introduction

An iSWM Site Plan is a comprehensive report that contains the technical information and analysis to allow a local review authority to determine whether a proposed new development or redevelopment project meets the general storm water management goals and the local storm water regulatory requirements. The iSWM site plan shall consist of site layout mapping, narrative, supporting design calculations, and plans that sufficiently represent the proposed storm water management system (recommended scale of 1" = 50' unless otherwise specified).

This section describes the typical contents and general procedure for preparing an iSWM Site Plan. The level of detail involved in the plan will depend on the project size and the individual site and development characteristics.

Prior to beginning the steps to prepare an iSWM Site Plan, the site developer should read and understand the design approach and contents of this manual. Each of the following steps is carried forward and builds upon the previous steps to result in the Final iSWM Site Plan.

Step 1 - Consider the Five (5) Principles of Storm Water Management Site Planning

Step 2 - Review of Local Requirements

Step 3 - Perform Site Analysis and Inventory

Step 4 - Prepare Conceptual iSWM Site Plan

Step 5 - Prepare Preliminary iSWM Site Plan

Step 6 - Complete Final iSWM Site Plan

Worksheets are provided in Appendix E to assist with the development of the iSWM Site Plan.

1.1.3.2 Step 1 - Consider the Five (5) Principles of Storm Water Management Site Planning

The following principles should be kept in mind during all steps of preparing an iSWM Site Plan for a development site:

1. The site design should utilize an integrated approach to deal with storm water quality protection, streambank protection and flood control requirements.
2. Storm water management practices should strive to utilize the natural drainage system and require as little maintenance as possible.
3. Structural storm water controls should be implemented only after all site design and nonstructural options have been exhausted.
4. Structural storm water solutions should attempt to be multi-purpose and be aesthetically integrated into a site's design.
5. "One size does not fit all" in terms of storm water management solutions.

1.1.3.3 Step 2 - Review of Local Requirements

The site developer should become familiar with the local storm water management and development requirements and design criteria that apply to the site. These requirements are identified in the Local Criteria section of this manual and may include:

- Design storm frequencies
- Credits for use of *integrated* Site Design Practices
- Requirements for Water Quality Protection Volume, if applicable
- Requirements for Streambank Protection Volume
- Conveyance design criteria
- Floodplain criteria
- Buffer/setback criteria
- Wetland provisions
- Watershed-based criteria
- Erosion and sedimentation control plan
- Maintenance requirements
- Need for physical site evaluations (infiltration tests, geotechnical evaluations, etc.)
- Grading plan
- Storm Water Pollution Prevention Plan (SWPPP)

Much of this guidance can be obtained at a meeting with the local review authority and should be detailed in various local ordinances (e.g., subdivision regulations, storm water and drainage codes, etc.).

Current land use plans, comprehensive plans, zoning ordinances, road and utility plans, watershed or overlay districts, and public facility plans should all be consulted to determine the need for compliance with other local, state, and federal regulatory requirements. Guidance for applicable regulatory requirements is available in Appendix C.

Opportunities for special types of development (e.g., clustering) or special land use opportunities (e.g., conservation easements or tax incentives) should be investigated. There may also be an ability to partner with a local community for the development of greenways, or other riparian corridor or open space developments.

1.1.3.4 Step 3 - Perform Site Analysis and Inventory

Using approved field and mapping techniques, the site engineer shall collect and review information on the existing site conditions and map the following site features:

- Topography
- Drainage patterns and basins
- Intermittent and perennial streams
- Soils
- Ground cover and vegetation
- Existing development
- Existing storm water facilities

- Adjacent areas
- Property lines and easements

In addition, the site engineer shall identify and map all previously unmapped natural features such as:

- Wetlands
- Critical habitat areas
- Boundaries of wooded areas
- Floodplain boundaries
- Steep slopes
- Required buffers
- Proposed stream crossing locations
- Other required protection areas (e.g., well setbacks)

Some of this information may be available from previously performed studies or from a feasibility study. For example, some of the resource protection features may have been mapped as part of erosion and sediment control activities. Other recommended site information to map or obtain includes utilities information, seasonal groundwater levels, and geologic data.

Individual map or geographic information system (GIS) layers can be designed to facilitate an analysis of the site through what is known as map overlay, or a composite analysis. Each layer (or group of related information layers) is placed on the map in such a way as to facilitate comparison and contrast with other layers. A composite layer is often developed to show all the layers at the same time (see Figure 1.1.3-1). This composite layer can be a useful tool for defining the best buildable areas and delineating and preserving natural feature conservation areas.

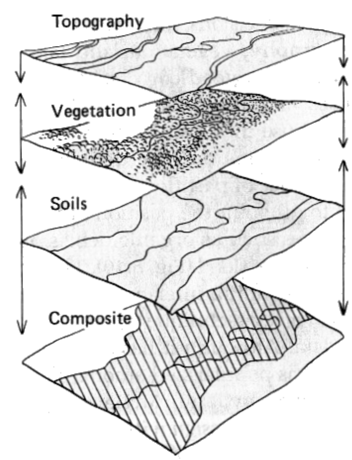

Figure 1.1.3-1
Composite Analysis
(Source: Marsh, 1983)

1.1.3.5 Step 4 - Prepare Conceptual iSWM Site Plan

Based upon the review of existing conditions and site analysis, the design engineer shall develop a Conceptual iSWM Site Plan for the project.

During the concept plan stage the site designer will perform most of the layout of the site including the conceptual storm water management system design and layout. The Conceptual iSWM Site Plan allows the design engineer to propose a potential site layout and gives the developer and local review authority a "first look" at the storm water management system for the proposed development. The Conceptual iSWM Site Plan should be submitted to the local plan reviewer before detailed preliminary site plans are developed.

The following steps shall be followed in developing the Conceptual iSWM Site Plan with the help of the Worksheet for Conceptual iSWM Site Plans found in Appendix E of this manual:

1. Use *integrated* site design practices (Section 1.3) as applicable to develop the site layout, including:
    - Preserving the natural feature conservation areas defined in the site analysis
    - Fitting the development to the terrain and minimizing land disturbance
    - Reducing impervious surface area through various techniques
    - Preserving and utilizing the natural drainage system wherever possible

2. Determine the credits for *integrated* site design (Section 1.3.4), and water quality volume reduction (Section 1.2.3.2) if applicable, to be accounted for in the design of structural and non-structural storm water controls on the site
3. Calculate conceptual estimates of the design requirements for water quality protection, streambank protection, and flood control (Section 1.2) based on the conceptual plan site layout
4. Perform screening and conceptual selection of appropriate structural storm water controls (Section1.4 and Chapter 5) and identification of potential siting locations

It is extremely important at this stage that storm water system design is integrated into the overall site design concept in order to best reduce the impacts of the development to the pre-developed drainage conditions as well as provide for the most cost-effective and environmentally sensitive approach. Using hydrologic calculations, the goal of mimicking pre-development conditions can serve a useful purpose in planning the storm water management system.

For local review purposes, following the Checklist found in Appendix E of this manual, the Conceptual iSWM Site Plan shall include site layout mapping and plans (recommended scale of 1" = 50' unless otherwise specified), which illustrate at a minimum:

Project Description

- Address and legal description of site
- Vicinity map
- Land use

Existing conditions

- Copy of applicable digital orthophotos showing proposed project boundaries
- A topographic map of existing site conditions (no greater than a 2-foot contour interval recommended) with drainage basin boundaries indicated and project boundaries shown
- Total size area (acres)
- Total impervious area as percentage (%) of total area
- Benchmarks used for site control
- Perennial and intermittent streams
- Mapping of predominant soils from USDA soil surveys
- Boundaries of existing predominant vegetation
- Location and boundaries of other natural feature protection and conservation areas such as wetlands, lakes, ponds, floodplains, stream buffers and other setbacks (e.g., drinking water well setbacks, septic setbacks, etc.)
- Location of existing roads, buildings, parking areas and other impervious surfaces
- Existing utilities (e.g., water, sewer, gas, electric) and easements
- Location of existing conveyance systems such as grass channels, swales, and storm drains
- Flow paths
- Location of floodplain/floodway limits and relationship of site to upstream and downstream properties and drainages
- Location and dimensions of existing channels, bridges or culvert crossings

Conceptual Site Layout

- Complete the iSWM Conceptual Plan Worksheet
- Hydrologic analysis to determine conceptual runoff rates, volumes, and velocities to support selection of Storm Water Controls
- Conceptual site design identifying *integrated* site design practices used

- Identification of storm water site design credits
- Identification and calculation of water quality volume reduction, if applicable
- Conceptual estimates of the three (3) storm design approach (Section 1.2) requirements
- Conceptual selection, location, and size of proposed structural storm water controls
- Conceptual limits of proposed clearing and grading
- Total proposed impervious area, as a percentage (%) of total area

The completed Conceptual iSWM Site Plan shall be submitted to the local review authority for review and comment.

1.1.3.6 Step 5 - Prepare Preliminary iSWM Site Plan

The Preliminary iSWM Site Plan ensures that requirements and criteria are being complied with and opportunities are being taken to minimize adverse impacts from the development. This step builds upon the data developed in the Conceptual iSWM Site Plan by refining and providing more detail to the concepts identified. The Worksheet for Preliminary iSWM Site Plan in Appendix E outlines the data that shall be included in the preliminary iSWM Site Plan.

The Preliminary iSWM Site Plan shall consist of maps, narrative, and supporting design calculations (hydrologic and hydraulic) for the proposed storm water management system, and shall include the following sections:

Existing Conditions Hydrologic Analysis

Provide an existing condition hydrologic analysis for storm water runoff rates, volumes, and velocities, which includes:

- Existing conditions data developed in the Conceptual iSWM Plan
- All existing storm water conveyances and structural control facilities
- Direction of flow and exits from the site
- Analysis of runoff provided by off-site areas upstream of the project site
- Methodologies, assumptions, site parameters and supporting design calculations used in analyzing the existing conditions site hydrology

Project Description and Design Considerations Provide an updated description of the project and the considerations and factors affecting the design approach that have changed between the conceptual and preliminary plans, including:

- A description of the overall project and the site plan showing facility locations, roadways, etc.
- A discussion of the applicable local criteria and how it will be integrated into the design of the project (see Local Criteria section)
- Identify the *integrated* Site Design Practices and their applicability to this site (see Section 1.3)
- If applicable, a discussion of Credits for *integrated* Site Design and their applicability to this site (see Section 1.3.4)
- A discussion of the water quality treatment techniques (pollution prevention practices) that are to be utilized on this site, if applicable
- A determination of groundwater recharge considerations, if applicable, for this site
- Identify hotspot land uses, if applicable, and how runoff will be addressed (see page 5.1-8 for examples of hotspots)

Post-Development Hydrologic Analysis

Provide a post-development hydrologic analysis using appropriate methods from Chapter 2 for storm water runoff rates, volumes, and velocities, which includes:

- A topographic map of developed site conditions (no greater than a 2-foot contour interval recommended) with the post-development basin boundaries indicated
- Total area of post-development impervious surfaces and other land cover areas for each subbasin affected by the project
- Runoff calculations for flood control and streambank protection for each subbasin, as well as any applicable water quality calculations
- Location and boundaries of proposed natural feature protection and conservation areas
- Documentation and calculations for any applicable site design credits or water quality volume reduction methods being utilized
- Methodologies, assumptions, site parameters and supporting design calculations used in analyzing the post-development conditions site hydrology
- Supporting documentation that there is existing streambank protection/reinforcement or that the planned development will provide such streambank protection downstream
- Supporting calculations for a downstream peak flow analysis to show safe passage of post-development design flows downstream. Document point downstream at which analysis ends, and how it was determined

In calculating runoff volumes and discharge rates, consideration may need to be given to any planned future upstream land use changes. Depending on the site characteristics and given local design criteria, upstream lands may need to be modeled as “existing condition” or “projected buildout/future condition” when sizing and designing on-site conveyances and storm water controls.

Storm Water Management System Design

Provide drawings and design calculations for the proposed storm water management system, including:

- A drawing or sketch of the storm water management system including the location of non-structural site design features and the placement of existing and proposed structural storm water controls. This drawing shall show design water surface elevations, storage volumes available from zero to maximum head, location of inlet and outlets, location of bypass and discharge systems, and all orifice/restrictor sizes.
- Narrative describing that appropriate and effective structural storm water controls from Chapter 5 have been selected
- Cross-section and profile drawings and design details for each of the structural storm water controls in the system. This should include supporting calculations to show that the facility is designed according to the applicable design criteria
- Hydrologic and hydraulic analysis of the storm water management system for all applicable design storms (should include stage-storage or outlet rating curves, and inflow and outflow hydrographs), refer to Chapters 2,3 and 4
- Documentation and supporting calculations to show that the storm water management system adequately meets the *integrated* Design Approach (Section 1.2)
- Drawings, design calculations and elevations for all existing and proposed storm water conveyance elements including storm water drains, pipes, culverts, catch basins, channels, swales and areas of overland flow, using guidance from Chapters 3 and 4

The completed Preliminary iSWM Site Plan shall be submitted to the local review authority for review and comment.

1.1.3.7 Step 6 - Complete Final iSWM Site Plan

The Final iSWM Site Plan adds further detail to the Preliminary iSWM Site Plan and reflects changes that are requested or required by the local review authority. The Final iSWM Site Plan, as outlined in the final iSWM Site Plan Worksheet in Appendix E, should include all of the revised elements of the Preliminary iSWM Site Plan as well as the following items:

Construction Storm Water Pollution Prevention Plan (SWPPP)

- Must contain all the elements specified in the iSWM Design Manual for Construction, local ordinances, and State regulations
- Sequence/phasing of construction and temporary stabilization measures
- Temporary structures that will be converted into permanent storm water controls

Landscaping Plan

- Arrangement of planted areas, natural areas, and other landscaped features on the site plan
- Information necessary to construct the landscaping elements shown on the plan drawings
- Descriptions and standards for the methods, materials, and vegetation that are to be used in the construction

Operations and Maintenance Plan

- Description of maintenance tasks, frequency of maintenance, responsible parties for maintenance, funding, access, and safety issues
- Reviewed and approved maintenance agreements

Evidence of Acquisition of Applicable Federal, State, and Local Permits

Description and copies of any applicable federal, state, and/or local environmental permits such as USACE Regulatory Program permits, 401 water quality certification, or construction TPDES permits. Permits must be obtained prior to or in conjunction with final plan submittal, including:

- Notice of Intent (NOI) or Construction Site Notice, as appropriate, for TPDES permits
- Permits obtained for any other storm water related development requirements (i.e. USACE Regulatory Program permits, erosion control, grading, water rights permits, TCEQ dam safety, etc.)

Waiver Requests

- Description of waiver requests

The completed Final iSWM Site Plan shall be submitted to the local review authority for final approval prior to any construction activities on the development site.

1.1.4 Local Community Plan Review Responsibilities

The iSWM Site Plans are to be reviewed by the local community. The approach recommended herein should be adopted by a community to adapt to its current plan review procedure. In most communities, part of their overall project approval process includes reviews of (1) Concept Plans, (2) Preliminary Plans, and (3) Final Plans.

The recommended approach is to incorporate the review of iSWM Site Plans into a community's current process, in an attempt to complement, not replace their overall process. Following is a brief discussion of each step with references to checklists that complement that procedure:

1. Concept Plan Stage

Review of the Conceptual iSWM Site Plan – During the concept plan stage the site designer will perform most of the layout of the site including the conceptual storm water management system design and layout. The Conceptual iSWM Site Plan allows the design engineer to propose a potential site layout and gives the developer and local review authority a "first look" at the storm water management system for the proposed development. The Conceptual iSWM Site Plan shall be submitted to and approved by the local plan reviewer before detailed preliminary site plans are developed.

It is in the Concept Plan Stage that the site developer is best able to integrate the storm water system design into the overall site design concept in order to reduce the impacts of the development, as well as provide for the most cost-effective and environmentally sensitive approach. This is done, in part, by evaluating and integrating as appropriate Credits for *integrated* Site Designs and Water Quality Protection Volume reduction. A recommended checklist for the Conceptual iSWM Site Plan Review is included in Appendix E of this Manual.

2. Preliminary Plan Stage

Review of Preliminary iSWM Site Plan - The preliminary plan ensures that local requirements and criteria are being complied with and opportunities are being taken to minimize adverse impacts from the development.

The Preliminary iSWM Site Plan shall consist of maps, narrative, and supporting design calculations (hydrologic and hydraulic) for the proposed storm water management system, and shall include the preliminary versions of the following iSWM Site Plan components:

a. Existing Conditions Hydrologic Analysis

b. Project Description and Design Considerations

c. Post-Development Hydrologic Analysis

d. Storm Water Management System Design

A recommended checklist for the Preliminary iSWM Site Plan Review is included in Appendix E of this Manual.

It shall be demonstrated that appropriate and effective storm water controls have been selected and adequately designed. The preliminary plan shall also include, among other things, street and site layout, delineation of natural feature protection and conservation areas, soils data, existing and proposed topography, relation of site to upstream drainage, limits of clearing and grading, and proposed methods to manage and maintain conservation areas (e.g., easements, maintenance agreements/responsibilities, etc.)

3. Final Plan Stage

Review Final iSWM Site Plan **-** The Final iSWM Site Plan adds further detail to the preliminary plan and reflects changes that are requested or required by the local review authority. The Final iSWM Site Plan shall include all of the revised elements from the preliminary plan as well as the following remaining items:

a. Construction Storm Water Pollution Prevention Plan (SWPPP)

b. Landscaping Plan

c. Operations and Maintenance Plan

d. Evidence of Acquisition of Applicable Federal, State, and Local Permits

e. Waiver Requests

A recommended checklist for the Final iSWM Site Plan Review is included in Appendix E of this Manual.

This process should be iterative. The reviewer should ensure that all submittal requirements have been satisfactorily addressed and permits, easements, and pertinent legal agreements (e.g., maintenance agreements, performance bond, etc.) have been obtained and/or executed.

The approved Final iSWM Site Plan shall be submitted during the platting development process to the local review authority for final approval. The iSWM Site Plan must be approved prior to the preliminary plat approval and prior to any construction activities on the development site. Approval of the Final iSWM Plan is the last major milestone in the storm water planning process. The remaining steps are to ensure the plan is installed, implemented, and maintained properly.

1.1.5 Local Community Responsibilities during Construction and Operation

After the iSWM Site Plan and the final plat have been prepared and approved, the project will move into construction and the ongoing operation of related facilities and storm water treatment areas. Again, most communities have as part of their overall process, steps to ensure that approved facilities are installed as approved and are appropriately maintained after construction. The approach recommended herein can be adopted by a community to adapt to its construction and facility review procedures. In most communities, part of their overall project process will include: (1) Construction Inspections and (2) Ongoing Maintenance Inspections.

The recommended approach is to incorporate the above steps into a community's current process, in an attempt to complement, not replace their overall process. The following steps are intended to provide a community with a review process and checklist that complement their current procedures:

1. Construction Inspections

Where possible, a pre-construction meeting shall occur before any clearing or grading is initiated on the site. This is the appropriate time to ensure that natural feature protection areas and limits of disturbance have been adequately staked and adequate erosion and sediment control measures are in place. This step ensures that the owner/developer, contractor, engineer, inspector, and plan reviewer can be sure that each party understands how the plan will be implemented on the site.

Project sites should periodically be inspected during construction by local agencies to ensure that conservation areas have been adequately protected and that storm water control and conveyance facilities are being constructed as designed. Inspection frequency may vary with regard to site size and location; however, monthly inspections are a minimum target. In addition, it is recommended that some inspections occur after larger storm events (e.g., 0.5 inches and greater to assure compliance with the TPDES Construction General Permit). The inspection process can prevent later problems that result in penalties and added cost to developers.

An added benefit of a formalized and regular inspection process is that it should help to motivate contractors to internalize regular maintenance of sediment controls as part of the daily construction operations and not disturb water quality area "set-asides." If necessary, a community can consider implementing a penalty system whereby things such as stop work orders could be issued.

A final inspection is needed to ensure that the construction conforms to the intent of the approved design. Prior to accepting the infrastructure components, issuing an occupancy permit, and releasing any applicable bonds, the review authority should ensure that: (1) temporary erosion control measures have been removed; (2) storm water controls are unobstructed and in good working order;

(3) permanent vegetative cover has been established in exposed areas; (4) any damage to natural feature protection and conservation areas has been mitigated; (5) conservation areas and buffers have been adequately marked or signed; and (6) any other applicable conditions have been met.

Record drawings of the structural storm water controls, drainage facilities, and other infrastructure components should also be acquired by the community, as they are important in the long-term maintenance of the facilities. The review authority should keep copies of the drawings and associated documents and develop a local storm water control inventory and data storage system. With geographic information systems (GIS) becoming more widely used, much of this data can be stored electronically.

2. Ongoing Maintenance Inspections

Ongoing inspection and maintenance of a project site's storm water management system is often the weakest component of storm water plans. It needs to be clearly detailed in the iSWM Site Plan which entity has responsibility for operation and maintenance of all structural storm water controls and drainage facilities. Often, the responsibility for maintenance is transferred from the developer and contractor to the owner. Communication about this important responsibility is usually inadequate. Therefore, communities may need to consider ways to notify property owners of their responsibilities. For example, notification can be made through a legal disclosure upon sale or transfer of property or public outreach programs may be instituted to describe the purpose and value of maintenance.

Ideally, preparation of maintenance plans should be a requirement of the iSWM Site Plan preparation and review process. A maintenance plan should outline the scope of activities, schedule, costs, funding source, and responsible parties. Vegetation, sediment management, access, and safety issues should also be addressed. In addition, the plan should address the testing and disposal of sediments that will likely be necessary and the ultimate replacement of structures as needed.

Annual inspections of storm water management facilities should be conducted by an appropriate local agency. Where chronic or severe problems exist, the local government should have the authority to remedy the situation and charge the responsible party for the cost of the work. This authority should be well established in an ordinance.

1.1.6 iSWM Site Plan Design Tools

There are several design tools that can be used by the developer, planner, and engineer in the development of an iSWM Site Plan for a specific project. The tools include the following, which are discussed in more detail in subsequent sections of this Manual:

***integrated* Planning and Design Approach** (Section 1.2)

- Design requirements to achieve water quality protection, streambank protection, and flood control goals

***integrated* Site Design Practices** (Section 1.3)

- Nonstructural approaches to be used during site planning

***integrated* Storm Water Controls** (Section 1.4)

- Controls to remove pollutants, regulate discharge, and/or convey storm water

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Section 1.2
integrated Planning and Design Approach

1.2.1 Introduction

This section presents an integrated approach for meeting the storm water runoff quality and quantity management goals by addressing the key adverse impacts of development on storm water runoff. The purpose is to provide guidance for designing a comprehensive storm water management system as part of the iSWM Site Plan to:

- Remove pollutants in storm water runoff to protect water quality;
- Assess discharge from the site to minimize downstream bank and channel erosion; and
- Control conveyance of runoff within and from the site to minimize flood risk to people and property.

