Planning:

1.0 *integrated* Planning and Design Focus Areas
2.0 *integrated* Site Design Practices

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1.0 *integrated* Planning and Design Focus Areas

1.1 Introduction

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

- Remove pollutants in stormwater runoff to protect water quality;
- Regulate discharge from the site to minimize downstream bank and channel erosion; and
- Control runoff within and from the site to minimize flood risk to people and properties for the conveyance storm, as well as the 100-year storm.

The *integrated* Design Focus Areas are a coordinated set of design standards that allow the site engineer to design and size stormwater controls to address these goals. Each of the *integrated* Design Focus Areas should be used in conjunction with the others to address the overall stormwater impacts from a development site. When used as a set, the *integrated* Design Focus Areas control the entire range of hydrologic events, from the smallest runoff-producing rainfalls up to the 100-year, 24-hour storm. Through the *integrated* Design Focus Areas, each community receives standardized options while retaining the flexibility to define their own program. The *iSWM Criteria Manual for Site Development and Construction (Criteria Manual)* specifies the options allowed and/or required by the community.

The design focus areas for each of the goals above is summarized in Table 1.1 below:

Table 1.1 Summary of Options for Design Focus Areas

Design Focus Area	Criteria Manual Reference Section	Required Downstream Assessment	Design Options
Water Quality Protection	3.2	no	**Option 1:** Use *integrated* Site Design Practices for conserving natural features, reducing impervious cover, and using the natural drainage systems
			Option 2: 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 (85^{th} percentile storm)
			Option 3: Assist in implementing off-site community stormwater pollution prevention programs/activities as designated in an approved stormwater master plan or TPDES Stormwater permit
Streambank Protection	3.4	yes	**Option 1:** Reinforce/stabilize downstream conditions
			Option 2: Install stormwater controls to maintain or improve existing downstream conditions
			Option 3: Provide on-site controlled release of the 1-year, 24-hour storm event over a period of 24 hours (Streambank Protection Volume, SP_V)
Flood Mitigation and Conveyance	3.5 and 3.6	yes	**Flood Mitigation** **Option 1:** Provide adequate downstream conveyance systems
			Option 2: Install stormwater controls on-site to maintain or improve existing downstream conditions
			Option 3: In lieu of a downstream assessment, maintain existing on-site runoff conditions
			Conveyance Minimize localized site flooding of streets, sidewalks, and properties by a combination of on-site stormwater controls and conveyance systems

1.2 Downstream Assessment

As part of the iSWM 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 Focus Areas 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 that 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
    - Streambank protection storm
    - Conveyance storm
    - Flood mitigation storm
- Separate analysis for each major outfall from the proposed development

Once the analysis is complete, the designer should ask the following four 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?
- Are the post-development flood heights more than 0.1 feet above the pre-development flood heights?

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 1.0 and 2.0 of the Hydrology Technical Manual* gives additional guidance on calculating the discharges and velocities, as well as determining the downstream extent of the assessment.

1.3 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 stormwater runoff from development. A community should provide adequate water quality protection for development sites by specifying in the *Criteria Manual* the acceptable *integrated* Site Design Practices for the local community. Water quality protection shall only be required as identified by the *Criteria Manual*. Enhanced water quality protection can be achieved by using one or both of Options 2 and 3.

Option 1: Use of *integrated* Site Design Practices

Through the consideration and use of *integrated* Site Design Practices, as discussed in *Section 2.0* below, natural drainage and treatment systems can be preserved. With conservation of natural features, reduced imperviousness, and the use of natural drainage systems, the generation of stormwater runoff and pollutants from the site are reduced.

Option 2: 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 *Criteria Manual*, stormwater 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 1.3 of the Water Quality Technical Manual*.

Option 3: 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 stormwater 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.

1.4 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 three options by which a community can provide adequate streambank protection downstream of a proposed development. The local jurisdiction should specify in the *Criteria Manual* 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 *Criteria Manual*.

Option 1: Reinforce/Stabilize Downstream Conditions

If the increased velocities are higher than the allowable velocity of the downstream receiving system, then the developer must reinforce/stabilize the downstream conveyance system. The proposed modifications must be designed so that the downstream post-development velocities (for all storm events required by the municipality) 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 3.2 and 3.3 in the Hydraulics Technical Manual* for allowable velocities.)

Option 2: Install Stormwater 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 storm events required by the municipality are within an allowable range once the controls are installed.

Option 3: Control the Release of the 1-yr, 24-hr Storm Event

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 (SPv)

SP_v Calculation Methods: Several methods can be used to calculate the SP_v storage volume required for a site. *Section 3.0 of the Hydrology Technical Manual* illustrates the recommended average outflow method for volume calculation.

Hydrograph Generation: The SCS TR-55 hydrograph methods provided in *Section 1.3 of the Hydrology Technical Manual* 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 *Section 5.0 of the Hydrology Technical Manual* 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 stormwater 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 stormwater 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 2.2 of the Hydraulics Technical Manual*). Clogging protection must be provided on all orifices.

1.5 Flood Control

Flood control analyses are based on the following three (3) storm events. The storm frequencies for each event shall be established in *Section 1.3 of the Criteria Manual*.

- Streambank Protection
- Conveyance
- Flood Mitigation

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 "Flood Mitigation" storm events; maintain the boundaries of the mapped 100-year floodplain; and protect the physical integrity of the on-site stormwater controls and the downstream stormwater and flood control facilities.

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

1.5.1 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 stormwater 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 *Criteria Manual*.

It is recommended that once the initial set of controls are selected in the iSWM Site Plan design, the full build-out Flood Mitigation (100-year, 24-hour) storm be routed through the on-site conveyance system and stormwater 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 Flood Mitigation 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 Flood Mitigation storm events, traffic may be limited in order to utilize all or portions of the right-of-way for stormwater conveyance in order to protect properties. As such, the effective management of stormwater throughout the development for the full range of storm events is needed.

1.5.2 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 “Flood Mitigation” storm events (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 *Criteria 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 *Criteria Manual*.

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 three options by which a community can address downstream flood control. The local jurisdiction should specify in the *Criteria Manual* which of these options are acceptable, as well as any other alternatives for downstream flood control. These options closely follow the three options for Streambank Protection.

Option 1: Provide Adequate Downstream Conveyance Systems

If the downstream receiving system does not have adequate capacity, then the developer shall 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 stormwater 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.

Option 2: Install Stormwater Controls to Maintain Existing Downstream Conditions

If the downstream receiving system does not have adequate capacity, then the developer shall provide stormwater 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.

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.

Option 3: In lieu of a Downstream Assessment, Maintain Existing On-Site Runoff Conditions

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 3 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 2.0 of the Hydrology Technical Manual*. The developer shall confirm that detention does not exacerbate peak flows or create a worse situation in downstream reaches.

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

- *Peak-Discharge and Hydrograph Generation:* Hydrograph methods provided in *Section 1.0 of the Hydrology Technical Manual* 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 *Section 5.0 of the Hydrology Technical Manual* 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 2.0 of the Hydrology Technical Manual.*

1.6 *integrated* Watershed Planning

1.6.1 Introduction

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

Stormwater 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 stormwater 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 stormwater master plan is the comprehensive watershed plan which is described in detail in this chapter.

For any stormwater 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.

1.6.2 Types of Stormwater Master Planning

There are several basic types of stormwater master plans that can be prepared. The *Criteria Manual* 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 stormwater 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 stormwater 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 stormwater 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. Stormwater 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 stormwater 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 stormwater 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 stormwater 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.

2.0 *integrated* Site Design Practices

2.1 Overview

2.1.1 Introduction

The first step in addressing stormwater 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 stormwater 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 stormwater (quantity and quality) as close to the point of origin as possible and minimizing collection and conveyance
- Preventing stormwater impacts rather than mitigating them
- Utilizing simple, nonstructural methods for stormwater 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 stormwater controls

Integrated site design for stormwater 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 stormwater 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 stormwater 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 stormwater 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 stormwater 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 3.2.2 of the Criteria Manual* describes the 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.

The use of stormwater *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

2.1.2 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 Stormwater "Islands"
- **Utilization of Natural Features for Stormwater 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 *Section 2.2*. 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.

The *integrated* Site Design Practices may be subject to other ordinances within a municipality and could require approval before implementation. Review all relevant materials before developing a site plan.