The *integrated* Design Approach is a coordinated set of design standards that allow the site engineer to design and size storm water controls to address these goals. Each of the *integrated* Design Steps should be used in conjunction with the others to address the overall storm water impacts from a development site. When used as a set, the *integrated* Design Approach controls the entire range of hydrologic events, from the smallest runoff-producing rainfalls up to the 100-year, 24-hour storm. Through the *integrated* Design Approach, each community receives standardized options while retaining the flexibility to define their own program. The Local Criteria section of this manual specifies the options allowed and/or required by the community.

The design approach for each of the goals above is summarized in Table 1.2.1-1 below:

Table 1.2.1-1 Steps for *integrated* Design Approach for Storm Water Control and Impact Mitigation

Steps	Approach
Step 1: Downstream Assessment	Conduct a downstream assessment to the point at which the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. The assessment shall analyze downstream impacts from a development for three (3) storm events based on Local Criteria: (1) a “Streambank Protection” storm, either the 1- or 2-year, 24-hour event, (2) a “Conveyance” storm, either the 5-, 10-, or 25-year, 24-hour event, and (3) the “100-year” storm, a 100-year 24-hour storm event.
Step 2: Water Quality Protection	Achieve by conserving natural features, reducing impervious cover, and using the natural drainage system by applying the *integrated* Site Design Practices; as approved by the local jurisdiction. For enhanced water quality protection use one or both of the following options: (1) If required by the Local Criteria, treat the Water Quality Protection Volume (WQ_V) by reducing total suspended solids from the development site for runoff resulting from rainfalls of up to 1.5 inches (85th percentile storm); (2) Assist in implementing off-site community storm water pollution prevention programs/activities as designated in an approved storm water master plan or TPDES Storm Water permit.

Table 1.2.1-1 Steps for *integrated* Design Approach for Storm Water Control and Impact Mitigation	
Step 3: Streambank Protection	Provide streambank protection from erosion due to increased storm water volumes and velocities caused by development using one or more of the following options: (1) Determine acceptable downstream conditions; (2) Reinforce/stabilize downstream conditions; (3) Install storm water controls to maintain existing downstream conditions; (4) Provide on-site controlled release of the 1-year, 24-hour storm event over a period of 24 hours (Streambank Protection Volume, SP_V).
Step 4: Flood Control	Flood impact reduction may be achieved by a combination of on-site control, downstream protection, floodplain management, and/or other mitigation measures. Onsite: Minimize localized site flooding of streets, sidewalks, and properties by a combination of on-site storm water controls and conveyance systems. These systems will be designed for the "Streambank Protection" and "Conveyance" storm event frequencies. Depending upon their location, function, and the requirements of the local jurisdiction, the full build-out "100-year" storm event is to be conveyed on-site such that no resulting habitable structural flooding occurs. Downstream: Based on the downstream assessment, manage downstream flood impacts caused by the increase of storm water discharges from the development using one or more of following options: (1) Determine acceptable downstream conditions; (2) Provide adequate downstream conveyance systems, (3) Install storm water controls on-site to maintain existing downstream conditions; (4) In lieu of a downstream assessment, maintain existing on-site runoff conditions.

Figure 1.2.1-1 graphically illustrates the relative volume requirements of each of the *integrated* Design Steps and demonstrates that the pieces typically overlay one another. If the downstream assessment for flood control indicated upstream detention was needed to limit the discharge from a development, the volume requirement to achieve the downstream flood control requirement could also contain the volume needed to provide for Streambank Protection and, if required, Water Quality Protection. The appropriate type of detention facility could be designed with outlet controls to address each of the steps of the Design Approach. Obviously, detention may not be required in all situations, but consideration of site design practices and storm water controls that work together to meet all the requirements is what is important. The following sections describe the *integrated* Design Approach in more detail.

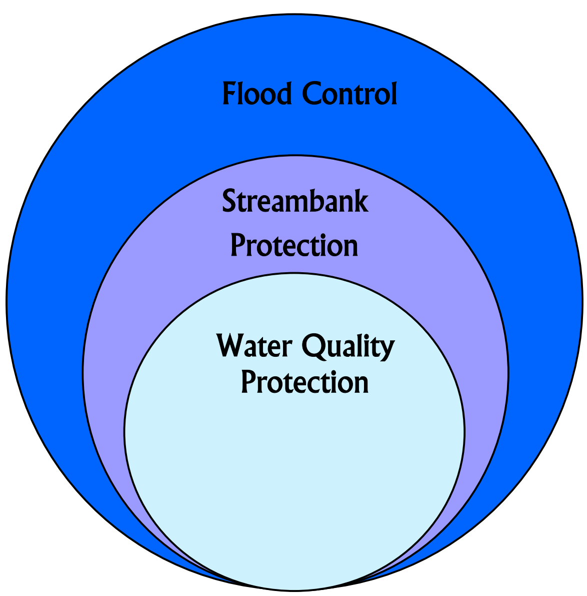

Figure 1.2.1-1 Representation of the *integrated* Design Approach

1.2.2 Downstream Assessment

As part of the iSWM Site Plan development, the downstream impacts of development must be carefully evaluated. The purpose of the downstream assessment is to protect downstream properties from increased flooding and downstream channels from increased erosion potential due to upstream development. The importance of the downstream assessment is particularly evident for larger sites or developments that have the potential to dramatically impact downstream areas. The cumulative effect of smaller sites, however, can be just as dramatic and, as such, following the *integrated* Design Approach is just as important for the smaller sites as it is for the larger sites.

The assessment should extend from the outfall of a proposed development to a point downstream where the discharge from a proposed development no longer has a significant impact on the receiving stream or storm drainage system. The assessment should be a part of the concept, preliminary, and final iSWM site plans, and should include the following properties:

- Hydrologic analysis of the pre- and post-development on-site conditions
- Drainage path which defines extent of the analysis.
- Capacity analysis of all existing constraint points along the drainage path, such as existing floodplain developments, underground storm drainage systems culverts, bridges, tributary confluences, or channels
- Offsite undeveloped areas are considered as "full build-out" for both the pre- and post-development analyses
- Evaluation of peak discharges and velocities for three (3) 24-hour storm events
  - Small-frequency storm for "Streambank Protection", either the 1- or 2-year event
  - A "Conveyance" storm of either the 5-, 10-, or 25-year event
  - A "100-year" storm event
- Separate analysis for each major outfall from the proposed development

Once the analysis is complete, the designer should ask the following three questions at each determined junction downstream:

- Are the post-development discharges greater than the pre-development discharges?
- Are the post-development velocities greater than the pre-development velocities?
- Are the post-development velocities greater than the velocities allowed for the receiving system?

These questions should be answered for each of the three storm events. The answers to these questions will determine the necessity, type, and size of non-structural and structural controls to be placed on-site or downstream of the proposed development. Section 2.1 gives additional guidance on calculating the discharges and velocities, as well as determining the downstream extent of the assessment.

1.2.3 Water Quality Protection

iSWM requires the use of *integrated* Site Design Practices as the primary means to protect the water quality of our streams, lakes, and rivers from the negative impacts of storm water runoff from development. A community should provide adequate water quality protection for development sites by specifying in their Local Criteria the acceptable *integrated* Site Design Practices for the local community. Enhanced water quality protection shall only be required as identified by the Local Criteria section of this manual.

<u>Use of *integrated* Site Design Practices</u>

Through the consideration and use of *integrated* Site Design practices, as discussed in Section 1.3, natural drainage and treatment systems can be preserved. With conservation of natural features, reduced imperviousness, and the use of the natural drainage system, the generation of storm water runoff and pollutants from the site is reduced.

Enhanced water quality protection can be achieved by use of one or both of the following two options:

Option 1: Treat the Water Quality Protection Volume

A municipality may identify specific watersheds with documented poor water quality and require design enhancements as a part of the on-site controls to address water quality protection. Therefore, using the Water Quality Protection Volume as required by the Local Criteria, storm water runoff generated from sites can be treated using a variety of on-site structural and nonstructural techniques with the goal of removing a target percentage of the average annual total suspended solids.

A system has been developed by which the Water Quality Protection Volume can be reduced, thus requiring less structural control. This is accomplished through the use of certain reduction methods, where affected areas can be deducted from the site area ("A") in the formula, thereby reducing the amount of runoff to be treated ("WQ_v"). For more information on the Water Quality Volume Reduction Methods see Section 1.2.3.2.

Option 2: Assist with Off-site Pollution Prevention Activities/Programs

Some communities may implement pollution prevention programs/activities in certain areas to remove pollutants from the runoff after it has been discharged from the site. This may be especially true in intensely urbanized areas facing site redevelopment where many of the BMP criteria would be difficult to apply. These programs will be identified in the local jurisdiction's approved TPDES storm water permit. In lieu of on-site treatment, the developer may be requested to simply assist with the implementation of these off-site pollution prevention programs/activities.

Through iSWM, each community receives standardized tools while retaining the flexibility to define their own program. The Local Criteria section of this manual allows for this flexibility.

1.2.3.1 Water Quality Protection Volume

Hydrologic studies show smaller, frequently occurring storms account for the majority of rainfall events. Consequently, the runoff from the many smaller storms also accounts for a major portion of the annual pollutant loadings. By treating these frequently-occurring, smaller rainfall events and the initial portion of the storm water runoff from larger events, it is possible to effectively mitigate the water quality impacts from a developed area.

Studies have shown the 85th percentile storm event (i.e., the storm event that is greater than 85% of the storms that occur) is a reasonable target event to address the vast majority of smaller, pollutant-loaded storms. Based on a rainfall analysis, 1.5 inches of rainfall has been identified as the average depth corresponding to the 85th percentile storm for the NCTCOG region. The runoff from these 1.5 inches of rainfall is referred to as the Water Quality Protection Volume (WQ_v). Thus, a storm water management system designed for the WQ_v will treat the runoff from all storm events of 1.5 inches or less, as well as a portion of the runoff for all larger storm events. The Water Quality Protection Volume is directly related to the amount of impervious cover and is calculated using the formula below:

$$WQ_v = \frac{1.5 R_v A}{12}$$

where:

WQ_v = Water Quality Protection Volume (in acre-feet)

R_v = 0.05 + 0.009(I) where I is percent impervious cover

A = site area in acres remaining after reduction

Determining the Water Quality Protection Volume (WQ_v)

- *Measuring Impervious Area*: The area of impervious cover can be taken directly off a set of plans or appropriate mapping. Where this is impractical, NRCS TR-55 land use/impervious cover relationships can be used to estimate impervious cover. I is expressed as a percent value not a fraction (e.g., I = 30 for 30% impervious cover)
- *Multiple Drainage Areas*: When a development project contains or is divided into multiple outfalls, WQ_v should be calculated and addressed separately for each outfall.
- *Water Quality Volume Reduction*: The use of certain *integrated* site design practices may allow the WQ_v to be reduced. These volume reduction methods are described in Section 1.2.3.3.
- *Determining the Peak Discharge for the Water Quality Storm:* When designing off-line structural control facilities, the peak discharge of the water quality storm (Q_{wq}) can be determined using the method provided in Section 2.1.10.2.
- *Extended Detention of the Water Quality Volume:* The water quality treatment requirement can be met by providing a 24-hour drawdown of a portion of WQ_v in a storm water pond or wetland system (as described in Chapter 5). Referred to as water quality ED (extended detention), it is different than providing extended detention of the 1-year storm for the streambank protection volume (SP_v). The ED portion of the WQ_v may be included when routing the SP_v.
- *Permanent Pool:* Wet ponds and wetlands will have permanent pools, the volume of which may be used to account for up to 50% of the WQ_v.
- WQ_v can be expressed in cubic feet by multiplying by 43,560. WQ_v can also be expressed in watershed-inches by removing the area (A) and the “12” in the denominator.

This approach to control pollution from storm water runoff treats the WQ_v from a site to reduce a target percentage of post-development total suspended solids (TSS). TSS was chosen as the representative storm water pollutant for measuring treatment effectiveness for several reasons:

- The measurement standard of using TSS as an “indicator” pollutant is well established.
- Suspended sediment and turbidity, as well as other pollutants of concern adhere to suspended solids, and are a major source of water quality impairment due to urban development in the region’s watersheds.
- A large fraction of many other pollutants of concern are removed either along with TSS, or at rates proportional to the TSS removal.

Even though TSS is a good indicator for many storm water pollutants, there are special cases that warrant further consideration including:

- The removal performance for pollutants that are soluble or that cannot be removed by settling must be specifically designed for. For pollutants of specific concern, individual analyses of specific pollutant sources should be performed and the appropriate removal mechanisms implemented.
- Runoff, which is atypical in terms of normal TSS concentrations, will be treated to a higher or lesser degree. For example, treatment of highly turbid waters would attain a higher removal percentage but still may not attain acceptable water quality without additional controls or a higher level of BMP maintenance.
- Bed and bank-material sediment loads not accurately measured by the TSS standard are also typically removed using this approach.
- Site, stream, or watershed specific criteria, different from the TSS standard, may be developed through a state or federal regulatory program necessitating a tailored approach to pollution prevention.

1.2.3.2 Water Quality Volume Reduction Methods

A set of storm water "volume reduction methods" is presented to provide developers and site designers an incentive to implement site designs that can reduce the volume of storm water runoff and minimize the pollutant loads from a site. The reduction directly translates into cost savings to the developer by reducing the size of structural storm water control and conveyance facilities.

The basic premise of the system is to recognize the water quality benefits of certain site design practices by allowing for a reduction in the water quality protection volume (WQ_v). If a developer incorporates one or more of the methods in the design of the site, the requirement for capture and treatment of the water quality protection volume will be reduced.

The methods by which the water quality volume can be reduced are listed in Table 1.2.3-1. Site-specific conditions will determine the applicability of each method. For example, the stream buffer reduction cannot be taken on upland sites that do not contain perennial or intermittent streams. Perennial streams flow 365 days a year in a normal year. Intermittent streams have short or lengthy periods of time when there is no flow in a normal year.

Table 1.2.3-1 Methods to Reduce the Water Quality Volume

Practice	Description
Natural area conservation	Undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics.
Stream buffers	Storm water runoff is treated by directing sheet flow runoff through a naturally vegetated or forested buffer as overland flow.
Use of vegetated channels	Vegetated channels are used to provide storm water treatment.
Overland flow filtration/infiltration zones	Overland flow filtration/infiltration zones are incorporated into the site design to receive runoff from rooftops and other small impervious areas.
Environmentally sensitive large lot subdivisions	A group of site design techniques are applied to low and very low density residential development.

Site designers are encouraged to use as many volume reduction methods as they can on a site. Greater reductions in storm water storage volumes can be achieved when many methods are combined (e.g., disconnecting rooftops and protecting natural conservation areas). However, volume reduction cannot be claimed twice for an identical area of the site (e.g. claiming a reduction for stream buffers and disconnecting rooftops over the same site area).

Due to local safety codes, soil conditions, and topography, some of these volume reduction methods may be restricted. Designers are encouraged to consult with the appropriate approval authority to ensure if and when a reduction is applicable and to determine restrictions on non-structural strategies.

The methods by which the water quality volume can be reduced are detailed below. For each volume reduction method, there is a minimum set of criteria and requirements that identify the conditions or circumstances under which the reduction may be applied. The intent of the suggested numeric conditions (e.g., flow length, contributing area, etc.) is to avoid situations that could lead to a volume reduction being granted without the corresponding reduction in pollution attributable to an effective site design modification.

Volume Reduction Method #1: Natural Area Conservation

A water quality volume reduction can be taken when undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics. Under this method, a designer would be able to subtract the conservation areas from the total site area when computing the water quality protection volume. An added benefit is that the post-development peak discharges will be smaller, and hence, water quantity control volumes will be reduced due to lower post-development curve numbers or rational formula "C" values.

Rule: Subtract conservation areas from total site area when computing water quality protection volume requirements.

Criteria:

- Conservation area cannot be disturbed during project construction and must be protected from sediment deposition.
- Shall be protected by limits of disturbance clearly shown on all construction drawings
- 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]
- Shall have a minimum contiguous area requirement of 10,000 square feet
- R_v is kept constant when calculating WQ_v
- Must be forested or have a stable, natural ground cover.

Example:

Residential Subdivision
Area = 38 acres
Natural Conservation Area = 7 acres
Impervious Area = 13.8 acres

R_v = 0.05 + 0.009 (I) = 0.05 + 0.009 (36.3%) = 0.38

Reduction:

7.0 acres in natural conservation area

New drainage area = 38 – 7 = 31 acres

Before reduction:
WQ_v = (1.5)(0.38)(38)/12 = 1.81 ac-ft

With reduction:
WQ_v = (1.5)(0.38)(31)/12 = 1.47 ac-ft

(19% reduction in water quality protection volume)

Volume Reduction Method #2: Stream Buffers

This reduction can be taken when a stream buffer effectively treats storm water runoff. Effective treatment constitutes treating runoff through overland flow in a naturally vegetated or forested buffer. Under the proposed method, a designer would be able to subtract areas draining via overland flow to the buffer from total site area when computing water quality protection volume requirements. In addition, the volume of runoff draining to the buffer can be subtracted from the streambank protection volume. The design of the stream buffer treatment system must use appropriate methods for conveying flows above the annual recurrence (1-yr storm) event.

Rule: Subtract areas draining via overland flow to the buffer from total site area when computing water quality protection volume requirements.

Criteria:

- The minimum undisturbed buffer width shall be 50 feet
- The maximum contributing length shall be 150 feet for pervious surfaces and 75 feet for impervious surfaces
- The average contributing slope shall be 3% maximum unless a flow spreader is used
- Runoff shall enter the buffer as overland sheet flow. A flow spreader can be installed to ensure this
- Buffers shall remain as naturally vegetated or forested areas and will require only routine debris removal or erosion repairs
- R_v is kept constant when calculating WQ_v
- Not applicable if overland flow filtration/groundwater recharge reduction is already being taken

Example:

Residential Subdivision
Area = 38 acres
Impervious Area = 13.8 acres
Area Draining to Buffer = 5 acres

$R_v = 0.05 + 0.009\ (I) = 0.05 + 0.009\ (36.3\%) = 0.38$

Reduction:

5.0 acres draining to buffer

New drainage area = 38 – 5 = 33 acres

Before reduction:
$WQ_v = (1.5)(0.38)(38)/12 = 1.81$ ac-ft

With reduction:
$WQ_v = (1.5)(0.38)(33)/12 = 1.57$ ac-ft

(13% reduction in water quality protection volume)

Volume Reduction Method #3: Enhanced Swales

This reduction may be taken when enhanced swales are used for water quality protection. Under the proposed method, a designer would be able to subtract the areas draining to an enhanced swale from total site area when computing water quality protection volume requirements. An enhanced swale can fully meet the water quality protection volume requirements for certain kinds of low-density residential development (see Volume Reduction Method #5). An added benefit is the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule: Subtract the areas draining to an enhanced swale from total site area when computing water quality protection volume requirements.

Criteria:

- This method is typically only applicable to moderate or low density residential land uses (3 dwelling units per acre maximum)
- The maximum flow velocity for water quality design storm shall be less than or equal to 1.0 feet per second
- The minimum residence time for the water quality storm shall be 5 minutes
- The bottom width shall be a maximum of 6 feet. If a larger channel is needed use of a compound cross section is required
- The side slopes shall be 3:1 (horizontal:vertical) or flatter
- The channel slope shall be 3 percent or less
- R_v is kept constant when calculating WQ_v

Example:

Residential Subdivision
Area = 38 acres
Impervious Area = 13.8 acres

R_v = 0.05 + 0.009 (I) = 0.05 + 0.009 (36.3%) = 0.38

Reduction:

12.5 acres meet enhanced swale criteria

New drainage area = 38 – 12.5 = 25.5 acres

Before reduction:
WQ_v = (1.5)(0.38)(38)/12 = 1.81 ac-ft

With reduction:
WQ_v = (1.5)(0.38)(25.5)/12 = 1.21 ac-ft

(33% reduction in water quality protection volume)

Volume Reduction Method #4: Overland Flow Filtration/Groundwater Recharge Zones

This reduction can be taken when “overland flow filtration/infiltration zones” are incorporated into the site design to receive runoff from rooftops or other small impervious areas (e.g., driveways, small parking lots, etc). This can be achieved by grading the site to promote overland vegetative filtering or by providing infiltration or “rain garden” areas. If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality protection volume requirements. An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule: If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality protection volume requirements.

Criteria:

- Relatively permeable soils (hydrologic soil groups A and B) should be present
- Runoff shall not come from a designated hotspot
- The maximum contributing impervious flow path length shall be 75 feet
- Downspouts shall be at least 10 feet away from the nearest impervious surface to discourage “re-connections”
- The disconnection shall drain continuously through a vegetated channel, swale, or filter strip to the property line or structural storm water control
- The length of the “disconnection” shall be equal to or greater than the contributing length
- The entire vegetative “disconnection” shall be on a slope less than or equal to 3 percent
- The surface imperviousness area to any one discharge location shall not exceed 5,000 square feet
- For those areas draining directly to a buffer, reduction can be obtained from either overland flow filtration *-or-* stream buffers (See Method #2)
- R_v is kept constant when calculating WQ_v

Example:

Site Area = 3.0 acres
Impervious Area = 1.9 acres (or 63.3% impervious cover)
“Disconnected” Impervious Area = 0.5 acres

R_v = 0.05 + 0.009 (I) = 0.05 + 0.009 (63.3%) = 0.62

Reduction:

0.5 acres of surface imperviousness hydrologically disconnected

New drainage area = 3 – 0.5 = 2.5 acres

Before reduction:
WQ_v = (1.5)(0.62)(3)/12 = 0.23 ac-ft

With reduction:
WQ_v = (1.5)(0.62)(2.5)/12 = 0.19 ac-ft

(17% reduction in water quality protection volume)

Volume Reduction Method #5: Environmentally Sensitive Large Lot Subdivisions

This reduction can be taken when a group of environmental site design techniques are applied to low and very low density residential development (e.g., 1 dwelling unit per 2 acres [du/ac] or lower). The use of this method can eliminate the need for structural storm water controls to treat water quality protection volume requirements. This method is targeted towards large lot subdivisions and will likely have limited application.

Rule: Targeted towards large lot subdivisions (e.g. 2 acre lots and greater). The requirement for structural practices to treat the water quality protection volume shall be waived.

Criteria:

For Single Lot Development:

- Total site impervious cover is less than 15%
- Lot size shall be at least two acres
- Rooftop runoff is disconnected in accordance with the criteria in Method #4
- Grass channels are used to convey runoff versus curb and gutter

For Multiple Lots:

- Total impervious cover footprint shall be less than 15% of the area
- Lot areas should be at least 2 acres, unless clustering is implemented. Open space developments should have a minimum of 25% of the site protected as natural conservation areas and shall be at least a half-acre average individual lot size
- Grass channels should be used to convey runoff versus curb and gutter (see Method #3)
- Overland flow filtration/infiltration zones should be established (see Method #4)

1.2.4 Streambank Protection

The increase in the frequency and duration of bankfull flow conditions in stream channels due to urban development is the primary cause of accelerated streambank erosion and the widening and downcutting of stream channels. Therefore, streambank protection criterion applies to all development sites for which there is an increase in the natural flows to downstream feeder streams, channels, ditches, and small streams.