2.1.3 Using integrated Site Design Practices

Site design should be done in unison with the design and layout of stormwater infrastructure in attaining stormwater management goals. Figure 2.1 illustrates the *integrated* site design process that utilizes the four *integrated* site design categories.

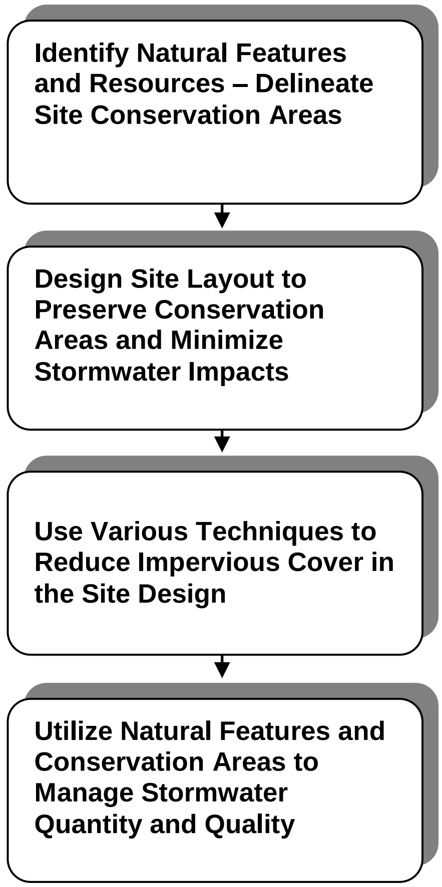


Figure 2.1 *integrated* Site Design Process

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 stormwater quantity and quality management purposes.

2.2 *integrated* Site Design Practices

2.2.1 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 stormwater runoff, providing runoff storage, reducing flooding, preventing soil erosion, promoting infiltration, and removing stormwater 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 *Section 2.2 of the Criteria Manual*). From this site analysis, a concept plan for a site can be prepared that provides for the conservation and protection of natural features. Figure 2.2 shows an example of the delineation of natural features on a base map of a development parcel.

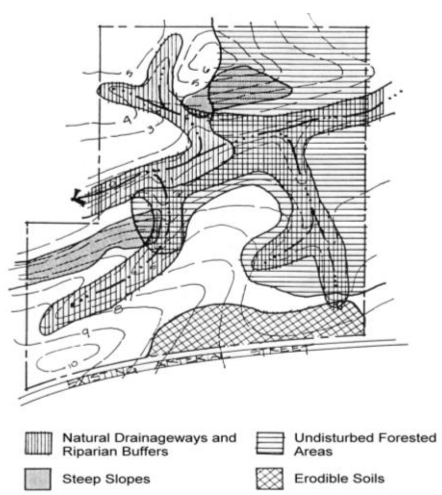


Figure 2.2 Example of Natural Feature Delineation
(Source: MPCA, 1989)

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 stormwater filtering and infiltration zones • Helps to preserve the site's natural character and aesthetic features • May increase the value of the developed property • A stormwater 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 stormwater 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 2.3 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.

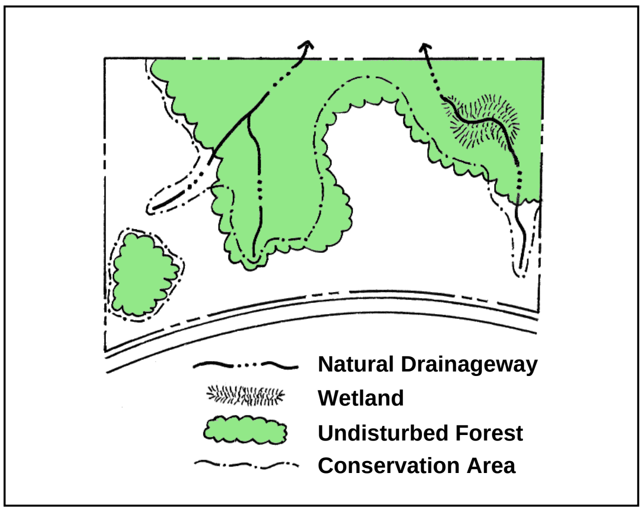


Figure 2.3 Delineation of Natural Conservation Areas

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
▪ Can be used as nonstructural stormwater filtering and infiltration zones ▪ Keeps structures out of the floodplain and provides a right-of-way for large flood events ▪ Helps to preserve riparian ecosystems and habitats ▪ A stormwater site design reduction credit can 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 stormwater 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 2.4

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 stormwater to concentrate and flow into the stream without first flowing through the buffer.

Figure 2.4 Riparian Stream Buffer

Ideally, riparian buffers should be sized to include the flood mitigation storm 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 2.5. The function, vegetative target and allowable uses vary by zone as described in Table 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 supersede 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.

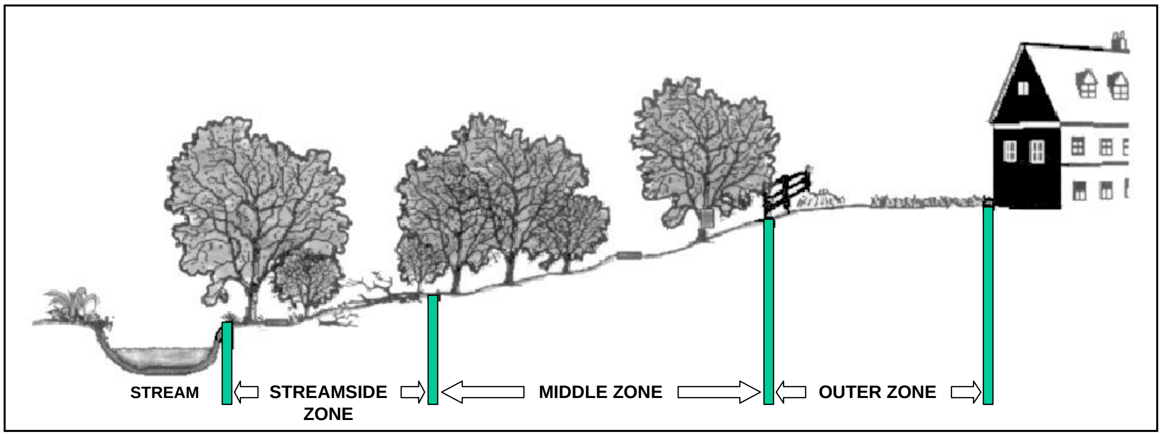


Figure 2.5 Three-Zone Stream Buffer System

Table 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 flood mitigation storm 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 stormwater controls, bike paths	**Unrestricted** e.g., residential uses including lawn, garden, most stormwater 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
▪ Provides a natural right-of-way and temporary storage for large flood events ▪ Keeps people and structures out of harm's way ▪ Helps to preserve riparian ecosystems and habitats ▪ Can be combined with riparian buffer protection to create linear greenways	☑ Obtain maps of the flood mitigation storm 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 stormwater, 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.

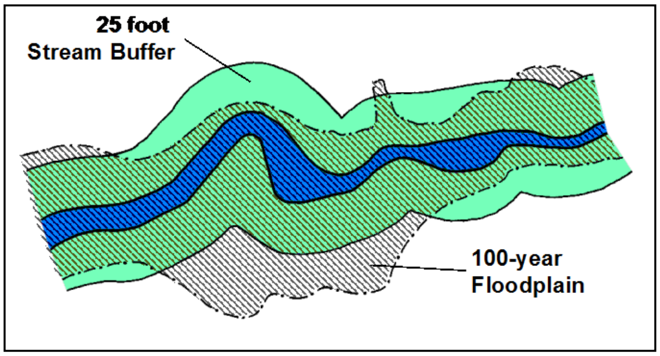


Figure 2.6 Floodplain Boundaries in Relation to a Riparian Buffer

As such, floodplain areas should be avoided on a development site. Ideally, the entire flood mitigation storm 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, flood mitigation storm floodplain boundaries may lie inside or outside of a preserved riparian buffer corridor, as shown in Figure 2.6.

Maps of the flood mitigation storm 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
▪ Preserving steep slopes helps to prevent soil erosion and degradation of stormwater runoff quality ▪ Steep slopes can be kept in an undisturbed natural condition to help stabilize hillsides and soils ▪ Building on flatter areas will reduce the need 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

<u>Discussion</u>

Developing on steep slope areas has the potential to cause excessive soil erosion and increased stormwater 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 2.7.

Therefore, development on slopes with a grade of 15% or greater should be avoided if possible to limit soil loss, erosion, excessive stormwater 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.