There are four options by which a community can provide adequate streambank protection downstream of a proposed development. The local jurisdiction should specify in their Local Criteria which of these options are acceptable, as well as any other alternatives for streambank protection. If on-site or downstream improvements are required for streambank protection, easements or right-of-entry agreements may need to be obtained in accordance with the Local Criteria.

Option 1: Determine Acceptable Downstream Conditions

The developer should first determine if existing downstream streambank protection is adequate to convey storm water velocities for post-development conditions. This is accomplished by first obtaining post-developed velocities for the “Streambank Protection” storm event from the downstream assessment, as described in Section 1.2.2. These velocities are then compared to the allowable velocity of the downstream receiving system. Allowable velocities can be found in Chapter 4 in Tables 4.4-2 and 4.4-3. If the downstream system is designed to handle the increase in velocity, the developer should provide all supporting calculations and/or documentation to show that the stream integrity will not be compromised.

Option 2: Reinforce/Stabilize Downstream Conditions

If the increased velocities are higher than the allowable velocity of the downstream receiving system, then the developer may choose to reinforce/stabilize the downstream conveyance system. The proposed modifications must be designed so that the downstream post-development velocities (for the 3 storm events described in Section 1.2.2) are less than or equal to either the allowable velocity of the downstream receiving system or the pre-development velocities, whichever is higher. The developer must provide supporting calculations and/or documentation that the downstream velocities do not exceed the allowable range once the downstream modifications are installed. (See Tables 4.4-2 and 4.4-3 for allowable velocities.)

Option 3: Install Storm Water Controls On-site to Maintain Existing Downstream Conditions

The developer may also choose to use on-site controls to keep downstream post-development discharges at or below allowable velocity limits described in Option 2. The developer must provide supporting calculations and/or documentation that the on-site controls will be designed such that downstream velocities for the three (3) storm events described in Section 1.2.2 are within an allowable range once the controls are installed.

Option 4: Provide On-site Controlled Release of the Streambank Protection Volume

Another approach to streambank protection is to specify that 24 hours of extended detention be provided for on-site, post-developed runoff generated by the 1-year, 24-hour rainfall event to protect downstream channels. The required volume for extended detention is referred to as the Streambank Protection Volume (denoted SP_v). The reduction in the frequency and duration of bankfull flows through the controlled release provided by extended detention of the SP_v will reduce the bank scour rate and severity.

Determining the Streambank Protection Volume (SP_v)

- *SP_v Calculation Methods:* Several methods can be used to calculate the SP_v storage volume required for a site. Subsection 2.1.11 illustrates the recommended average outflow method for volume calculation.
- *Hydrograph Generation:* The SCS TR-55 hydrograph methods provided in Section 2.1.5 can be used to compute the runoff hydrograph for the 1-year, 24-hour storm.
- *Rainfall Depths:* The rainfall depth of the 1-year, 24-hour storm will vary depending on location and can be determined from the rainfall tables included in Appendix A for various locations across North Central Texas.
- *Multiple Drainage Areas*: When a development project contains or is divided into multiple outfalls, SP_v should be calculated and addressed separately for each outfall.
- *Off-site Drainage Areas:* A structural storm water control located "on-line" will need to safely bypass any off-site flows. Maintenance agreements may be required.
- *Routing/Storage Requirements:* The required storage volume for the SP_v must lie above the permanent pool elevation in storm water ponds. Wet ponds and wetlands will have permanent pools. The portion of the WQ_v above the permanent pool may be included when routing the SP_v.
- Hydraulic control structures appropriate for each storage requirement may be needed.
- *Control Orifices*: Orifice diameters for SP_v control of less than 3 inches are not recommended without adequate clogging protection (see Section 4.6). Clogging protection must be provided on all orifices.

1.2.5 Flood Control

Flood control analyses are based on the following three (3) storm events. The storm frequencies for each event shall be established in the Local Criteria section.

- *"Streambank Protection":* Either the 1- or 2-year, 24-hour storm event
- *"Conveyance"*: Either the 5-, 10-, or 25-year, 24-hour storm event
- "100-year" the 100-year, 24-hour storm event

The intent of the flood control criteria is to provide for public safety; minimize on-site and downstream flood impacts from the "Streambank Protection", "Conveyance", and "100-year" storm events; maintain the boundaries of the mapped 100-year floodplain; and protect the physical integrity of the on-site storm water controls and the downstream storm water and flood control facilities.

Flood control must be provided for on-site conveyance, as well as downstream outfalls as described in the following sections.

1.2.5.1 On-Site Conveyance

The "Conveyance" storm event is used to design standard levels of flood protection for streets, sidewalks, structures, and properties within the development. This is typically handled by a combination of conveyance systems including street and roadway gutters, inlets and drains, storm drain pipe systems, culverts, and open channels. Other storm water controls may affect the design of these systems.

The design storms used to size the various on-site conveyance systems will vary depending upon their location and function. For example, open channels, culverts, and street rights-of way are generally designed for larger events (25- to 100-year storm), whereas inlets and storm drain pipes are designed for smaller events (5- to 25-year storm). The requirements of the local jurisdiction should be obtained and utilized as shown in the Local Criteria section of this manual.

It is recommended that once the initial set of controls are selected in the iSWM Site Plan design, the full build-out 100-year, 24-hour storm be routed through the on-site conveyance system and storm water controls to determine the effects on the systems, adjacent property, and downstream areas. Even though the conveyance systems may be designed for smaller storm events, overall, the site should be designed appropriately to safely pass the resulting flows from the full build-out 100-year storm event with no flood waters entering habitable structures.

On-site flood control has many considerations for the safeguarding of people and property. On residential streets, for the "Conveyance" storm event, the safe passage of vehicular traffic is an important concern. For the 100-year storm events, traffic may be limited in order to utilize all or portions of the right-of-way for storm water conveyance in order to protect properties. As such, the effective management of storm water throughout the development for the full range of storm events is needed.

1.2.5.2 Downstream Flood Control

The downstream assessment is the first step in the process to determine if a specific development will have a flooding impact on downstream properties, structures, bridges, roadways, or other facilities. This assessment should be conducted downstream of a development to the point where the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system.. Hydrologic and hydraulic evaluations must be conducted to determine if there are areas of concerns, i.e. an increase of the Base Flood Elevations. The local jurisdiction should be consulted to obtain records and maps related to the National Flood Insurance Program and the availability of Flood Insurance Studies and Flood Insurance Rate Maps (FIRMs) which will be helpful in this assessment.

The downstream flood control criterion is based on an analysis of the "Streambank Protection" and "Conveyance" storm events, as well as the "100-year", defined as the 100-year, 24-hour storm event (denoted Q_{p100}). The local jurisdiction should quantify the frequency of the "Streambank Protection" and "Conveyance" storm events, as well as other events that may be required based on local policy or site-specific conditions, as identified in the Local Criteria section of this manual. If on-site or downstream modifications are required for downstream flood control, easements or right-of-entry agreements may need to be obtained in accordance with the Local Criteria.

Initially, the assessment will determine if the downstream receiving system has adequate capacity in its "full build-out" floodplain. To make this determination, Q_f, the runoff which the stream can handle without having an impact on downstream properties, structures, bridges, roadways, or other facilities, must be determined. There are four options by which a community can address downstream flood control. The local jurisdiction should specify in their Local Criteria which of these options are acceptable, as well as any other alternatives for downstream flood control. These options closely follow the four options for Streambank Protection.

<u>Option 1: Determine Acceptable Downstream Conditions</u>

The developer should provide all supporting calculations and/or documentation to show that the existing downstream conveyance system has capacity (Q_f) to safely pass the full build-out Q_{p100} discharge. Systems shown to be adequate are reflective of areas where attempts have been made to keep flood-susceptible development out of the "full build-out" floodplain through a combination of regulatory controls, storm water master planning, and incentives. This includes communities that have regulated floodplains for fully-developed conditions. This approach recognizes that the impacts of new development might not be completely mitigated at the extreme flood level and provides a much greater assurance that local flooding will not be a problem because people and structures are kept out of harm's way.

<u>Option 2: Provide Adequate Downstream Conveyance Systems</u>

If the downstream receiving system does not have adequate capacity, then the developer may choose to provide modifications to the off-site, downstream conveyance system. If this option is chosen the proposed modifications must be designed to adequately convey the full build-out storm water peak discharges for the three (3) storm events. The modifications must also extend to the point at which the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. The developer must provide supporting calculations and/or documentation that the downstream peak discharges and water surface elevations are safely conveyed by the proposed system, without endangering downstream properties, structures, bridges, roadways, or other facilities.

<u>Option 3: Install Storm Water Controls to Maintain Existing Downstream Conditions</u>

If the downstream receiving system does not have adequate capacity, then the developer may also choose to provide storm water controls to reduce downstream flood impacts. These controls include on-site controls such as detention, regional controls, and, as a last resort, local flood protection such as levees, floodwalls, floodproofing, etc. Storm water master plans are a necessity to attempt to ensure public safety for the extreme storm event. The developer must provide supporting calculations and/or documentation that the controls will be designed and constructed so that there is no increase in downstream peak discharges or water surface elevations due to development.

<u>Option 4: In lieu of a Downstream Assessment, Maintain Existing On-Site Runoff Conditions</u>

Lastly, on-site controls may be used to maintain the pre-development peak discharges from the site. The developer must provide supporting calculations and/or documentation that the on-site controls will be designed and constructed to maintain on-site existing conditions.

It is important to note that Option 4 does not require a downstream assessment. It is a detention-based approach to addressing downstream flood control after the application of the *integrated* site design practices. For many developments however, the results of a downstream assessment may show that significantly less flood control is required than "detaining to pre-development conditions". This method may also exacerbate downstream flooding problems due to timing of flows as discussed in Section 2.1.9. Therefore, it is strongly recommended that a downstream assessment be performed for all developments, and that Option 4 only be used when Options 1, 2, and 3 are not feasible.

The following items should be considered when providing downstream flood control.

- *Peak-Discharge and Hydrograph Generation:* Hydrograph methods provided in Section 2.1 can be used to compute the peak discharge rate and runoff for the three (3) storm events ("Streambank Protection", "Conveyance", and 100-year).
- *Rainfall Depths:* The rainfall depth of the three storm events will vary depending on location and can be determined from rainfall tables included in Appendix A for various locations across North Central Texas.
- *Off-site Drainage Areas:* Off-site drainage areas should be modeled as "full build-out" for the three storm events to ensure safe passage of future flows.
- *Downstream Assessment:* If flow is being detained on-site, downstream areas should be checked to ensure there is no peak flow or water surface increase above pre-development conditions to the point where the undetained discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. More detail on Downstream Assessments is given in Section 2.1.9.

1.2.6 *integrated* Watershed Planning

1.2.6.1 Introduction

Storm water master planning is an important tool used to assess and prioritize both existing and potential future storm water problems and to consider alternative storm water management solutions. A storm water master plan is prepared to consider, in detail, what storm water management practices and measures are to be provided for an urban drainage area or a large development project.

Storm water master plans are most often used to address specific single functions such as drainage provision, flood mitigation, cost/benefit analysis, or risk assessment. These plans prescribe specific management alternatives and practices. Multi-objective storm water master planning broadens this traditional definition to potentially include land use planning and zoning, water quality, habitat, recreation, and aesthetic considerations. The broadest type of storm water master plan is the comprehensive watershed plan which is described in detail in this chapter.

For any storm water master plan, it is important at the outset to: (1) clearly identify and quantify the objectives and issues the plan will address; (2) recognize the constraints (technical, political, legal, financial, social, physical) that limit the possible solutions; and (3) develop a clear technical approach that will address the key issues and needs while staying within the constraints to potential solutions.

1.2.6.2 Types of Storm Water Master Planning

There are several basic types of storm water master plans that can be prepared. The Local Criteria section should specify whether and how master planning is applicable within the local jurisdiction. Below are descriptions of representative types of master plans.

Flood Assessment Master Plans

Flood assessment is the simplest form of storm water master planning where only the essential components, alignments, and functions of a drainage system are analyzed. The focus of these studies is on water quantity control and flood prevention and/or mitigation.

Frequently, a flood assessment study analyzes both existing conditions and projected future build-out conditions. The study is based upon estimates (usually modeled) of peak and total discharges for selected return period runoff events. The selected events should be based on local standards. Both the hydrology and hydraulics of the system are analyzed to determine water surface profiles and elevations. This, in turn, assists in determining probable locations where impacts can be expected to occur. Frequently, an alternatives analysis will be performed as part of the master plan to provide potential solutions to mitigating the flood impacts. This typically involves the modeling of proposed modifications or development scenarios.

Examples include examining the effects of detention on flooding and providing improved flood protection (e.g., flood proofing structures, levies, etc). A local community might develop HEC-HMS and HEC-RAS models for the hydrology and hydraulics of a watershed for the purposes of estimating the full build-out floodplain and regulating new development on this basis rather than the ever-changing “existing conditions” approach.

Flood Study Cost/Benefit Analysis Master Plans

Another type of master planning builds on a flood assessment master plan to determine acceptable risks and the associated costs. Using information developed in the flood analysis, economic and/or environmental impacts can be assessed. This initially entails establishing a relation between water surface elevation and associated damage (often referred to as stage-damage curves). Based on this relationship, an acceptable level of risk is determined, from which design discharges and associated water surface profiles and elevations are established. Acceptable levels of risk might be based upon the likelihood of loss of human life, impacts to residences, impacts to non-residential structures, or damage to utilities. This information then is used to determine the ultimate drainage infrastructure that will be needed to achieve the planning goals. Both a formal benefit-cost analyses and a more subjective “cost-effectiveness” approach could be used. Based on the design criteria, preliminary designs can be developed which in turn yield initial cost estimates for the infrastructure.

For example, a community might look at different flood protection strategies along a stream and estimate the costs and flood damage savings for each alternative in an effort to select the most appropriate solution(s) for that community.

Water Quality Master Plans

Master planning for storm water quality is becoming increasingly important, as nonpoint source loads are a critical component of watershed-wide water quality assessments. It may become necessary to estimate pollutant loads from storm water runoff to determine Total Maximum Daily Loads (TMDL’s), as well as for the expansion of wastewater treatment facilities. A water quality master plan can provide the foundation from which to develop broader water quality assessments. Storm water quality studies will typically analyze water quality impacts to receiving waters (and groundwater) and develop structural and nonstructural strategies to reduce or minimize the pollutant loads. Studies usually involve the development, calibration, and verification of a water quality model. The level of model sophistication can vary from simple to complex. Often, a cost/benefit analysis will be performed as a component of the water quality study to quantify the efficacy of various strategies.

For example, a community might develop a simple spreadsheet-based loading model to perform planning level analyses of loadings of pollutants, potential removal by storm water controls, and the impacts of development strategies—or they may use a more complex continuous simulation water quality model and supporting monitoring to develop a combination of point and non-point source loading estimates in support of a watershed assessment or TMDL.

Biological/Habitat Master Plans

Biological/habitat master planning is similar to a water quality master plan. However, rather than focusing on water chemistry, the focus is on the aquatic biological communities and supporting habitats. Biological assessments are being implemented on a more frequent basis to assess overall water body health. Biological studies provide the ability to assess both acute and long-term effects of nonpoint source impacts to a receiving water in the absence of continuous monitoring data. The resulting data can be used in the design and development of habitat improvements, stream restoration projects, riparian buffers, structural control retrofits, etc.

For example, a community may desire to improve the quality and aesthetics of a stream. Biological monitoring and habitat assessment establishes the baseline health of the stream and can be compared to a reference stream in the area. This information is assessed to determine causes of impairment (often paired with chemical monitoring) and methods to reduce impairment are investigated. The plan might then include riparian corridor planning, land use zoning changes, and planned habitat restoration.

Comprehensive Watershed Master Plans

The comprehensive watershed approach is the most general type of storm water master planning as well as the most extensive. The intent of a comprehensive watershed plan is to assess the health of the existing water resources and to make informed land use and storm water planning decisions. These decisions are based on the current and projected land use and development within the targeted watershed and its associated subwatersheds. Watershed-based water quantity and water quality goals are typically aimed at maintaining the pre-development hydrologic and water quality conditions to the extent practicable through peak discharge control, volume reduction, groundwater recharge, channel protection, and flood protection. In addition, watershed plans may also promote a wide range of additional goals including streambank and stream corridor restoration, habitat protection, protection of historical and cultural resources, and enhancement of recreational opportunities, aesthetic, and quality of life issues.

Watershed-based studies often involve a holistic approach to master planning, where hydrology, geomorphology, habitat, water quality, and biological community impacts are analyzed and solutions are developed.

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CHAPTER

1

Section 1.3
integrated Site Design Practices

1.3.1 Overview

1.3.1.1 Introduction

The first step in addressing storm water management begins with the site planning and design process. Development projects can be designed to reduce their impact on watersheds when careful efforts are made to conserve natural areas, reduce impervious cover, and better integrate storm water treatment. By implementing a combination of these nonstructural approaches collectively known as *integrated* site design practices, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some nonstructural on-site treatment and control of runoff. The goals of *integrated* site design include:

- Managing storm water (quantity and quality) as close to the point of origin as possible and minimizing collection and conveyance
- Preventing storm water impacts rather than mitigating them
- Utilizing simple, nonstructural methods for storm water management that are lower cost and lower maintenance than structural controls
- Creating a multifunctional landscape
- Using hydrology as a framework for site design
- Reducing the peak runoff rates and volumes, therefore, reducing the size and cost of drainage infrastructure and structural storm water controls

Integrated site design for storm water management includes a number of site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact, reducing the amount of impervious surfaces, and utilizing natural features on the site for storm water management. The aim is to reduce the environmental impact "footprint" of the site while retaining and enhancing the owner/developer's purpose and vision for the site. Many of the *integrated* site design practices can reduce the cost of infrastructure while maintaining or even increasing the value of the property.

Reduction of adverse storm water runoff impacts through the use of *integrated* site design should be the first consideration of the design engineer. Operationally, economically, and aesthetically, the use of *integrated* site design practices offers significant benefits over treating and controlling runoff downstream. Therefore, all opportunities for using these methods should be explored and all options exhausted before considering structural storm water controls.

The reduction in runoff and pollutants using *integrated* site design can reduce the required runoff peak and volumes that need to be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and structural storm water controls. In some cases, the use of *integrated* site design practices may eliminate the need for structural controls entirely. Hence, *integrated* site design practices can be viewed as both a water quantity and water quality management tool.

To provide an incentive for the use of the *integrated* Site Design Practices, point values may be assigned to each practice. Depending on the amount of points accumulated for a particular development, various types of credits can be granted by the local jurisdiction. Section 1.3.4 describes an example point system and credits in more detail. Furthermore, several of the site design practices described in this section provide a calculable reduction in the volume requirements for Water Quality Protection. Section 1.2.3.2 discusses these reduction opportunities and provides examples of their application.

The use of storm water *integrated* site design also has a number of other ancillary benefits including:

- Reduced construction costs
- Increased property values
- More open space for recreation
- More pedestrian friendly neighborhoods
- Protection of sensitive forests, wetlands, and habitats
- More aesthetically pleasing and naturally attractive landscape
- Easier compliance with wetland and other resource protection regulations

1.3.1.2 List of *integrated* Site Design Practices and Techniques

The *integrated* site design practices and techniques covered in this manual are grouped into four categories and are listed below:

- Conservation of Natural Features and Resources
    - Preserve Undisturbed Natural Areas
    - Preserve Riparian Buffers
    - Avoid Floodplains
    - Avoid Steep Slopes
    - Minimize Siting on Porous or Erodible Soils
- **Lower Impact Site Design Techniques**
    - Fit Design to the Terrain
    - Locate Development in Less Sensitive Areas
    - Reduce Limits of Clearing and Grading
    - Utilize Open Space Development
    - Consider Creative Designs
- Reduction of Impervious Cover
    - Reduce Roadway Lengths and Widths
    - Reduce Building Footprints
    - Reduce the Parking Footprint
    - Reduce Setbacks and Frontages
    - Use Fewer or Alternative Cul-de-Sacs
    - Create Parking Lot Storm Water "Islands"
- Utilization of Natural Features for Storm Water Management
    - Use Buffers and Undisturbed Areas
    - Use Natural Drainageways Instead of Storm Sewers
    - Use Vegetated Swale Instead of Curb and Gutter
    - Drain Rooftop Runoff to Pervious Areas

More detail on each site design practice is provided in the *integrated* Site Design Practice Summary Sheets in subsection 1.3.2. The Summary Sheets are after the work of the Center for Watershed Protection found in its 1998 publication **Better Site Design: A Handbook for changing Development Rules in Your Community**. These summaries provide the key benefits of each practice, examples, and details on how to apply them in site design.

1.3.1.3 Using *integrated* Site Design Practices

Site design should be done in unison with the design and layout of storm water infrastructure in attaining storm water management goals. Figure 1.3.1-1 illustrates the *integrated* site design process that utilizes the four *integrated* site design categories.

Figure 1.3.1-1 *integrated* Site Design Process

The first step in *integrated* site design involves identifying significant natural features and resources on a site such as undisturbed forest areas, stream buffers and steep slopes that should be preserved to retain some of the original hydrologic function of the site.

Next, the site layout is designed such that these conservation areas are preserved and the impact of the development is minimized. A number of techniques can then be used to reduce the overall imperviousness of the development site.

Finally, natural features and conservation areas can be utilized to serve storm water quantity and quality management purposes.

1.3.2 *integrated* Site Design Practices

1.3.2.1 Conservation of Natural Features and Resources

Conservation of natural features is integral to *integrated* site design. The first step in the *integrated* site design process is to identify and preserve the natural features and resources that can be used in the protection of water resources by reducing storm water runoff, providing runoff storage, reducing flooding, preventing soil erosion, promoting infiltration, and removing storm water pollutants. Some of the natural features that should be taken into account include:

- Areas of undisturbed vegetation
- Floodplains and riparian areas
- Ridge tops and steep slopes
- Natural drainage pathways
- Intermittent and perennial streams
- Wetlands
- Aquifers and recharge areas
- Soils
- Shallow bedrock or high water table
- Other natural features or critical areas

Some of the ways used to conserve natural features and resources described over the next several pages include the following methods:

- Preserve Undisturbed Natural Areas
- Preserve Riparian Buffers
- Avoid Floodplains
- Avoid Steep Slopes
- Minimize Siting on Porous or Erodible Soils

Delineation of natural features is typically done through a comprehensive site analysis and inventory before any site layout design is performed (see Subsection 1.1.3.4). From this site analysis, a concept plan for a site can be prepared that provides for the conservation and protection of natural features. Figure 1.3.2-1 shows an example of the delineation of natural features on a base map of a development parcel.

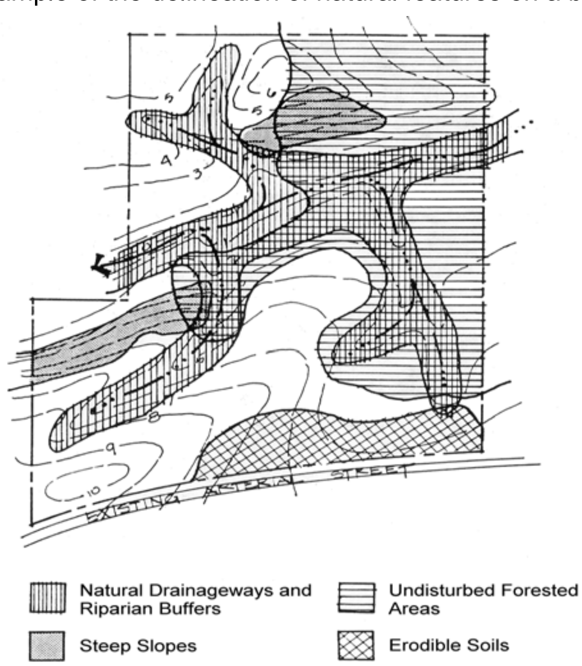


Figure 1.3.2-1 Example of Natural Feature Delineation
(Source: MPCA, 1989)

integrated Site Design Practice #1:
Preserve Undisturbed Natural Areas

Conservation of Natural Features and Resources

Description: Important natural features and areas such as undisturbed forested and vegetated areas, natural drainageways, stream corridors, wetlands and other important site features should be delineated and placed into conservation areas.

KEY BENEFITS	USING THIS PRACTICE
• Helps to preserve a portion of the site's natural predevelopment hydrology • Can be used as nonstructural storm water filtering and infiltration zones • Helps to preserve the site's natural character and aesthetic features • May increase the value of the developed property • A storm water site design credit can be taken if allowed by the local review authority	☑ Delineate natural areas before performing site layout and design ☑ Ensure that conservation areas are protected in an *undisturbed state* throughout construction and occupancy

Discussion

Preserving natural conservation areas such as undisturbed forested and vegetated areas, natural drainageways, stream corridors and wetlands on a development site helps to preserve the original hydrology of the site and aids in reducing the generation of storm water runoff and pollutants. Undisturbed vegetated areas also stabilize soils, provide for filtering and infiltration, decreases evaporation, and increases transpiration.

Natural conservation areas are typically identified through a site analysis using maps and aerial/satellite photography, or by conducting a site visit. These areas should be delineated before any site design, clearing or construction begins. When done before the concept plan phase, the planned conservation areas can be used to guide the layout of the site. Figure 1.3.2-2 shows a site map with undisturbed natural areas delineated.

Conservation areas should be incorporated into site plans and clearly marked on all construction and grading plans to ensure equipment is kept out of these areas and native vegetation is kept in an undisturbed state. The boundaries of each conservation area should be mapped by carefully determining the limit that should not be crossed by construction activity.

Once established, natural conservation areas must be protected during construction and managed after occupancy by a responsible party able to maintain the areas in a natural state in perpetuity. Typically, conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements. Permanent signage and fences should be required.

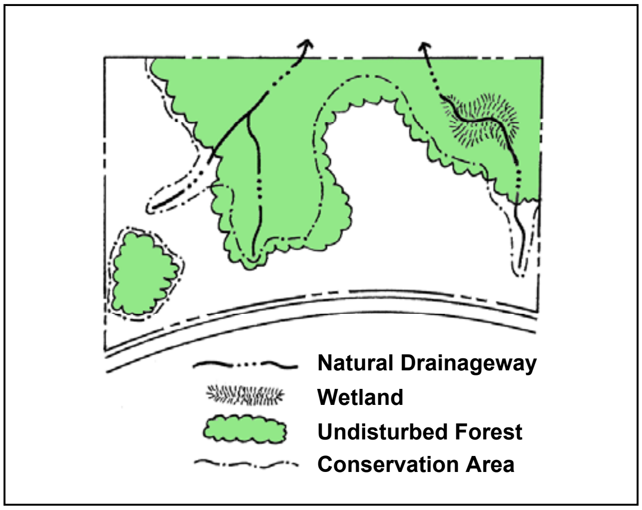


Figure 1.3.2-2 Delineation of Natural Conservation Areas

integrated Site Design Practice #2:
Preserve Riparian Buffers

Conservation of Natural Features and Resources

Description: Naturally vegetated buffers should be delineated and preserved along perennial streams, rivers, lakes, and wetlands.

KEY BENEFITS	USING THIS PRACTICE
▪ filtering and infiltration zones ▪ provides a right-of-way for large flood events ▪ habitats ▪ be taken if allowed by the local review authority	☑ Delineate and preserve naturally vegetated riparian buffers ☑ Ensure buffers and native vegetation are protected throughout construction and occupancy

Discussion

A riparian buffer is a special type of natural conservation area along a stream, wetland or shoreline where development is restricted or prohibited. The primary function of buffers is to protect and physically separate a stream, lake or wetland from future disturbance or encroachment. If properly designed, a buffer can provide storm water management functions, can act as a right-of-way during floods, and can sustain the integrity of stream ecosystems and habitats. An example of a riparian stream buffer is shown in Figure 1.3.2-3.

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. A riparian buffer can be of fixed or variable width, but should be continuous and not interrupted by impervious areas that would allow storm water to concentrate and flow into the stream without first flowing through the buffer.

Figure 1.3.2-3 Riparian Stream Buffer

Ideally, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and wetlands. The buffer depth needed to perform properly will depend on the size of the stream and the surrounding conditions, but a minimum 25-foot undisturbed vegetative buffer is needed for even the smallest perennial streams and a 50-foot or larger undisturbed buffer is ideal. Even with a 25-foot undisturbed buffer, additional zones can be added to extend the total buffer to at least 75 feet from the edge of the stream. The three distinct zones within the 75-foot depth are shown in Figure 1.3.2-4. The function, vegetative target and allowable uses vary by zone as described in Table 1.3.2-1.

These recommendations are minimum standards to apply to most streams. Some streams and watershed may require additional measures to achieve protection. In some areas, specific state laws or local ordinances already require stricter buffers than are described here. The buffer widths discussed are not intended to modify or supercede deeper or more restrictive buffer requirements already in place.

As stated above, the streamside or inner zone should consist of a minimum of 25 feet of undisturbed mature forest. 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. 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. An outer zone allows more clearing and acts as a further setback for impervious surfaces. It also functions to prevent encroachment and filter runoff. In the outer zone, flow into the buffer should be transformed from concentrated flow into sheet flow to maximize ground contact with the runoff.

Development within the riparian buffer should be limited only to those structures and facilities that are absolutely necessary. Such limited development should be specifically identified in any codes or ordinances enabling the buffers. When construction activities do occur within the riparian corridor, specific mitigation measures should be required, such as larger buffers or riparian buffer improvements.

Generally, the riparian buffer should remain in its 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.

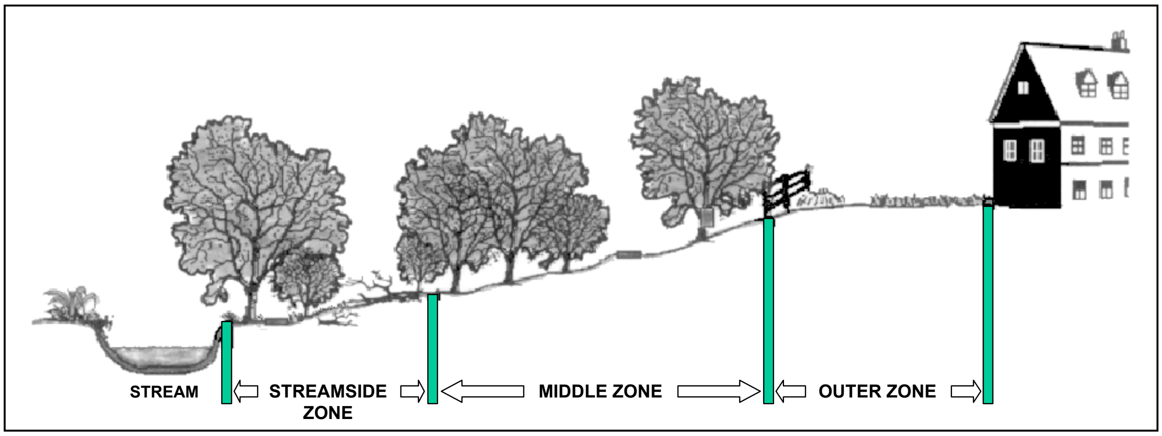


Figure 1.3.2-4 Three-Zone Stream Buffer System

Table 1.3.2-1 Riparian Buffer Management Zones

	Streamside Zone	Middle Zone	Outer Zone
Width	Minimum 25 feet plus wetlands and critical habitat	Variable depending on stream order, slope, and 100-year floodplain (min. 25 ft)	25-foot minimum setback from structures
Vegetative Target	Undisturbed mature forest. Reforest if necessary.	Managed forest, some clearing allowed.	Forest encouraged, but turf grass at a minimum
Allowable Uses	**Very Restricted** e.g., flood control, utility easements, footpaths	**Restricted** e.g., some recreational uses, some storm water controls, bike paths	**Unrestricted** e.g., residential uses including lawn, garden, most storm water controls

integrated Site Design Practice #3: Avoid Floodplains

Conservation of Natural Features and Resources

Description: Floodplain areas should be avoided for homes and other structures to minimize risk to human life and property damage, and to allow the natural stream corridor to accommodate flood flows.

KEY BENEFITS	USING THIS PRACTICE
▪ storage for large flood events ▪ way ▪ habitats ▪ protection to create linear greenways	☑ Obtain maps of the 100-year floodplain from the local review authority ☑ Ensure all development activities do not encroach on the designated floodplain areas

Discussion

Floodplains are the low-lying lands 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 by filtering runoff, and provide habitat for both aquatic and terrestrial life. Development in floodplain areas can reduce the ability of the floodplain to convey storm water, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties. Most communities regulate the use of floodplain areas to minimize the risk to human life as well as to avoid flood damage to structures and property.

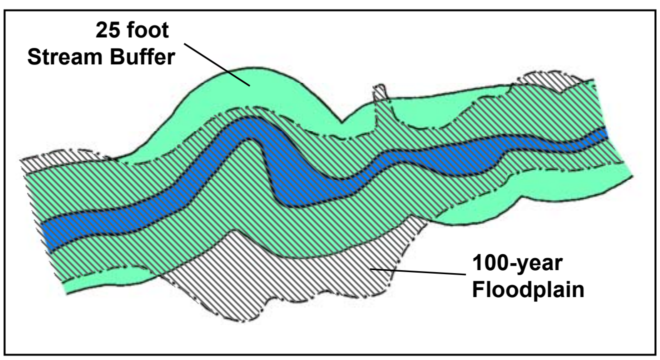


Figure 1.3.2-5 Floodplain Boundaries in Relation to a Riparian Buffer

As such, floodplain areas should be avoided on a development site. Ideally, the entire 100-year full-buildout floodplain should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. Floodplain protection is complementary to riparian buffer preservation. Both of these *integrated* site design practices preserve stream corridors in a natural state and allow for the protection of vegetation and habitat. Depending on the site topography, 100-year floodplain boundaries may lie inside or outside of a preserved riparian buffer corridor, as shown in Figure 1.3.2-5.

Maps of the 100-year floodplain can typically be obtained through the local review authority. Developers and builders should also ensure their site designs comply with any other relevant local floodplain and FEMA requirements.

integrated Site Design Practice #4:
Avoid Steep Slopes

Conservation of Natural Features and Resources

Description: Steep slopes should be avoided due to the potential for soil erosion and increased sediment loading. Excessive grading and flattening of hills and ridges should be minimized.

KEY BENEFITS	USING THIS PRACTICE
▪ erosion and degradation of storm water runoff quality ▪ natural condition to help stabilize hillsides and soils ▪ for cut-and-fill and grading	☑ Avoid development on steep slope areas, especially those with a grade of 15% or greater. ☑ Minimize grading and flattening of hills and ridges

Discussion

Developing on steep slope areas has the potential to cause excessive soil erosion and increased storm water runoff during and after construction. Past studies by the SCS (now NRCS) and others have shown that soil erosion is significantly increased on slopes of 15% or greater. In addition, the nature of steep slopes means that greater areas of soil and land area are disturbed to locate facilities on them compared to flatter slopes as demonstrated in Figure 1.3.2-6.

Therefore, development on slopes with a grade of 15% or greater should be avoided if possible to limit soil loss, erosion, excessive storm water runoff, and the degradation of surface water. Excessive grading should be avoided on all slopes, as should the flattening of hills and ridges. Steep slopes should be kept in an undisturbed natural condition to help stabilize hillsides and soils. If slopes are already bare and eroding, controls to stabilize and revegetate the slopes must be considered.

On slopes greater than 25%, no development, regrading, or stripping of vegetation should be considered unless the disturbance is for roadway crossings or utility construction and it can be demonstrated that the roadway or utility improvements are absolutely necessary in the sloped area.

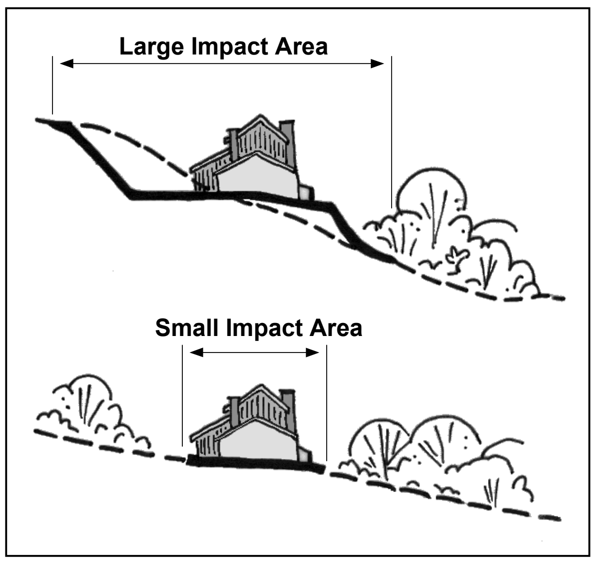


Figure 1.3.2-6 Flattening Steep Slopes for Building Sites Uses More Land Area than Building on Flatter Slopes
(Source: MPCA, 1989)

integrated Site Design Practice #5:
Minimize Siting on Permeable or Erodible Soils

Conservation of Natural Features and Resources

Description: Permeable soils such as sand and gravels provide an opportunity for groundwater recharge of storm water runoff and should be preserved as a potential storm water management option. Unstable or easily erodible soils should be avoided due to their greater erosion potential.

KEY BENEFITS	USING THIS PRACTICE
■ used as nonstructural storm water infiltration zones. A storm water site design credit can be taken if allowed by the local review authority ■ prevent erosion and sedimentation problems and water quality degradation	☑ Use soil surveys to determine site soil types ☑ Leave areas of porous or highly erodible soils as undisturbed conservation areas

Discussion

Infiltration of storm water into the soil reduces both the volume and peak discharge of runoff from a given rainfall event, and also provides for water quality treatment and groundwater recharge. Soils with maximum permeabilities (hydrologic soil group A and B soils such as sands and sandy loams) allow for the most infiltration of runoff into the subsoil. Thus, areas of a site with these soils should be conserved as much as possible and these areas should ideally be incorporated into undisturbed natural or open space areas. Conversely, buildings and other impervious surfaces should be located on those portions of the site with the *least* permeable soils to the extent that soil stability, shrink-swell potential, and other soil characteristics allow.

Similarly, areas on a site with highly erodible or unstable soils should be avoided for land disturbing activities and buildings to prevent erosion and sedimentation problems as well as potential future structural problems. These areas should be left in an undisturbed and vegetated condition.

Soils on a development site should be mapped in order to preserve areas with permeable soils, and to identify those areas with unstable or erodible soils as shown in Figure 1.3.2-7. Soil surveys can provide a considerable amount of information relating to all relevant aspects of soils. Appendix B of this Manual provides permeability, shrink-swell potential and hydrologic soils group information for all North Central Texas soil series. General soil types should be delineated on concept site plans to guide site layout and the placement of buildings and impervious surfaces.

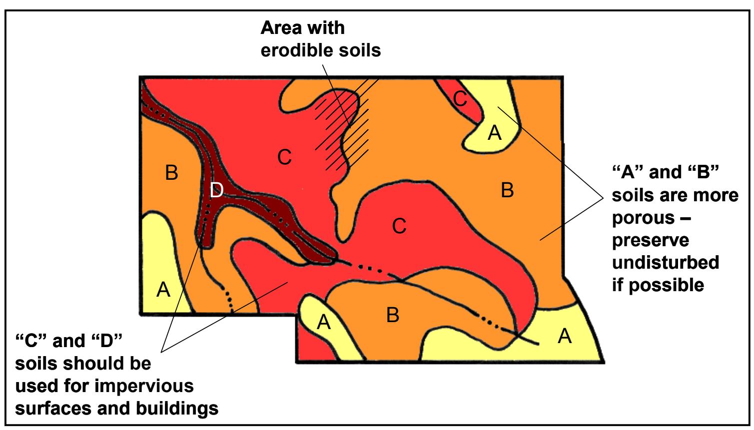


Figure 1.3.2-7 Soil Mapping Information Can Be Used to Guide Development

1.3.2.2 Lower Impact Site Design Techniques

After a site analysis has been performed and conservation areas have been delineated, there are numerous opportunities in the site design and layout phase to reduce both water quantity and quality impacts of storm water runoff. These primarily deal with the location and configuration of impervious surfaces or structures on the site and include the following practices and techniques covered over the next several pages:

- Fit the Design to the Terrain
- Locate Development in Less Sensitive Areas
- Reduce Limits of Clearing and Grading
- Utilize Open Space Development
- Consider Creative Development Design

The goal of lower impact site design techniques is to lay out the elements of the development project in such a way that the site design (i.e. placement of buildings, parking, streets and driveways, lawns, undisturbed vegetation, buffers, etc.) is optimized for effective storm water management. That is, the site design takes advantage of the site's natural features, including those placed in conservation areas, as well as any site constraints and opportunities (topography, soils, natural vegetation, floodplains, shallow bedrock, high water table, etc.) to prevent both on-site and downstream storm water impacts.

Figure 1.3.2-8 shows a development that has utilized several lower impact site design techniques in its overall layout and design.

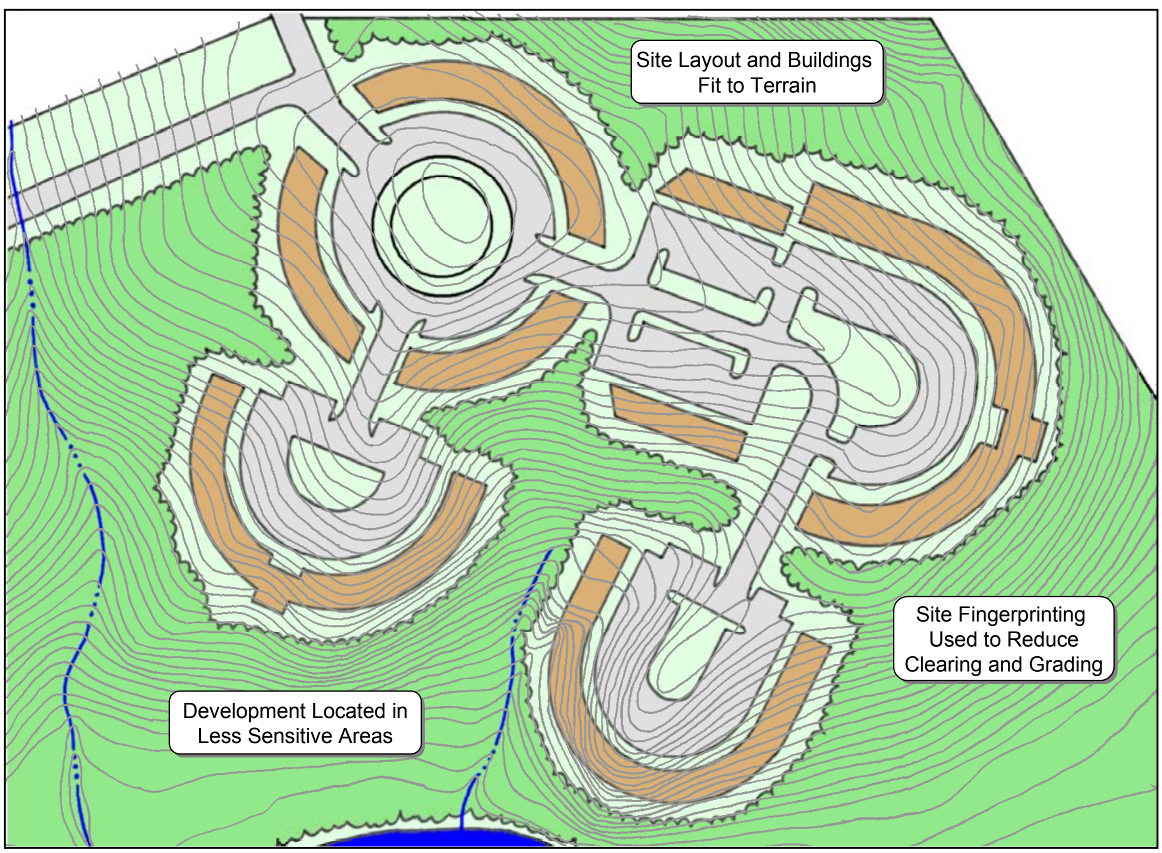


Figure 1.3.2-8 Development Design Utilizing Several Lower Impact Site Design Techniques

integrated Site Design Practice #6:
Fit Design to the Terrain

Lower Impact Site Design Techniques

Description: The layout of roadways and buildings on a site should generally conform to the landforms on a site. Natural drainageways and stream buffer areas should be preserved by designing road layouts around them. Buildings should be sited to utilize the natural grading and drainage system and avoid the unnecessary disturbance of vegetation and soils.

KEY BENEFITS	USING THIS PRACTICE
▪ drainageways of a site ▪ disturbance ▪ layout	☑ Develop roadway patterns to fit the site terrain. ☑ Locate buildings and impervious surfaces away from steep slopes, drainageways and floodplains

Discussion

All site layouts should be designed to conform with or "fit" the natural landforms and topography of a site. This helps to preserve the natural hydrology and drainageways on the site, as well as reduces the need for grading and disturbance of vegetation and soils. Figure 1.3.2-9 illustrates the placement of roads and homes in a residential development.