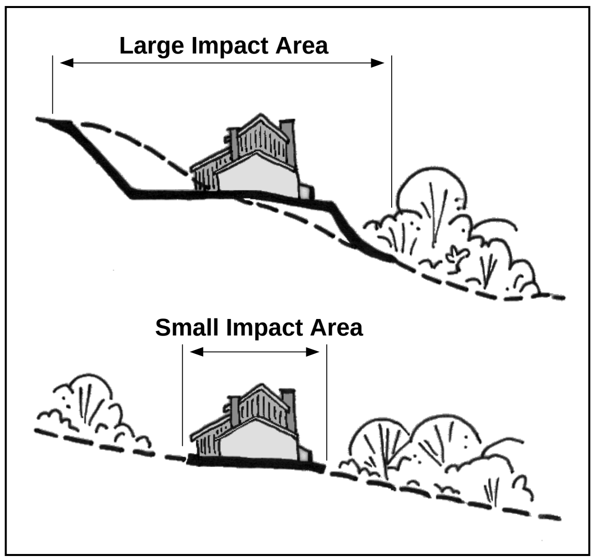


Figure 2.7 Flattening Steep Slopes for Building Sites Uses More Land Area than Building on Flatter Slopes
(Source: MPCA, 1989)

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 stormwater runoff and should be preserved as a potential stormwater management option. Unstable or easily erodible soils should be avoided due to their greater erosion potential.

KEY BENEFITS	USING THIS PRACTICE
▪ Areas with highly permeable soils can be used as nonstructural stormwater infiltration zones. A stormwater site design credit can be taken if allowed by the local review authority ▪ Avoiding highly erodible or unstable soils can 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

<u>Discussion</u>

Infiltration of stormwater 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 2.8. Soil surveys can provide a considerable amount of information relating to all relevant aspects of soils. *Section 6.0 of the Hydrology Technical 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.

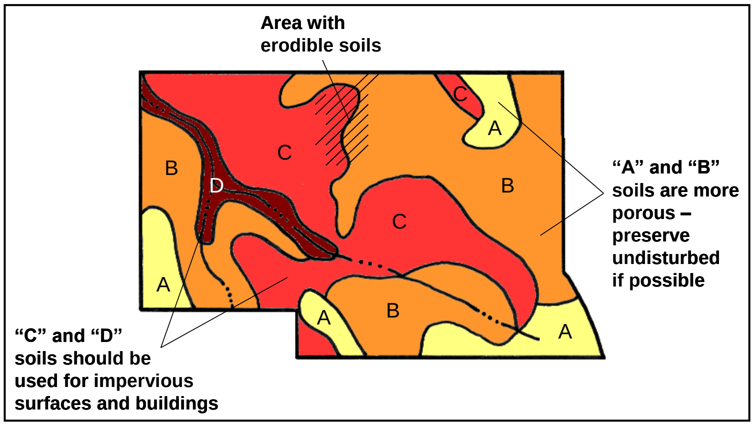


Figure 2.8 Soil Mapping Information Can Be Used to Guide Development

2.2.2 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 stormwater 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 stormwater 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 stormwater impacts.

Figure 2.9 shows a development that has utilized several lower impact site design techniques in its overall layout and design.