Roadway patterns on a site should be chosen to provide access schemes which match the terrain. In rolling or hilly terrain, streets should be designed to follow natural contours to reduce clearing and grading. Street hierarchies with local streets branching from collectors in short loops and cul-de-sacs along ridgelines help to prevent the crossing of streams and drainageways as shown in Figure 1.3.2-10. In flatter areas, a traditional grid pattern of streets or "fluid" grids which bend and may be interrupted by natural drainageways may be more appropriate (see Figure 1.3.2-11). A grid pattern may also allow for narrower streets and less imperviousness as having more than one route for emergency vehicles makes it easier to relax minimum street width requirements. In either case, buildings and impervious surfaces should be kept off of steep slopes, away from natural drainageways, and out of floodplains and other lower lying areas. In addition, the major axis of buildings should be oriented parallel to existing contours.

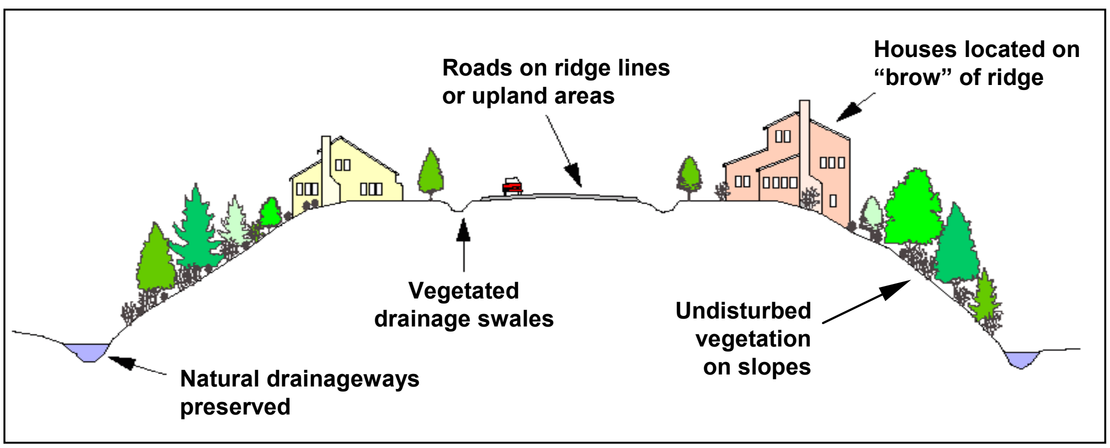


Figure 1.3.2-9 Preserving the Natural Topography of the Site
(Adapted from Sykes, 1989)

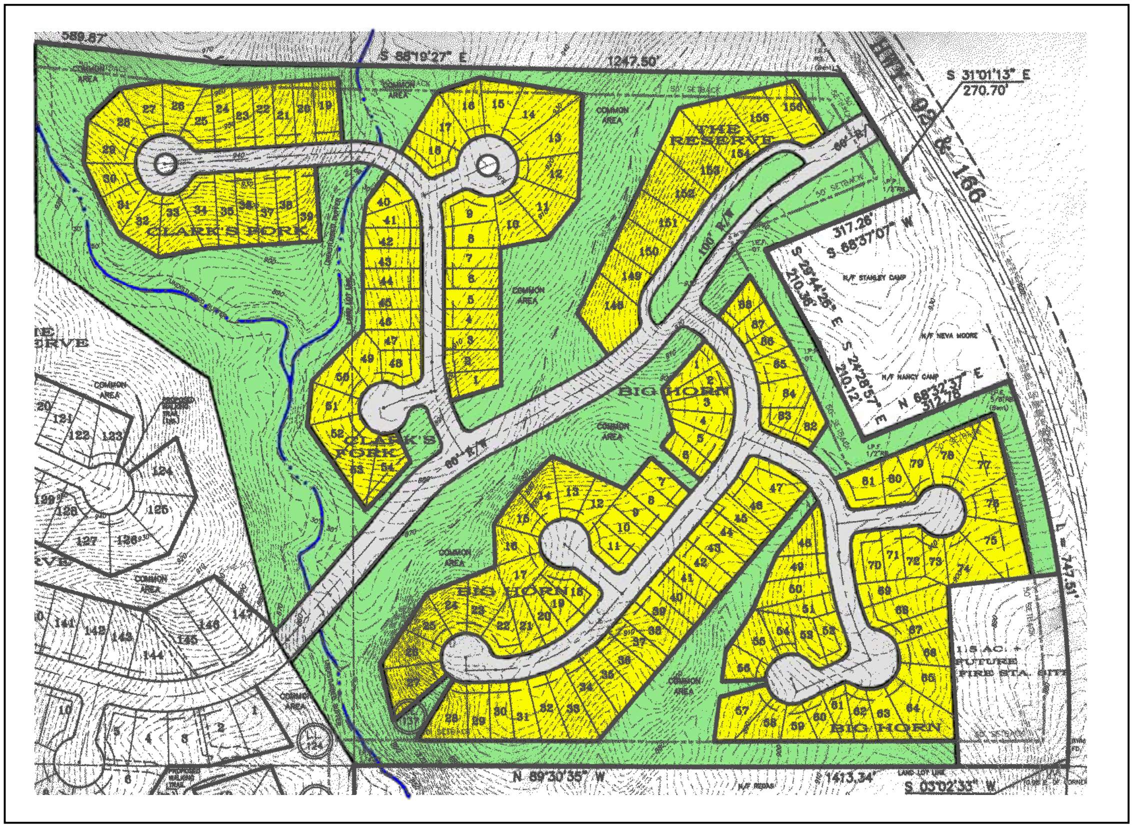


Figure 1.3.2-10 Subdivision Design for Hilly or Steep Terrain Utilizes Branching Streets from Collectors that Preserves Natural Drainageways and Stream Corridors

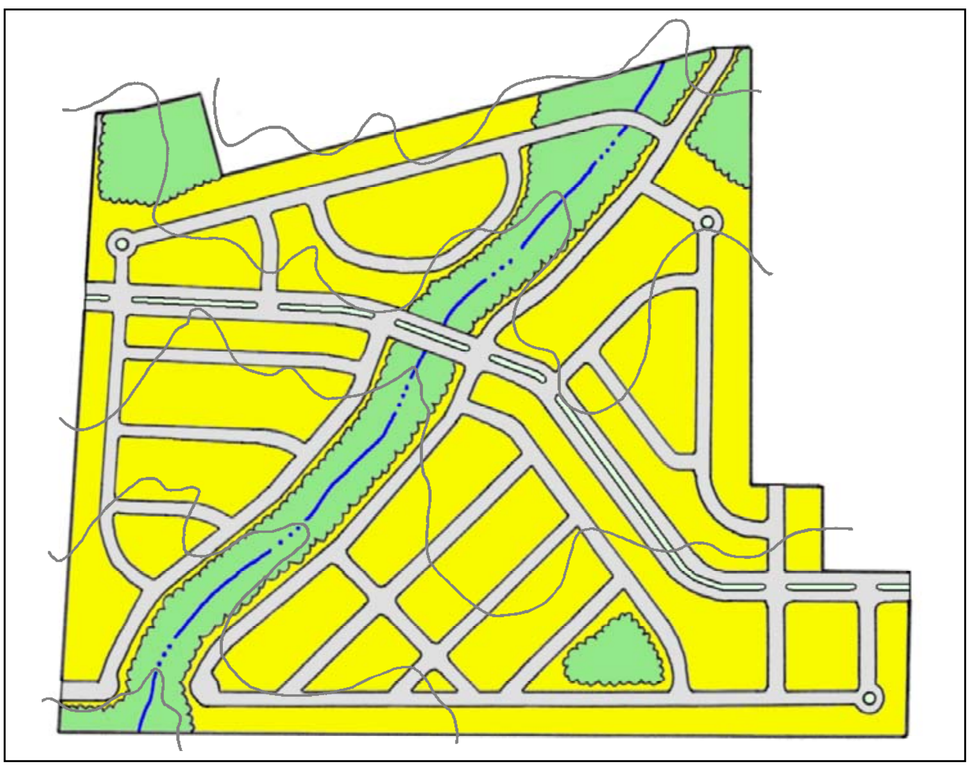


Figure 1.3.2-11 A Subdivision Design for Flat Terrain Uses a Fluid Grid Layout that is Interrupted by the Stream Corridor

integrated Site Design Practice #7:
Locate Development in Less Sensitive Areas

Lower Impact Site Design Techniques

Description: To minimize the hydrologic impacts on the existing site land cover, the area of development should be located in areas of the site that are less sensitive to disturbance or have a lower value in terms of hydrologic function.

KEY BENEFITS	USING THIS PRACTICE
▪ drainageways of a site ▪ features for preventing and mitigating storm water impacts ▪ layout	☑ Lay out the site design to minimize the hydrologic impact of structures and impervious surfaces

Discussion

In much the same way that a development should be designed to conform to terrain of the site, a site layout should also be designed so the areas of development are placed in the locations of the site that minimize the hydrologic impact of the project. This is accomplished by steering development to areas of the site that are less sensitive to land disturbance or have a lower value in terms of hydrologic function using the following methods:

Locate buildings and impervious surfaces away from stream corridors, wetlands and natural drainageways. Use buffers to preserve and protect riparian areas and corridors.

Areas of the site with permeable soils should left in an undisturbed condition and/or used as storm water runoff infiltration zones. Buildings and impervious surfaces should be located in areas with less permeable soils.

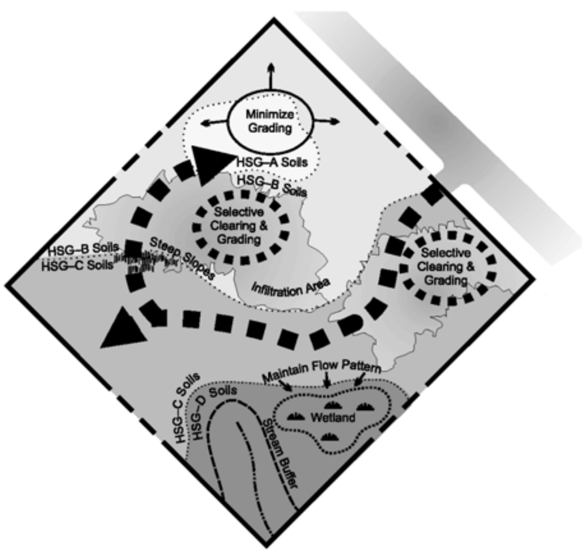


Figure 1.3.2-12 Guiding Development to Less Sensitive Areas of a Site
(Source: Prince George's County, MD, 1999)

- Avoid land disturbing activities or construction on areas with steep slopes or unstable soils.
- Minimize the clearing of areas with dense tree canopy or thick vegetation, and ideally preserve them as natural conservation areas.
- Ensure natural drainageways and flow paths are preserved, where possible. Avoid the filling or grading of natural depressions and ponding areas.

Figure 1.3.2-12 shows a development site where the natural features have been mapped in order to delineate the hydrologically sensitive areas. Through careful site planning, sensitive areas can be set aside as natural open space areas (see *integrated* Site Design Practice #9). In many cases, such areas can be used as buffer spaces between land uses on the site or between adjacent sites.

integrated Site Design Practice #8:
Reduce Limits of Clearing and Grading

Lower Impact Site Design Techniques

Description: Clearing and grading of the site should be limited to the minimum amount needed for the development and road access. Site footprinting should be used to disturb the smallest possible land area on a site.

KEY BENEFITS	USING THIS PRACTICE
■ development site ■ conservation areas and other site features	☑ Establish limits of disturbance for all development activities ☑ Use site footprinting to minimize clearing and land disturbance

Discussion

Minimal disturbance methods should be used to limit the amount of clearing and grading that takes place on a development site, preserving more of the undisturbed vegetation and natural hydrology of a site. These methods include:

- Establishing a limit of disturbance (LOD) 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. LOD distances may vary by type of development, size of lot or site, and by the specific development feature involved.
- Using site "footprinting" which maps all of the limits of disturbance to identify the smallest possible land area on a site which requires clearing or land disturbance. Examples of site footprinting are illustrated in Figures 1.3.2-13 and 1.3.2-14.
- Fitting the site design to the terrain.
- Using special procedures and equipment which reduce land disturbance.

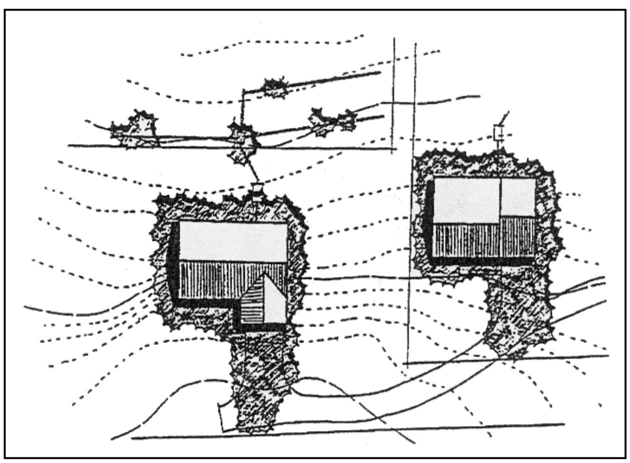


Figure 1.3.2-13 Establishing Limits of Clearing
(Source: DDNREC, 1997)

Figure 1.3.2-14 Example of Site Footprinting

integrated Site Design Practice #9:
Utilize Open Space Development

Lower Impact Site Design Techniques

Description: Open space site designs incorporate smaller lot sizes to reduce overall impervious cover while providing more undisturbed open space and protection of water resources.

KEY BENEFITS	USING THIS PRACTICE
▪ site ▪ drainageways ▪ areas and other site features ▪ ▪ development costs	☑ Use a site design which concentrates development and preserves open space and natural areas of the site

Discussion

Open space development, also known as *conservation development* or *clustering*, is an *integrated* site design technique that concentrates structures and impervious surfaces in a compact area in one portion of the development site in exchange for providing open space and natural areas elsewhere on the site. Typically, smaller lots and/or nontraditional lot designs are used to cluster development and create more conservation areas on the site.

Open space developments have many benefits compared with conventional commercial developments or residential subdivisions: they can reduce impervious cover, storm water pollution, construction costs, and the need for grading and landscaping, while providing for the conservation of natural areas. Figures 1.3.2-15 and 1.3.2-16 show examples of open space developments.

Along with reduced imperviousness, open space designs provide a host of other environmental benefits lacking in most conventional designs. These developments reduce potential pressure to encroach on conservation and buffer areas because enough open space is usually reserved to accommodate these protection areas. As less land is cleared during the construction process, alteration of the natural hydrology and the potential for soil erosion are also greatly diminished. Perhaps most importantly, open space design reserves 25 to 50 percent of the development site in conservation areas, which would not otherwise be protected.

Open space developments can also be significantly less expensive to build than conventional projects. Most of the cost savings are due to reduced infrastructure cost for roads and storm water management controls and conveyances. While open space developments are frequently less expensive to build, developers also find these properties often command higher prices than those in more conventional developments. Several studies estimate that residential properties in open space developments garner premiums higher than conventional subdivisions resulting in higher selling or leasing rates.

Once established, common open space and natural conservation areas must be managed by a responsible party, typically a municipality, to maintain the areas in a natural state in perpetuity. Typically, the conservation areas are protected by legally enforceable deed restrictions, conservation easements, and maintenance agreements.

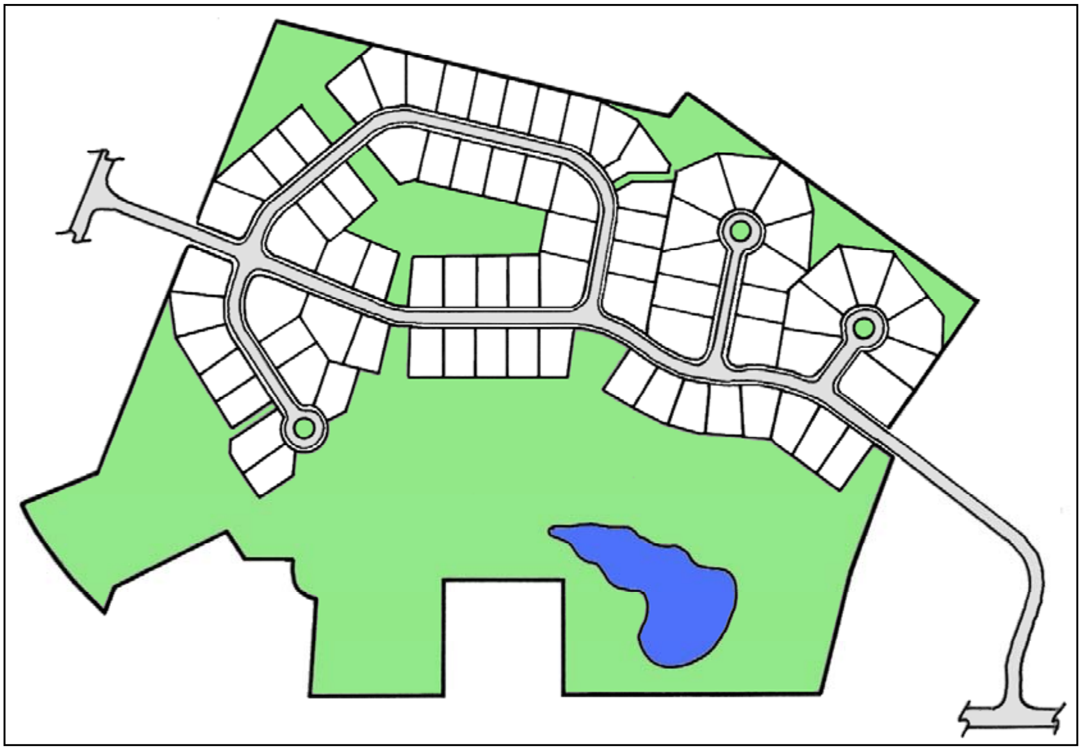


Figure 1.3.2-15 Open Space Subdivision Site Design Example

Figure 1.3.2-16 Aerial View of an Open Space Subdivision

integrated Site Design Practice #10:
Consider Creative Development Design

Lower Impact Site Design Techniques

Description: Planned Unit Developments (PUDs) allow a developer or site designer the flexibility to design a residential, commercial, industrial, or mixed-use development in a fashion that best promotes effective storm water management and the protection of environmentally sensitive areas.

KEY BENEFITS	USING THIS PRACTICE
▪ implement creative site designs which include *integrated* site design practices	☑ Check with your local review authority to determine if the community supports PUDs
▪ space development	☑ Determine the type and nature of deviations allowed and other criteria for receiving PUD approval

Discussion

A Planned Unit Development (PUD) is a type of planning approval available in some communities which provides greater design flexibility by allowing deviations from the typical development standards required by the local zoning code with additional variances or zoning hearings. The intent is to encourage better designed projects through the relaxation of some development requirements, in exchange for providing greater benefits to the community. PUDs can be used to implement many of the other *integrated* site design practices covered in this Manual and to create site designs that maximize natural nonstructural approaches to storm water management.

Examples of the types of zoning deviations which are often allowed through a PUD process include:

- Allowing uses not listed as permitted, conditional or accessory by the zoning district in which the property is located
- Modifying lot size and width requirements
- Reducing building setbacks and frontages from property lines
- Altering parking requirements
- Increasing building height limits

Many of these changes are useful in reducing the amount of impervious cover on a development site (see *integrated* Site Design Practices #11 through #16).

A developer or site designer should consult the local review authority to determine whether the community supports PUD approvals. If so, the type and nature of deviations allowed from individual development requirements should be obtained from the review authority in addition to any other criteria that must be met to obtain a PUD approval.

1.3.2.3 Reduction of Impervious Cover

The level of impervious cover, i.e. rooftops, parking lots, roadways, sidewalks and other surfaces that do not allow rainfall to infiltrate into the soil, is an essential factor to consider in *integrated* site design for storm water management. Increased impervious cover means increased storm water generation and increased pollutant loadings.

Thus by reducing the area of total impervious surface on a site, a site designer can directly reduce the volume of storm water runoff and associated pollutants that are generated. It can also reduce the size and cost of necessary infrastructure for storm water drainage, conveyance, and control and treatment. Some of the ways impervious cover can be reduced in a development include:

- Reduce Roadway Lengths and Widths
- Reduce Building Footprints
- Reduce the Parking Footprint
- Reduce Setbacks and Frontages
- Use Fewer or Alternative Cul-de-Sacs
- Create Parking Lot Storm Water Islands

Figure 1.3.2-17 shows an example of a residential subdivision that employed several of these principles to reduce the overall imperviousness of the development. The next several pages cover these methods in more detail.

Figure 1.3.2-17 Example of Reducing Impervious Cover (clockwise from upper left): (a) Cul-de-sac with Landscaped Island; (b) Narrower Residential Street; (c) "Green" Parking Lot with Landscaped Islands; and (d) Landscape Median in Roadway.

integrated Site Design Practice #11:
Reduce Roadway Lengths and Widths

Reduction of Impervious Cover

Description: Roadway lengths and widths should be minimized on a development site where possible to reduce overall imperviousness.

KEY BENEFITS	USING THIS PRACTICE
■ and associated runoff and pollutants generated ■ construction and maintenance	✓ Consider different site and road layouts that reduce overall street length ✓ Minimize street width by using narrower street designs

Discussion

The use of alternative road layouts that reduce the total linear length of roadways can significantly reduce overall imperviousness of a development site. Site designers are encouraged to analyze different site and roadway layouts to see if they can reduce overall street length. The length of local cul-de-sacs and cross streets should be shortened to a maximum of 200 ADT (average trips per day) to minimize traffic and road noise so shorter setbacks may be employed.

In addition, residential streets and private streets within commercial and other development should be designed for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency access. Figure 1.3.2-18 shows a number of different options for narrower street designs. One-way single-lane loop roads are another way to reduce the width of lower traffic streets.

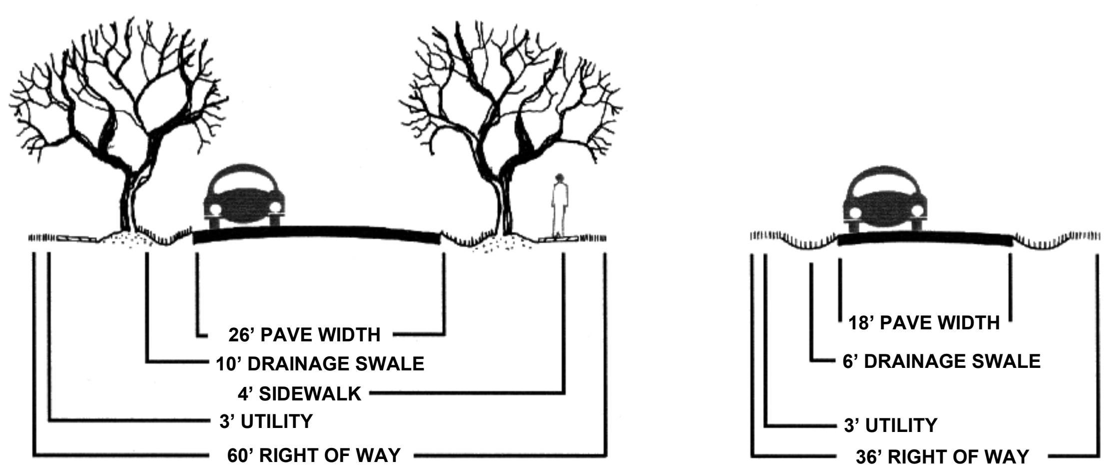


Figure 1.3.2-18 Potential Design Options for Narrower Roadway Widths
(Source: VPISU, 2000)

integrated Site Design Practice #12:
Reduce Building Footprints

Reduction of Impervious Cover

Description: The impervious footprint of commercial buildings and residences can be reduced by using alternate or taller buildings while maintaining the same floor to area ratio.

KEY BENEFITS	USING THIS PRACTICE
■ associated runoff and pollutants generated	☑ Use alternate or taller building designs to reduce the impervious footprint of buildings

Discussion

In order to reduce the imperviousness associated with the footprint and rooftops of buildings and other structures, alternative and/or vertical (taller) building designs should be considered. Consolidate functions and buildings, as required, or segment facilities to reduce the footprint of individual structures. Figure 1.3.2-19 shows the reduction in impervious footprint by using a taller building design.

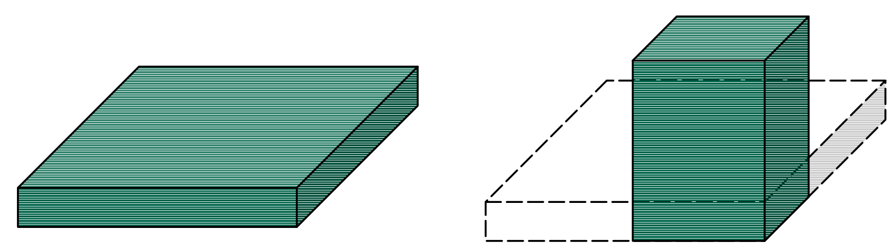


Figure 1.3.2-19 Building Up Rather Than Out Can Reduce the Amount of Impervious Cover

integrated Site Design Practice #13:
Reduce the Parking Footprint

Reduction of Impervious Cover

Description: Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, parking decks, and using porous paver surfaces or porous concrete in overflow parking areas where feasible and where soils allow for infiltration.

KEY BENEFITS	USING THIS PRACTICE
▪ cover and associated runoff and pollutants generated	☑ Reduce the number of parking spaces ☑ Minimize stall dimensions ☑ Consider parking structures and shared parking ☑ Use alternative porous surface for overflow areas

Discussion

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

Sometimes parking lot designs result in far more spaces than actually required. This problem may be caused 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. Table 1.3.2-2 provides examples of conventional parking requirements and compares them to average parking demand.

Table 1.3.2-2 Conventional Minimum Parking Ratios
(Source: ITE, 1987; Smith, 1984; Wells, 1994)

Land Use	Parking Requirement		Actual Average Parking Demand
	Parking Ratio	Typical Range	
Single family homes	2 spaces per dwelling unit	1.5–2.5	1.11 spaces per dwelling unit
Shopping center	5 spaces per 1000 ft^2 GFA	4.0–6.5	3.97 per 1000 ft^2 GFA
Convenience store	3.3 spaces per 1000 ft^2 GFA	2.0–10.0	--
Industrial	1 space per 1000 ft^2 GFA	0.5–2.0	1.48 per 1000 ft^2 GFA
Medical/ dental office	5.7 spaces per 1000 ft^2 GFA	4.5–10.0	4.11 per 1000 ft^2 GFA

GFA = Gross floor area of a building without storage or utility spaces.

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 to implementing stall minimization techniques, stall width requirements in most local parking codes are much larger than the widest SUVs.

Structured parking decks are one method to significantly reduce the overall parking footprint by minimizing surface parking. Figure 1.3.2-20 shows a parking deck used for a commercial development.

Figure 1.3.2-20 Structured Parking at an Office Park Development

Shared parking in mixed-use areas and structured parking are techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings.

Utilizing alternative surfaces such as porous pavers or porous concrete is an effective way to reduce the amount of runoff generated by parking lots. They can replace conventional asphalt or concrete in both new developments and redevelopment projects. Figure 1.3.2-21 is an example of porous paver used at an overflow lot. Alternative pavers can also capture and treat runoff from other site areas. However, porous pavement surfaces are generally more costly to construct and require more maintenance than conventional asphalt or concrete. For more specific information using these alternative surfaces, see the sections in Chapter 5 on (Modular Porous Paver Systems) and (Porous Concrete). These surfaces can only be used if the soils allow for adequate infiltration.

Figure 1.3.2-21 Grass Paver Surface Used for Parking

integrated Site Design Practice #14:
Reduce Setbacks and Frontages

Reduction of Impervious Cover

Description: Use smaller front and side setbacks and narrower frontages to reduce total road length and driveway lengths. This would not apply to rear access (i.e. alleys) home developments.

KEY BENEFITS	USING THIS PRACTICE
▪ and associated runoff and pollutants generated	☑ Reduce building and home front and side setbacks ☑ Consider narrower frontages

Discussion

Building and home setbacks should be shortened to reduce the amount of impervious cover from driveways and entry walks. A setback of 20 feet is more than sufficient to allow a car to park in a driveway without encroaching into the public right of way, and reduces driveway and walk pavement by more than 30% compared with a setback of 30 feet (see Figure 1.3.2-22).

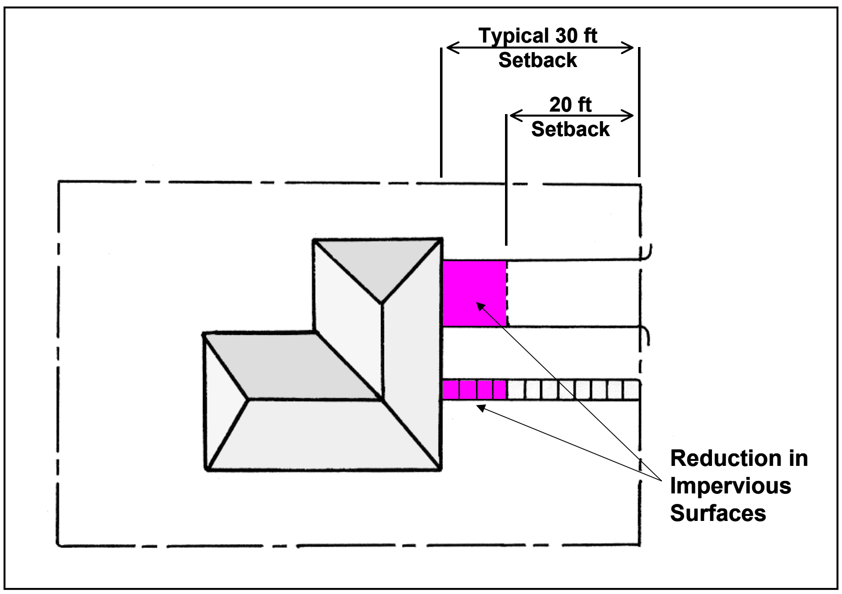


Figure 1.3.2-22 Reduced Impervious Cover by Using Smaller Setbacks
(Adapted from: MPCA, 1989)

Further, reducing side yard setbacks and using narrower frontages can reduce total street length when the same number of lots are used, especially in cluster and open space designs. Figure 1.3.2-23 shows examples of reduced front and side yard setbacks and narrow frontages.

Flexible lot shapes and setback and frontage distances allow site designers to create attractive and unique lots, which provide homeowners with enough space while allowing for the preservation of natural areas in a residential subdivision. Figure 1.3.2-24 illustrates various nontraditional lot designs.

Figure 1.3.2-23 Examples of Reduced Frontages and Side Yard Setbacks

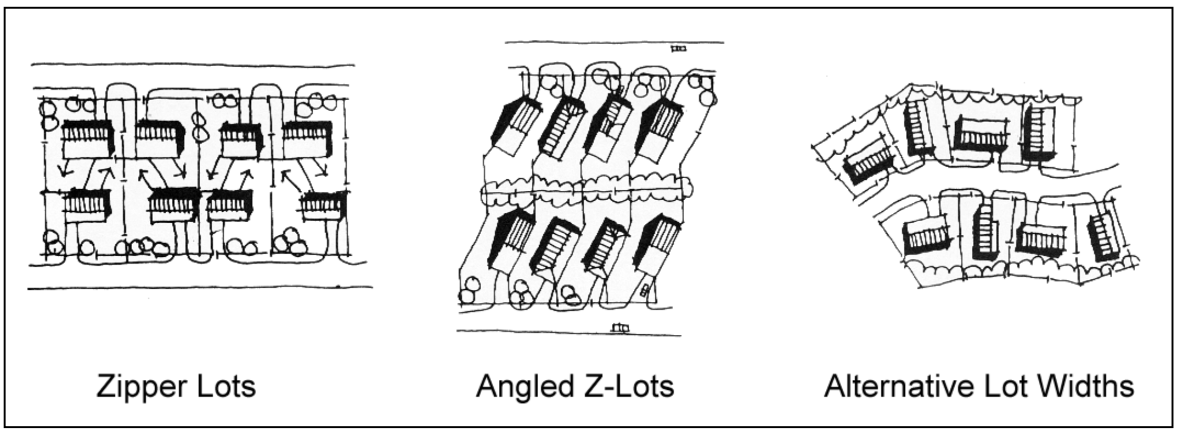


Figure 1.3.2-24 Nontraditional Lot Designs
(Source: ULI, 1992)

integrated Site Design Practice #15:
Use Fewer or Alternative Cul-de-Sacs

Reduction of Impervious Cover

Description: Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should also be considered.

KEY BENEFITS	USING THIS PRACTICE
▪ and associated runoff and pollutants generated	☑ Consider alternative cul-de-sac designs

Discussion

Alternative turnarounds are designs for end-of-street vehicle turnarounds that replace cul-de-sacs and reduce the amount of impervious cover created in developments. Cul-de-sacs are local access streets with a closed circular end that allows for vehicle turnarounds. Many of these cul-de-sacs can have a radius of more than 40 feet. From a storm water perspective, cul-de-sacs create a huge bulb of impervious cover, increasing the amount of runoff. For this reason, reducing the size of cul-de-sacs through the use of alternative turnarounds or eliminating them altogether can reduce the amount of impervious cover created at a site.

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 Figure 1.3.2-25).

Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. In particular, the types of vehicles entering into the cul-de-sac should be considered. 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 many school buses usually do not enter individual cul-de-sacs.

Implementing alternative turnarounds will require addressing local regulations and marketing issues. Communities may have specific design criteria for cul-de-sacs and other alternative turnarounds that need to be modified.

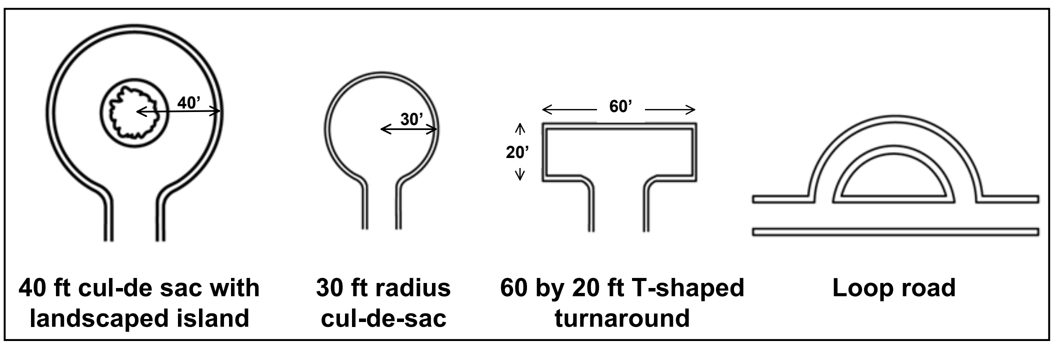


Figure 1.3.2-25 Four Turnaround Options for Residential Streets
(Source: Schueler, 1995)

integrated Site Design Practice #16:
Create Parking Lot Storm Water "Islands"

Reduction of Impervious Cover

Description: Provide storm water treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

KEY BENEFITS	USING THIS PRACTICE
▪ associated runoff and pollutants generated ▪ control facilities ▪ are more visually appealing	☑ Integrate porous areas such as landscaped islands, swales, filter strips and bioretention areas in a parking lot design.

Discussion

Parking lots should be designed with landscaped storm water management "islands" which reduce the overall impervious cover of the lot as well as provide for runoff treatment and control in storm water facilities.

When possible, expanses of parking should be broken up with landscaped islands which include shade trees and shrubs. Fewer large islands will sustain healthy trees better than more numerous very small islands. The most effective solutions in designing for tree roots in parking lots is to use a long planting strip at least 8 feet wide, constructed with sub-surface drainage and compaction resistant soil.

Structural control facilities such as filter strips, dry swales and bioretention areas can be incorporated into parking lot islands. Storm water 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 storm water facility. These facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of filter strips, enhanced swales and bioretention areas, refer to Chapter 5.

Figure 1.3.2-26 Parking Lot Storm Water "Island"

1.3.2.4 Utilization of Natural Features for Storm Water Management

Traditional storm water drainage design tends to ignore and replace natural drainage patterns and often results in overly efficient hydraulic conveyance systems. Structural storm water controls are costly and often can require high levels of maintenance for optimal operation. Through use of natural site features and drainage systems, careful site design can reduce the need and size of structural conveyance systems and controls.

Almost all sites contain natural features that can be used to help manage and mitigate runoff from development. Features on a development site might include natural drainage patterns, depressions, permeable soils, wetlands, floodplains, and undisturbed vegetated areas that can be used to reduce runoff; provide infiltration and storm water filtering of pollutants and sediment; recycle nutrients; and maximize on-site storage of storm water. Site design should seek to utilize the natural and/or nonstructural drainage system and improve the effectiveness of natural systems rather than to ignore or replace them. These natural systems typically require low or no maintenance and will continue to function many years into the future.

Some of the methods of incorporating natural features into an overall *integrated* storm water management site plan include the following practices:

- Use Buffers and Undisturbed Areas
- Use Natural Drainageways Instead of Storm Sewers
- Use Vegetated Swales Instead of Curb and Gutter
- Drain Runoff to Pervious Areas

The following pages cover each practice in more detail.

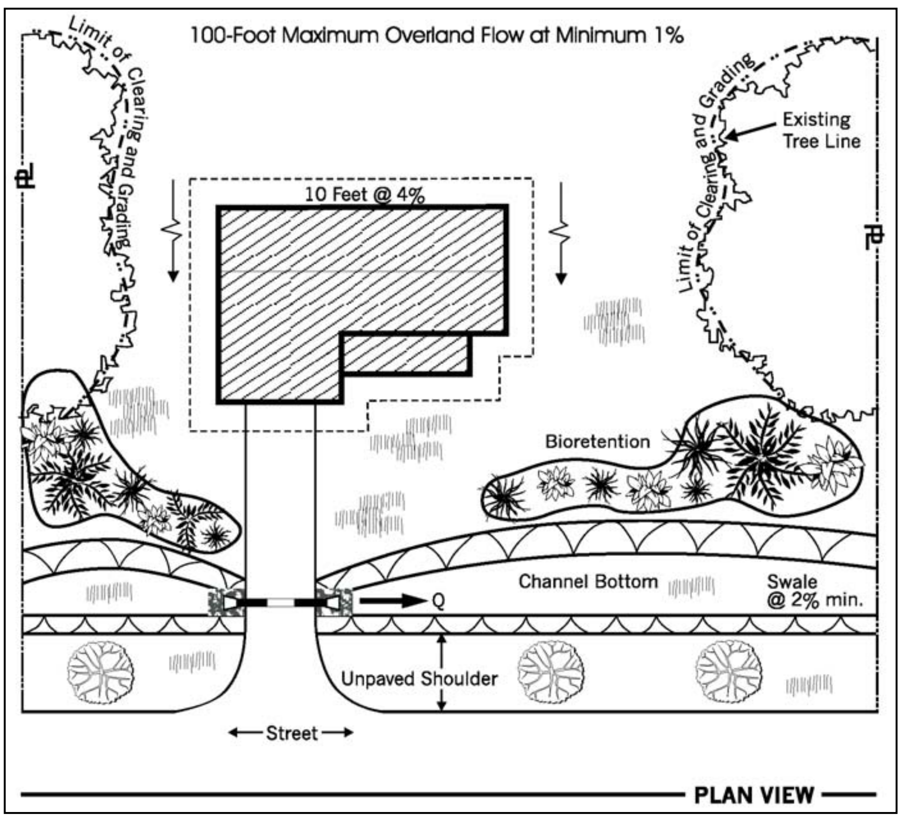


Figure 1.3.2-27 Residential Site Design Using Natural Features for Storm Water Management
(Source: Prince George's County, MD, 1999)

integrated Site Design Practice #17:
Use Buffers and Undisturbed Areas

Utilization of Natural Features for Storm Water Management

Description: Undisturbed natural areas such as forested conservation areas and stream buffers can be used to treat and control storm water runoff from other areas of the site with proper design.

KEY BENEFITS	USING THIS PRACTICE
▪ areas can be used to filter and infiltrate storm water runoff ▪ storage and detention of storm water flows ▪ if allowed by the local review authority	☑ Direct runoff towards buffers and undisturbed areas using a level spreader to ensure sheet flow ☑ Utilize natural depressions for runoff storage

Discussion

Runoff can be directed towards riparian buffers and other undisturbed natural areas delineated in the initial stages of site planning to infiltrate runoff, reduce runoff velocity and remove pollutants. Natural depressions can be used to temporarily store (detain) and infiltrate water, particularly in areas with permeable (hydrologic soil group A and B) soils.

The objective in utilizing natural areas for storm water infiltration is to intercept runoff before it has become substantially concentrated and then distribute this flow evenly (as sheet flow) to the buffer or natural area. This can typically be accomplished using a level spreader, as seen in Figure 1.3.2-28. A mechanism for the bypass of higher flow events should be provided to reduce erosion or damage to a buffer or undisturbed natural area.

Carefully constructed berms can be placed around natural depressions and below undisturbed vegetated areas with pervious soils to provide for additional runoff storage and/or infiltration of flows. See the section on bioretention areas as a storm water control with a similar goal.

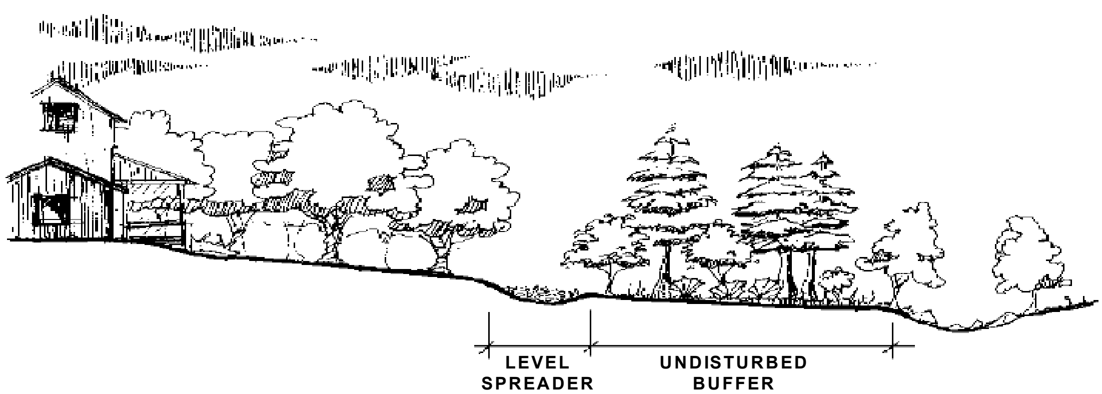


Figure 1.3.2-28 Use of a Level Spreader with a Riparian Buffer
(Adapted from NCDENR, 1998)

integrated Site Design Practice #18:

Use Natural Drainageways Instead of Storm Sewers

Utilization of Natural Features for Storm Water Management

Description: The natural drainage paths of a site can be used instead of constructing underground storm sewers or concrete open channels.

KEY BENEFITS

- constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading
- efficient than man-made conveyances, resulting in longer travel times and lower peak discharges
- storm water filtration and infiltration

USING THIS PRACTICE

- ✓ Preserve natural flow paths in the site design
- ✓ Direct runoff to natural drainageways, ensuring peak flows and velocities will not cause channel erosion

Discussion

Structural drainage systems and storm sewers are designed to be hydraulically efficient in removing storm water 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 drainageways and vegetated swales (where slopes and soils permit) to carry storm water flows to their natural outlets, particularly for low-density development and residential subdivisions.

The use of natural open channels (see Figure 1.3.2-29) allows for more storage of storm water flows on-site, lower storm water peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of storm water pollutants. It is critical that natural drainageways be protected from higher post-development flows by applying downstream streambank protection methods (including the SP_v criteria) to prevent erosion and degradation.

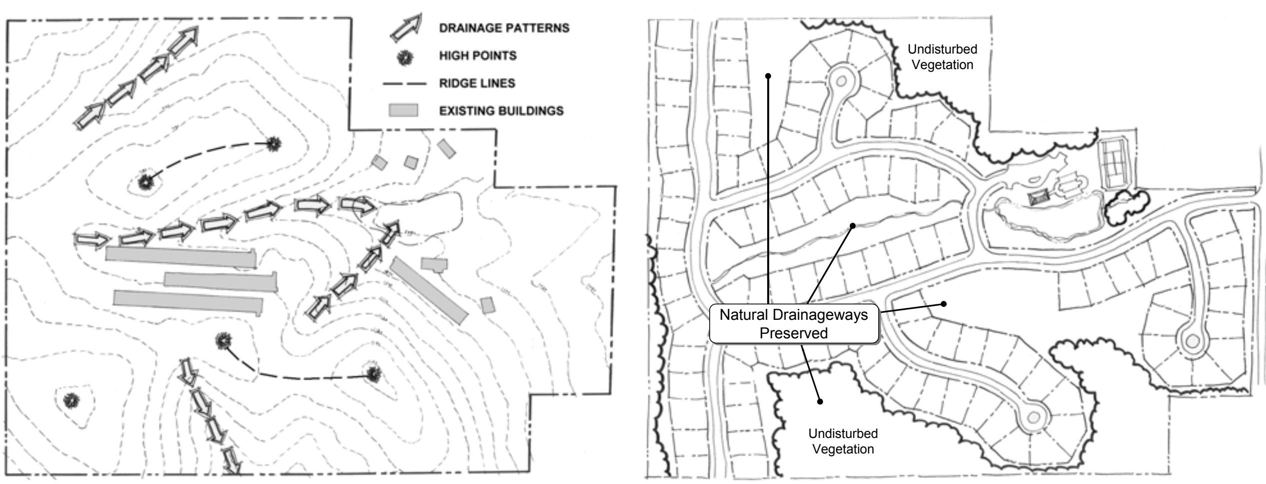


Figure 1.3.2-29 Example of a Subdivision Using Natural Drainageways for Storm Water Conveyance and Management

integrated Site Design Practice #19:
Use Vegetated Swales Instead of Curb and Gutter

Utilization of Natural Features for Storm Water Management

Description: Where density, topography, soils, slope, and safety issues permit, vegetated open channels can be used in the street right-of-way to convey and treat storm water runoff from roadways.

KEY BENEFITS	USING THIS PRACTICE
▪ construction ▪ as well as treatment of storm water ▪ taken if allowed by the local review authority	☑ Use vegetated open channels (enhanced wet or dry swales or grass channels) in place of curb and gutter to convey and treat storm water runoff

Discussion

Curb and gutter and storm drain systems allow for quicker transport of storm water from a site to a drainageway, which results in increased peak flow and flood volumes and reduced runoff infiltration. Curb and gutter systems also do not provide treatment of storm water that is often polluted from vehicle emissions, pet waste, lawn runoff and litter.

Open vegetated channels along a roadway (see Figure 1.3.2-30) remove pollutants by allowing infiltration and filtering to occur, unlike curb and gutter systems which move water with virtually no treatment. Older roadside ditches which have not been maintained suffer from erosion, standing water, and break up of the road edge. Grass channels and enhanced dry swales are two alternatives when properly installed and maintained under the right site conditions, are excellent methods for treating storm water on-site. In addition, open vegetated channels can be less expensive to install than curb and gutter systems. Further design information and specifications for grass channels/enhanced swales can be found in Chapter 5.

Figure 1.3.2-30 Using Vegetated Swales Instead of Curb and Gutter

integrated Site Design Practice #20:
Drain Runoff to Pervious Areas

Utilization of Natural Features for Storm Water Management

Description: Where possible, direct runoff from impervious areas such as rooftops, roadways and parking lots to pervious areas, open channels or vegetated areas to provide for water quality treatment and infiltration. Avoid routing runoff directly to the structural storm water conveyance system.

KEY BENEFITS	USING THIS PRACTICE
▪ increases overland flow time and reduces peak flows ▪ storm water runoff ▪ allowed by the local review authority	☑ Minimize directly connected impervious areas and drain runoff as sheet flow to pervious vegetated areas

Discussion

Storm water quantity and quality benefits can be achieved by routing the runoff from impervious areas to pervious areas such as lawns, landscaping, filter strips and vegetated channels. Much like the use of undisturbed buffers and natural areas (*integrated* Site Design Practice #17), revegetated areas such as lawns and engineered filter strips and vegetated channels can act as biofilters for storm water runoff and provide for infiltration in pervious (hydrologic group A and B) soils. In this way, the runoff is “disconnected” from a hydraulically efficient structural conveyance such as a curb and gutter or storm drain system.

Some of the methods for disconnecting impervious areas include:

- Designing roof drains to flow to vegetated areas or infiltration areas
- Directing flow from paved areas such as driveways to stabilized vegetated areas
- Breaking up flow directions from large paved surfaces (see Figure 1.3.2-31)
- Carefully locating impervious areas and grading landscaped areas to achieve sheet flow runoff to the vegetated pervious areas

For maximum benefit, runoff from impervious areas to vegetated areas must occur as sheet flow and vegetation must be stabilized. See Chapter 5 for more design information and specifications on filter strips and vegetated channels.

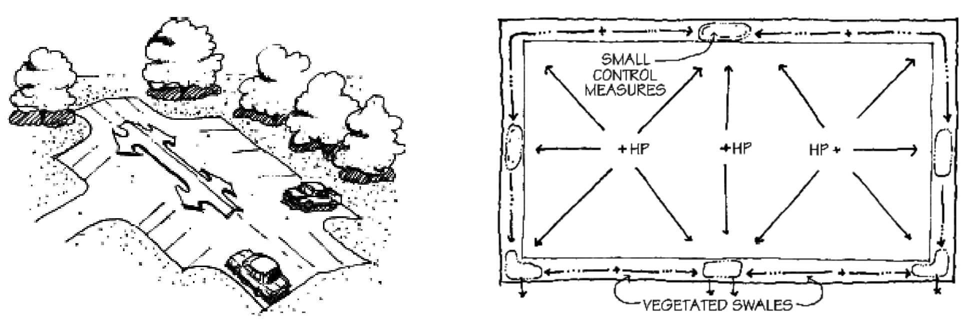


Figure 1.3.2-31 Design Paved Surfaces to Disperse Flow to Vegetated Areas
Source: NCDENR, 1998

1.3.3 *integrated* Site Design Examples

1.3.3.1 Residential Subdivision Example 1

A typical residential subdivision design on a parcel is shown in Figure 1.3.3-1 (a). The entire parcel except for the subdivision amenity area (clubhouse and tennis courts) is used for lots. The entire site is cleared and mass graded, and no attempt is made to fit the road layout to the existing topography. Because of the clearing and grading, all of the existing tree-cover, vegetation and topsoil are removed dramatically altering both the natural hydrology and drainage of the site. The wide residential streets create unnecessary impervious cover and a curb and gutter system that carries storm water flows to the storm sewer system. No provision for non-structural storm water treatment is provided on the subdivision site.

A residential subdivision employing *integrated* site design practices is presented in Figure 1.3.3-1 (b). This subdivision configuration preserves a quarter of the property as undisturbed open space and vegetation. The road layout is designed to fit the topography of the parcel, following the high points and ridgelines. The natural drainage patterns of the site are preserved and are utilized to provide natural storm water treatment and conveyance. Narrower streets reduce impervious cover and grass channels provide for treatment and conveyance of roadway and driveway runoff. Landscaped islands at the ends of cul-de-sacs also reduce impervious cover and provide storm water treatment functions. Where possible, constructing and building homes, only the building envelopes of the individual lots are cleared and graded, further preserving the natural hydrology of the site.

1.3.3.2 Residential Subdivision Example 2

Another typical residential subdivision design is shown in Figure 1.3.3-2 (a). Most of this site is cleared and mass graded, with the exception of a small riparian buffer along the large stream at the right boundary of the property. Almost no buffer was provided along the small stream that runs through the middle of the property. In fact, areas within the 100-year floodplain were cleared and filled for home sites. As is typical in many subdivision designs, this one has wide streets for on-street parking and large cul-de-sacs.

The *integrated* site design subdivision can be seen in Figure 1.3.3-2 (b). This subdivision layout was designed to conform to the natural terrain. The street pattern consists of a wider main thoroughfare, which winds through the subdivision along the ridgeline. Narrower loop roads branch off of the main road and utilize landscaped islands. Large riparian buffers are preserved along both the small and large streams. The total undisturbed conservation area is close to one-third of the site.

1.3.3.3 Commercial Development Example

Figure 1.3.3-3 (a) shows a typical commercial development containing a supermarket, drugstore, smaller shops and a restaurant on an outlot. The majority of the parcel is a concentrated parking lot area. The only pervious area is a small replanted vegetation area acting as a buffer between the shopping center and adjacent land uses. Storm water quality and quantity control are provided by a wet extended detention pond in the corner of the parcel.

An *integrated* site design commercial development can be seen in Figure 1.3.3-3 (b). Here the retail buildings are dispersed on the property, providing more of an “urban village” feel with pedestrian access between the buildings. The parking is broken up, and bioretention areas for storm water treatment are built into parking lot islands. A large bioretention area which serves as open green space is located at the main entrance to the shopping center. A larger undisturbed buffer has been preserved on the site. Because the bioretention areas and buffer provide water quality treatment, only a dry extended detention basin is needed for water quantity control.

1.3.3.4 Office Park Example

An office park with a conventional design is shown in Figure 1.3.3-4 (a). Here the site has been graded to fit the building layout and parking area. All of the vegetated areas of this site are replanted areas.

The *integrated* site design layout, presented in Figure 1.3.3-4 (b), preserves undisturbed vegetated buffers and open space areas on the site. Both the parking areas and buildings have been designed to fit the natural terrain of the site. In addition, a modular porous paver system is used for the overflow parking areas.

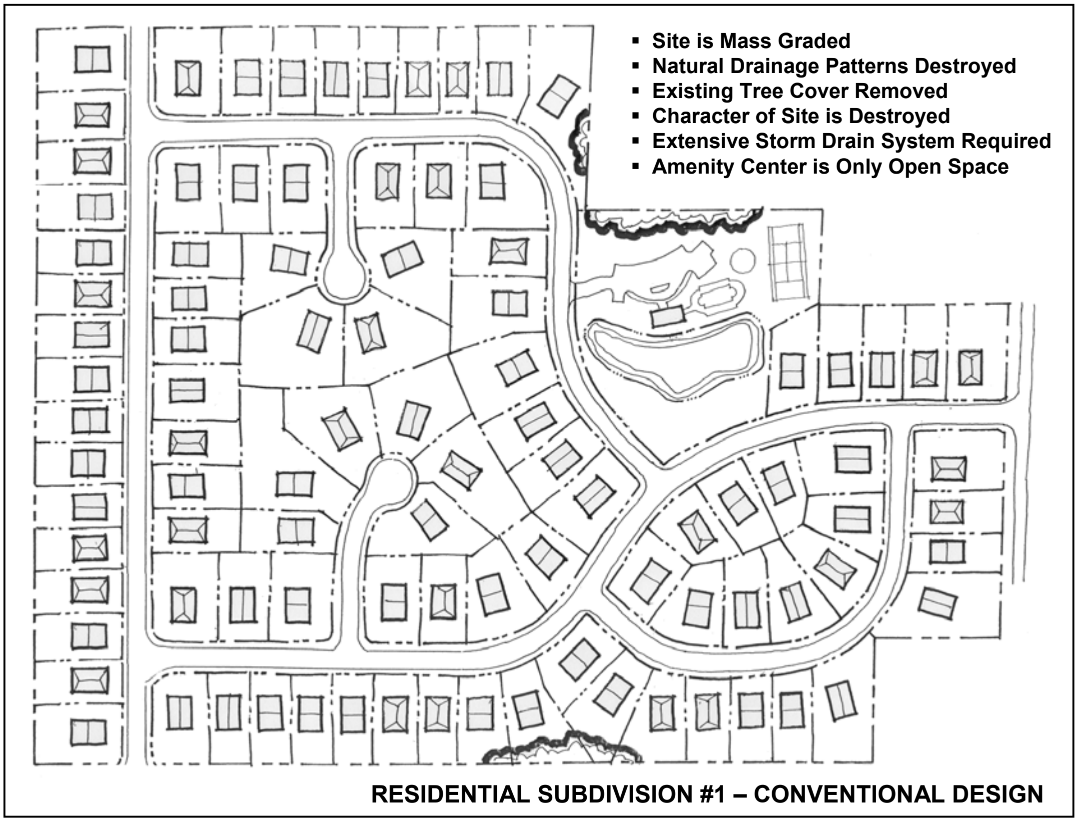
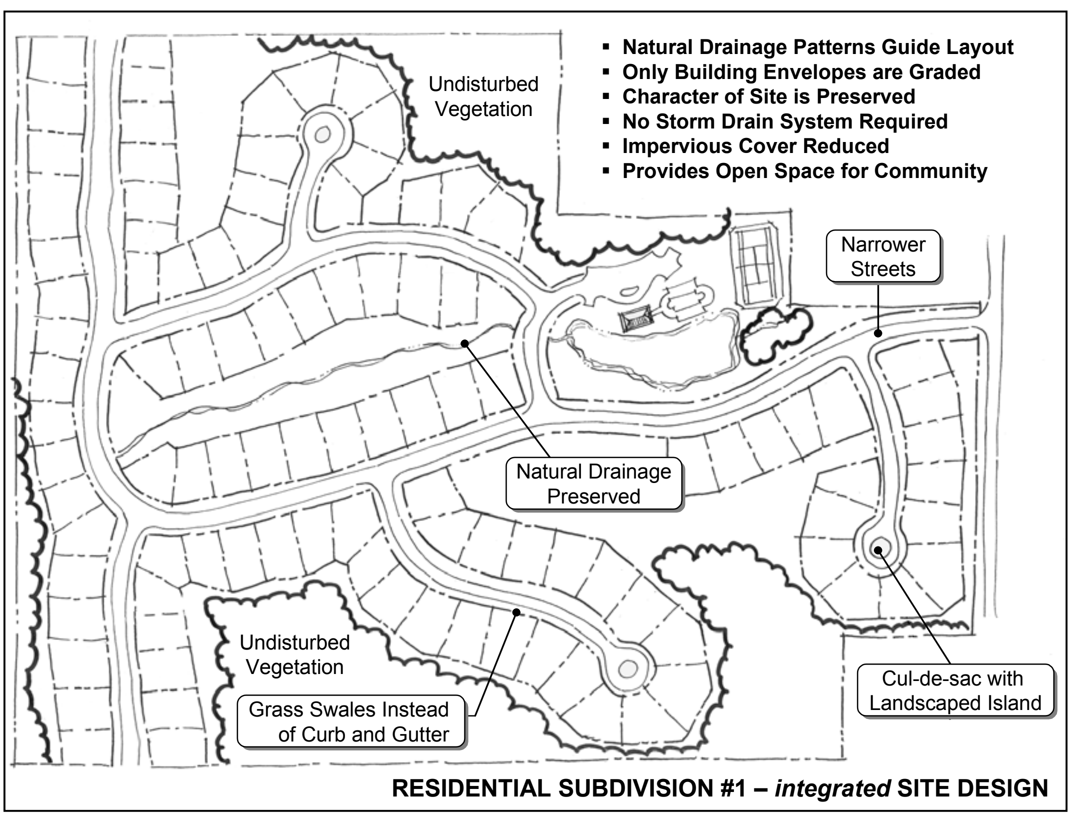


Figure 1.3.3-1 Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



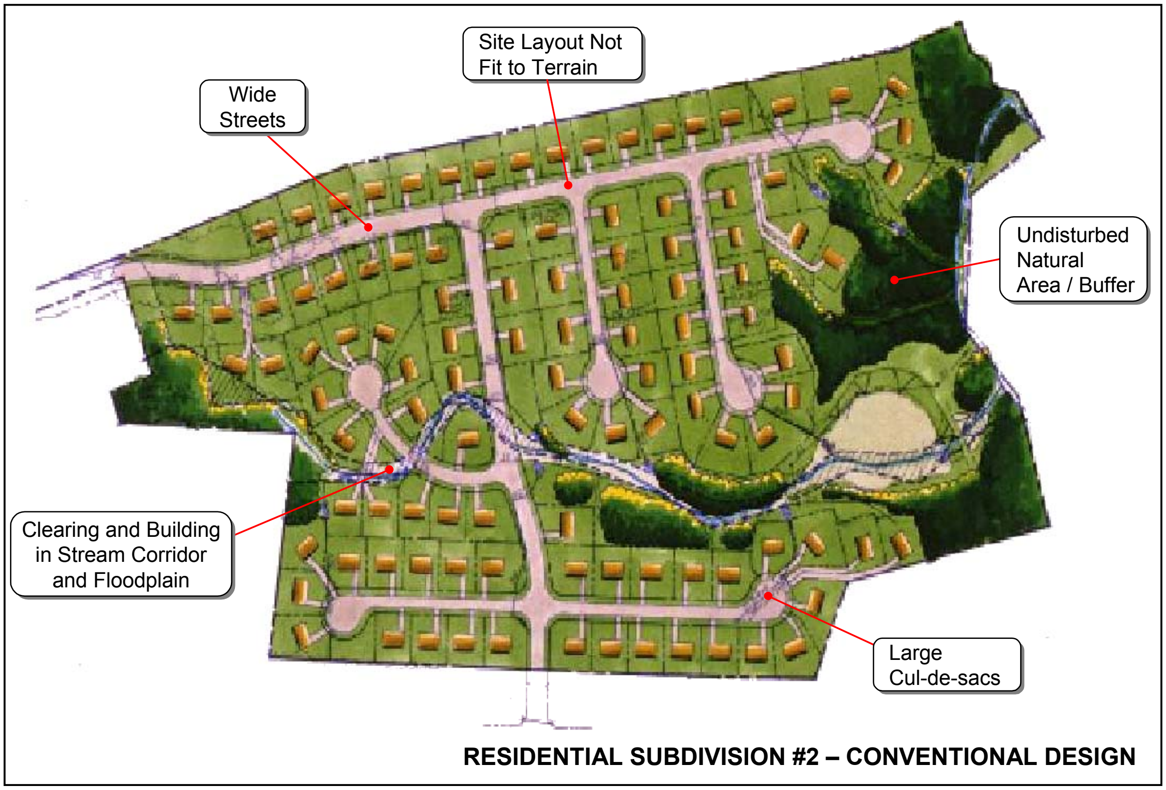
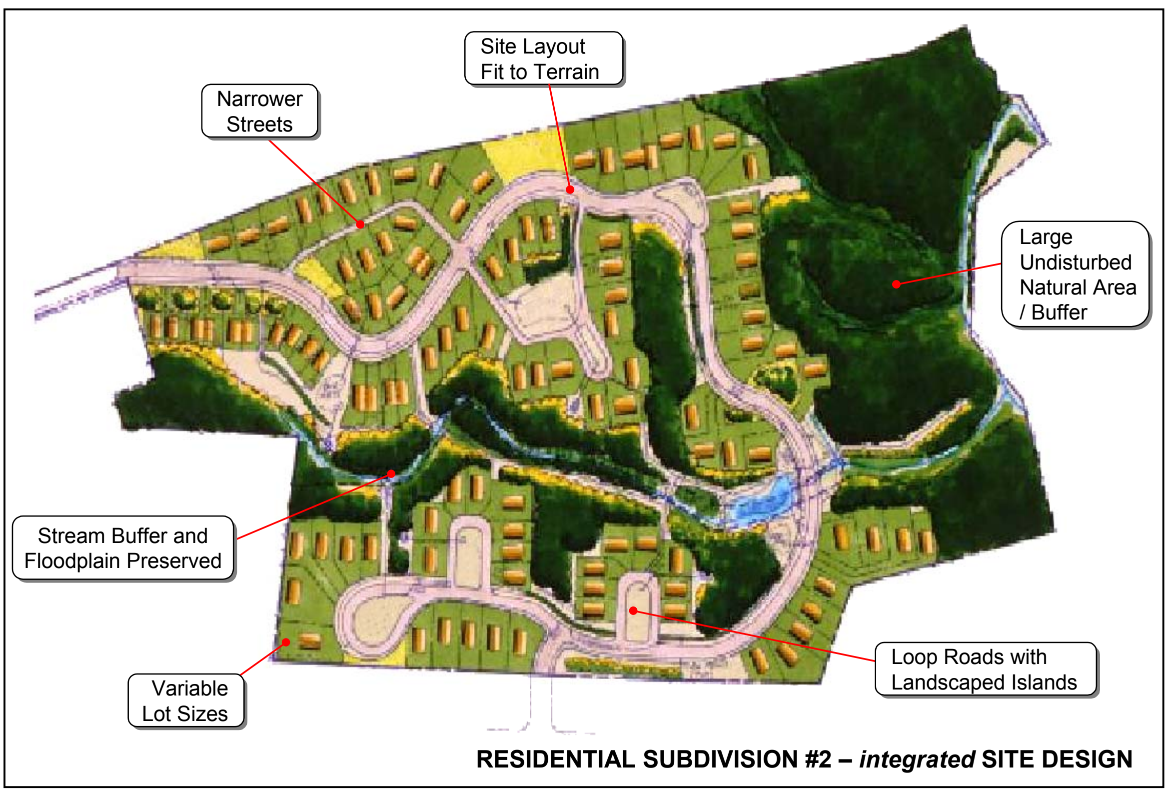


Figure 1.3.3-2 Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



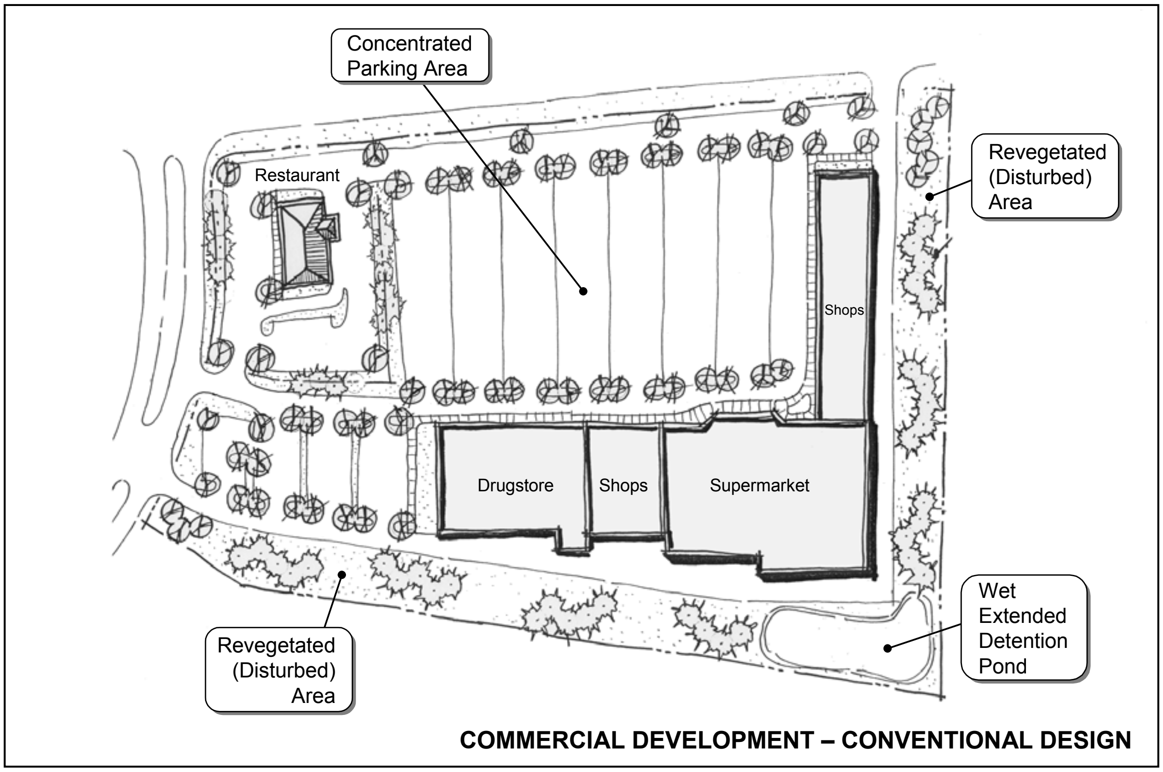
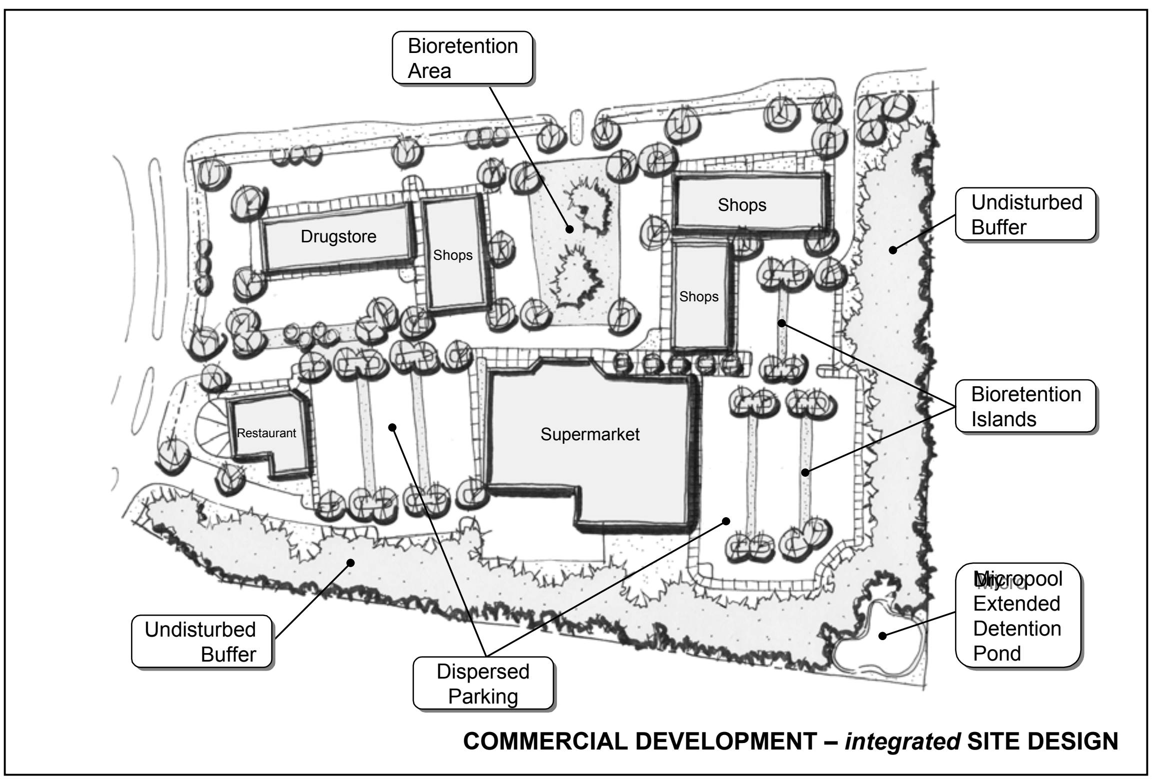


Figure 1.3.3-3 Comparison of a Traditional Commercial Development (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



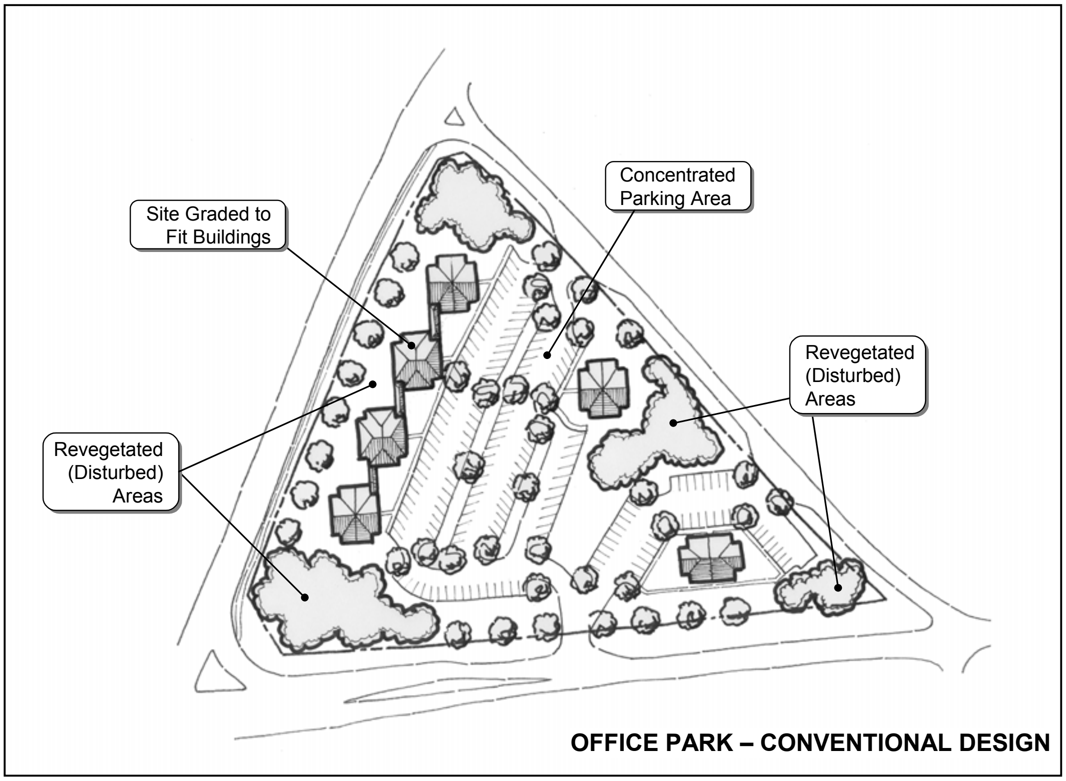
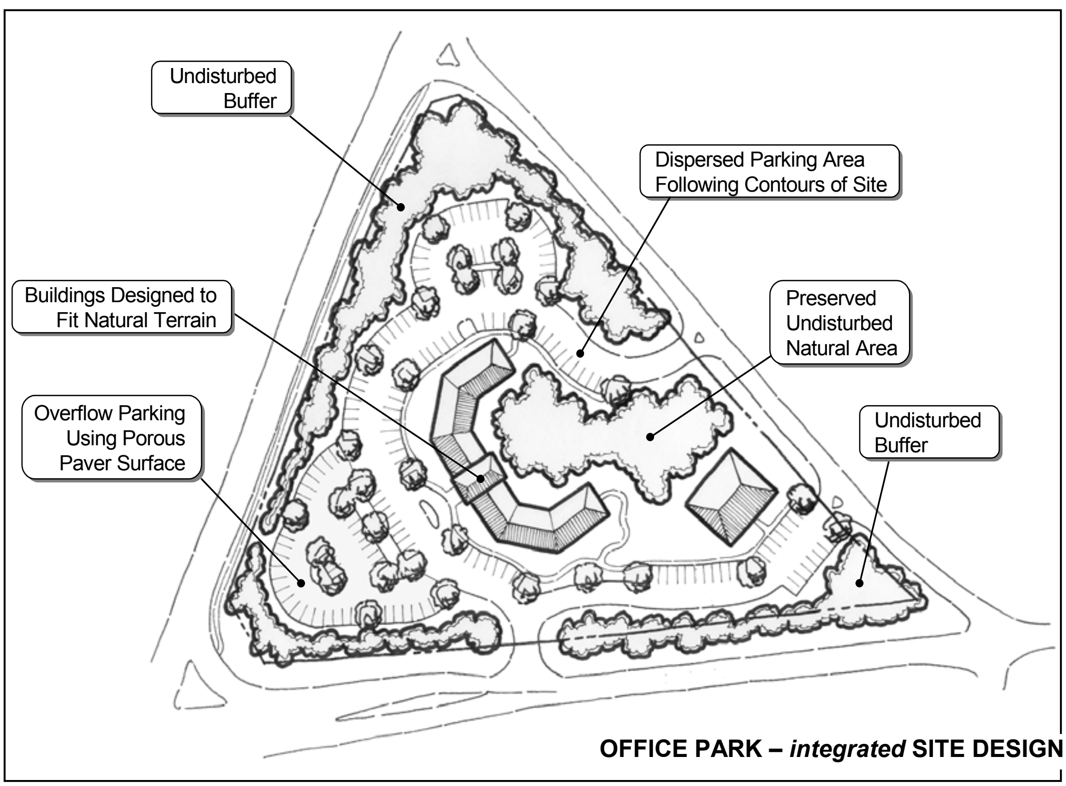


Figure 1.3.3-4 Comparison of a Traditional Office Park Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



1.3.4 *integrated* Site Design Credits

1.3.4.1 Introduction

Non-structural storm water control practices are increasingly recognized as a critical feature in every site design. As such, a set of storm water "credits" has been developed to provide developers and site designers an incentive to implement *integrated* site design practices that can minimize the pollutant loads from a site.

Site designers are encouraged to utilize as many site design practices as they can on a site. Greater reductions in storm water pollutant loading can be achieved when many practices are combined (e.g., disconnecting rooftops and protecting natural conservation areas).

The type and amount of credit that is available for a development will depend on the amount of points it has accumulated, or its total "score". Multiple points can be obtained by applying one or multiple practices. Points are accumulated based on the implementation of various site design practices.

During the site planning process described in Section 1.1, there are several steps involved in site layout and design, each more clearly defining the location and function of the various components of the storm water management system. The site design practices can be integrated with this process as shown in Table 1.3.4-1.

Table 1.3.4-1 Integration of Site Design Practices with Site Development Process

Site Development Phase	Site Design Practice Activity
Feasibility Study	• Determine storm water management requirements • Perform site reconnaissance to identify potential areas for and types of credits
Site Analysis	• Identify and delineate natural feature conservation areas (natural areas and stream buffers)
Concept Plan	• Preserve natural areas and stream buffers during site layout • Reduce impervious surface area through various techniques • Identify locations for use of vegetated channels and groundwater recharge • Look for areas to disconnect impervious surfaces • Document the use of site design practices.
Preliminary and Final Plan	• Perform layout and design of credit areas – integrating them into treatment trains • Ensure *integrated* Design Approach is satisfied • Ensure appropriate documentation of site design credits according to local requirements.
Construction	• Ensure protection of key areas • Ensure correct final construction of areas needed for credits
Final Inspection	• Develop maintenance requirements and documents • Ensure long term protection and maintenance • Ensure credit areas are identified on final plan and plat if applicable

1.3.4.2 Point System

To appropriately allocate credit for using the integrated site design practices, a guideline point system has been presented. This system assigns a point value to each practice, as shown in Table 1.3.4-2. The total number of points for a given development becomes the score for the development. The score determines the type and amount of credit available to that particular development. The local jurisdiction should, as part of their Local Criteria, determine which practices (if any) they wish to give credit for. The local jurisdiction should also determine the number of points, or point weighting, assigned to each practice, and which criteria must be met in order to obtain the credit.

Table 1.3.4-2 Example Point System for *integrated* Site Design Practices

Practice	Maximum Points	Point Allocation Based on % of Practice Utilized					
		0%	<15	<30	<50	<75	>75
Conservation of Natural Features and Resources							
Preserve Undisturbed Natural Areas	5	0	1	2	3	4	5
Preserve Riparian Buffers	5	0	1	2	3	4	5
Avoid Floodplains	5	0	1	2	3	4	5
Avoid Steep Slopes	5	0	1	2	3	4	5
Minimize Siting on Porous or Erodible Soils	5	0	1	2	3	4	5
Lower Impact Site Design Techniques							
Fit Design to the Terrain	5	0	1	2	3	4	5
Locate Development in Less Sensitive Areas	5	0	1	2	3	4	5
Reduce Limits of Clearing and Grading	5	0	1	2	3	4	5
Utilize Open Space Development	5	0	1	2	3	4	5
Consider Creative Design	5	0	1	2	3	4	5
Reduction of Impervious Cover							
Reduce Roadway Lengths and Widths	5	0	1	2	3	4	5
Reduce Building Footprints	5	0	1	2	3	4	5
Reduce the Parking Footprint	5	0	1	2	3	4	5
Reduce Setbacks and Frontages	5	0	1	2	3	4	5
Use Fewer or Alternative Cul-de-Sacs	5	0	1	2	3	4	5
Create Parking Lot Storm Water "Islands"	5	0	1	2	3	4	5
Utilization of Natural Features for Storm Water Management							
Use Buffers and Undisturbed Areas	5	0	1	2	3	4	5
Use Natural Drainageways Instead of Storm Sewers	5	0	1	2	3	4	5
Use Vegetated Swale Instead of Curb and Gutter	5	0	1	2	3	4	5
Drain Rooftop Runoff to Pervious Areas	5	0	1	2	3	4	5
Total Points	100						

1.3.4.3 Example Design Credits

There are various areas of credit available for use in a storm water management program. The list below is only an example of areas of credit and should not be considered comprehensive.

- Reduction in Storm Water Utility fees
- Reduction in Park dedication requirements
- Reduction in Open space dedication requirements
- Reduction in Landscape requirements
- Decrease in plan approval process time
- Simplified planning and variance process for implementing storm water practices
- Ability to receive variance in parking or lot size requirements
- Reduction in Storm Water Quality Volume (see Section 1.2.3.3)
- Other City-Developer Agreements

Depending on the local storm water management program, some of these site design credits may be restricted, or no credits may be available. It is up to the local jurisdiction to define the types and amounts of credit they will offer to a development. Designers are encouraged to consult with the appropriate approval authority to ensure if and when a credit is applicable and to determine restrictions and guidelines on non-structural strategies.

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CHAPTER

1

Section 1.4
integrated Storm Water Controls

1.4.1 Introduction

The impacts of storm water runoff from development cannot always be completely mitigated by land use and nonstructural approaches. Therefore, the use of appropriate structural storm water controls on development sites is sometimes necessary as an integrated part of the storm water management system. Storm water controls (sometimes referred to as *best management practices* or *BMPs*) are constructed storm water management facilities designed to treat storm water runoff and/or mitigate the effects of increased storm water runoff peak rate, volume, and velocity due to urbanization.

Chapter 5 recommends a number of structural storm water controls that can be used for meeting the *integrated* design approach including very specific performance and design criteria. The next several pages provide a brief overview of the range of storm water controls recommended for use in North Central Texas communities. Clearly not every control is applicable for every site or goal.

1.4.2 Recommended Storm Water Control Practices for North Central Texas Communities

Bioretention Areas

- Bioretention areas are shallow storm water basins or landscaped areas that utilize engineered soils and vegetation to capture and treat storm water runoff. Runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.

Channels

- *Enhanced Swale:* A vegetated open channel that is explicitly designed and constructed to capture and treat storm water runoff within wet or dry cells formed by check dams or other means.
- *Grass Channel:* A vegetated open channel designed to filter storm water runoff and meet velocity targets for the water quality and streambank protection design storm events.
- *Open Conveyance Channel:* Includes such conveyance systems as drainage ditches, grass channels, dry and wet enhanced swales, riprap channels, and concrete channels.

Chemical Treatment

- *Alum Treatment System:* This chemical treatment provides for the injection of liquid alum into storm water runoff on a flow-weighted basis during rain events as it enters a settling basin. The alum precipitate or 'floc' that is formed during coagulation combines with nutrients, suspended solids, and heavy metals and settles in the settling basin.

Conveyance Components

- *Culverts:* Typically, short, closed (covered) conduits that convey storm water runoff under an embankment, usually a roadway. The primary purpose of a culvert is to convey surface water, but it may also be used to restrict flow and reduce downstream peak flows.

- *Energy Dissipators:* Energy dissipaters are engineered devices such as riprap or concrete baffles placed at the outlet of a storm water conveyance for the purpose of reducing the velocity, energy, and turbulence of the discharged flow.
- *Inlets/Street Gutters:* Drainage elements that remove runoff from sidewalks, streets, and sumps for public safety purposes and function to input storm water to the storm drain pipe systems.
- *Pipe Systems:* A branching system of closed conduits that accumulate storm water runoff and convey it to an open channel, natural stream, or storage facility.

<u>Detention</u>

- **Dry Detention:* Dry detention basins are surface storage basins or facilities typically designed to provide water quantity control through detention or extended detention of storm water runoff.
- **Extended Dry Detention Basins:* Extended dry detention basins are surface storage basins or facilities that can be designed to provide water quality and quantity control through extended detention of storm water runoff.
- *Multi-Purpose Detention Areas:* Multi-purpose detention areas are facilities designed primarily for another purpose, such as parking lots and rooftops, that can provide water quantity control through detention of storm water runoff.
- *Underground Detention:* Underground detention storage is provided by underground tanks or vaults designed to provide water quantity control through detention and/or extended detention of storm water runoff.

<u>Filtration</u>

- *Filter Strip:* Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration.
- *Organic Filter:* Organic filters are design variant of the surface sand filter using organic materials such as peat or compost in the filter media.
- *Planter Boxes:* Planter boxes are used on impervious surfaces to collect and detain/infiltrate rainfall and runoff. They usually contain growing plants.
- *Surface Sand Filter / Perimeter Sand Filter:* Sand filters are multi-chamber structures designed to treat storm water runoff through filtration, using a sand bed as the primary filter media. Filtered runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.
- *Underground Sand Filter:* The underground sand filter is a design variant of the surface sand filter located in an underground vault designed for high density land use where there is not enough space for a surface sand filter or other storm water controls.

<u>Hydrodynamic Devices</u>

- *Gravity (Oil-Grit) Separator:* The gravity (oil-grit) separator is a hydrodynamic separation device designed to remove settleable solids, oil, grease, debris, and floatables from storm water runoff through gravitational settling and trapping of pollutants.

<u>Infiltration</u>

- *Downspout Drywells:* Downspout Drywells are essentially perforated manholes, but they can be manufactured in various sizes. Located underground, they allow storm water infiltration even in highly urbanized areas. They should be used in conjunction with some type of pretreatment devices where there are minimal risks of groundwater contamination.
- *Infiltration Trench:* Infiltration trenches are excavated trenches filled with stone aggregate used to

capture and allow infiltration of storm water runoff into the surrounding soils from the bottom and sides of the trench.

- *Soakage Trench:* Soakage trenches are a variation of infiltration trenches. Soakage trenches drain through a perforated pipe buried in gravel. They are used in highly impervious areas where conditions do not allow surface infiltration and where pollutant concentrations in runoff are minimal (i.e. non-industrial rooftops). They may be used in conjunction with other storm water devices, such as draining downspouts or planter boxes.

*Ponds

There are two storm water storage functions: detention and retention. Detention ponds are designed to store water and release it over time to empty the basin. Retention basins have a permanent pool (or micropool) of water. Some basins are designed to include both detention and retention. Runoff from each rain event is detained and treated in the pool. Pond design variants include:

- Micropool Extended Detention Pond
- Multiple Pond Systems
- Wet Extended Detention Pond
- Wet Pond

Porous Surfaces

- *Green Roofs:* A green roof uses a small amount of substrate over an impermeable membrane to support a covering of plants. The green roof slows down runoff from the otherwise impervious roof surface as well as moderating rooftop temperatures. With the right plants, a green roof will also provide aesthetic or habitat benefits. Green roofs have been used in Europe for decades.
- *Modular Porous Paver Systems:* Modular porous paver systems are pavement surfaces composed of structural units with void areas that are filled with pervious materals such as sand or grass turf. Porous pavers are installed over a gravel base course to provide storage as runoff infiltrates through the porous paver system into underlying permeable soils.
- *Porous Concrete:* Porous concrete is the term for a mixture of coarse aggregate, Portland cement, and water that allows for rapid infiltration of water and overlays a stone aggregate reservoir. The reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and/or out through an underdrain system.

Proprietary Structural Controls

There are numerous manufactured structural control systems available from commercial vendors designed to treat storm water runoff and/or provide water quantity control.

Re-Use

- *Rain Harvesting (Tanks/Barrels):* A rain harvesting system is a container or system designed to capture and store rainwater discharged from a roof. The rain harvesting system consists of a storage container, a downspout diversion, a sealed lid, and an overflow system. Typical rain harvesting systems hold between 50 and 500 gallons of water, and may work in series to provide larger volumes of storage. For larger roof tops an underground storage tank and pump system can provide water for irrigation purposes on site.

Wetlands

- **Storm Water Wetlands:* Storm water wetlands are constructed wetland systems used for storm water management. Storm water wetlands consist of a combination of shallow marsh areas, open water areas, and semi-wet areas above the permanent water surface. Wetland design variants include:

- Extended Detention Shallow Wetland
- Pocket Wetland
- Pond/Wetland Systems
- Shallow Wetland

- *Submerged Gravel Wetlands:* Submerged gravel wetlands are also known as subsurface flow wetlands and consist of one or more cells filled with crushed rock designed to support wetland plants. Storm water runoff flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

* *Consideration must be given in the design of storm water ponds, wetlands, and detention basins to minimize potential mosquito breeding areas. This can be accomplished in a variety of ways including aquatic and chemical techniques which should be utilized as appropriate for the situation.*

1.4.3 Suitability of Storm Water Controls to Meet Storm Water Management Goals

Table 1.4.3-1 summarizes the storm water management suitability of the various storm water controls in addressing the *integrated* Design Approach. Given that some storm water controls cannot alone meet all of the design requirements, typically two or more controls are used in series to form what is known as a storm water "treatment train." Chapter 5 provides guidance on the use of a treatment train as well as how to calculate the pollutant removal efficiency for storm water controls in series. Chapter 5 also provides guidance for choosing the appropriate storm water control(s) for a site as well as the basic considerations and limitations on the use of a particular storm water control.

Table 1.4.3-1 Suitability of Storm Water Controls to Meet *integrated* Design Approach

Category	*integrated* Storm Water Controls	Water Quality Protection	Streambank Protection	On-Site Flood Control	Downstream Flood Control
Bioretention Areas	Bioretention Areas	P	S	S	-
Channels	Enhanced Swales	P	S	S	S
	Channels, Grass	S	S	P	S
	Channels, Open	-	-	P	S
Chemical Treatment	Alum Treatment System	P	-	-	-
Conveyance Components	Culverts	-	-	P	P
	Energy Dissipation	-	P	S	S
	Inlets/Street Gutters	-	-	P	-
	Pipe Systems	-	P	P	P
Detention	Detention, Dry	S	P	P	P
	Detention, Extended Dry	S	P	P	P
	Detention, Multi-purpose Areas	-	P	P	P
	Detention, Underground	-	P	P	P
Filtration	Filter Strips	S	-	-	-
	Organic Filters	P	-	-	-
	Planter Boxes	P	-	-	-
	Sand Filters, Surface/Perimeter	P	S	-	-
	Sand Filters, Underground	P	-	-	-
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	S	-	-	-
Infiltration	Downspout Drywell	P	-	-	-
	Infiltration Trenches	P	S	-	-
	Soakage Trenches	P	S	-	-
Ponds	Ponds, Storm Water	P	P	P	P
Porous Surfaces	Green Roof	P	S	-	-
	Modular Porous Paver Systems	S	S	-	-
	Porous Concrete	S	S	-	-
Proprietary Systems	Proprietary Systems *	S	S	S	S
Re-Use	Rain Barrels	P	-	-	-
Wetlands	Wetlands, Storm Water	P	P	P	P
	Wetlands, Submerged Gravel	P	P	S	-

P = **Primary Control:** Able to meet design criterion if properly designed, constructed and maintained.

S = **Secondary Control:** May partially meet design criteria. May be a Primary Control but designated as a Secondary due to other considerations. For Water Quality Protection, recommended for limited use in approved community-designated areas.

- = Not typically used or able to meet design criterion.

***** = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data.

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