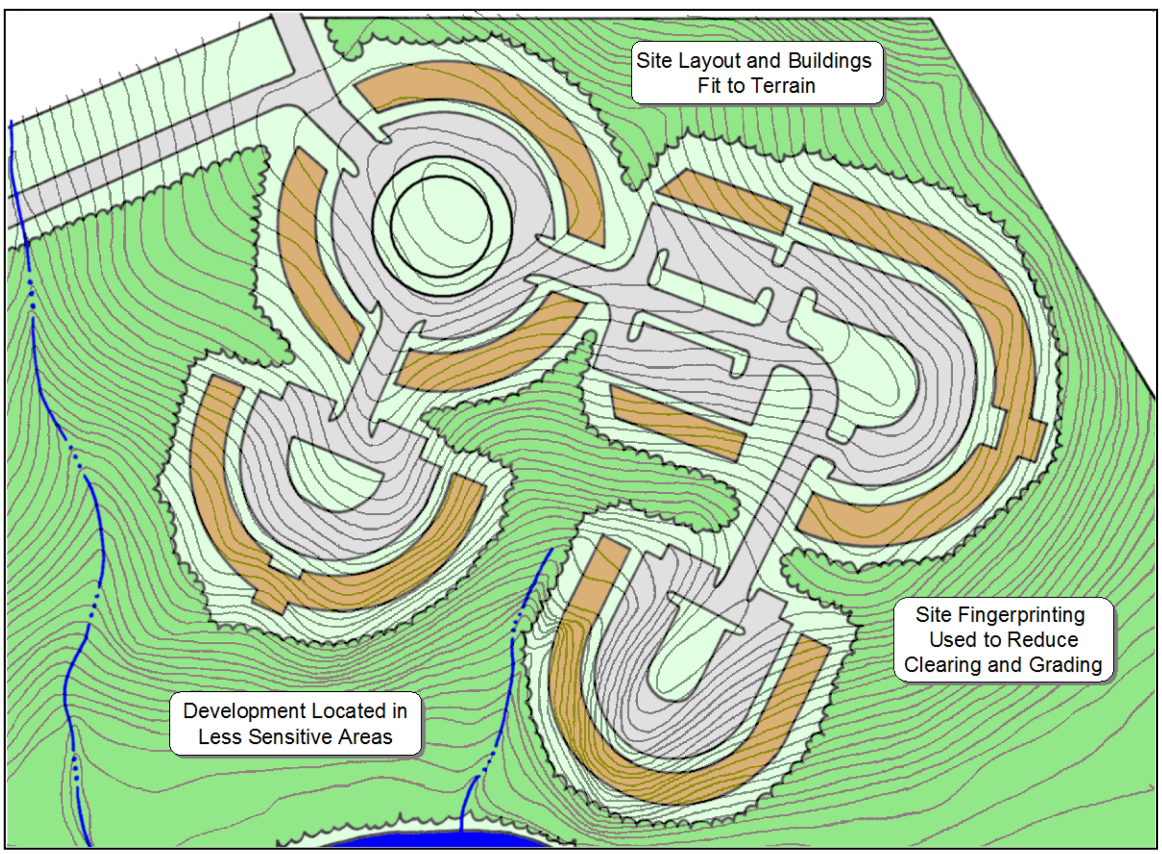


Figure 2.9 Development Design Utilizing Several Lower Impact Site Design Techniques

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
▪ Helps to preserve the natural hydrology and drainageways of a site ▪ Reduces the need for grading and land disturbance ▪ Provides a framework for site design and 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 2.10 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 2.11. 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 2.12). 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.

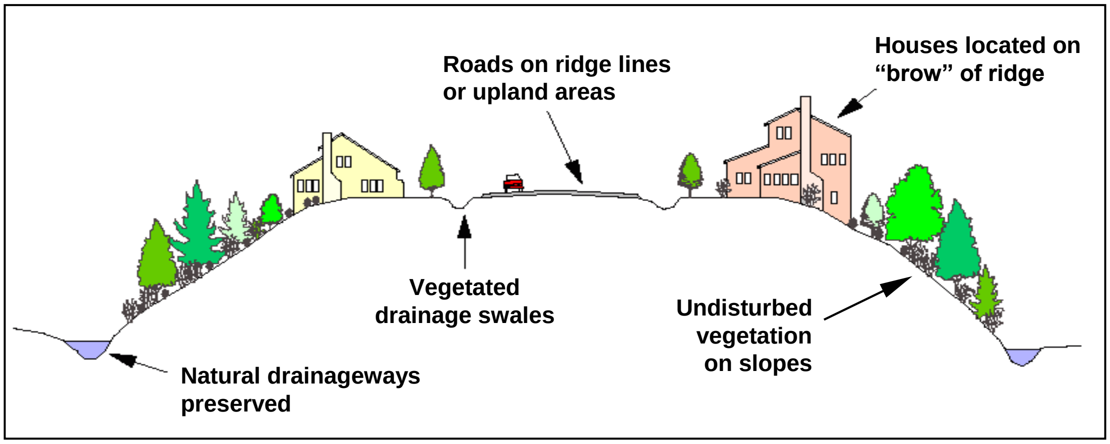


Figure 2.10 Preserving the Natural Topography of the Site
(Adapted from Sykes, 1989)

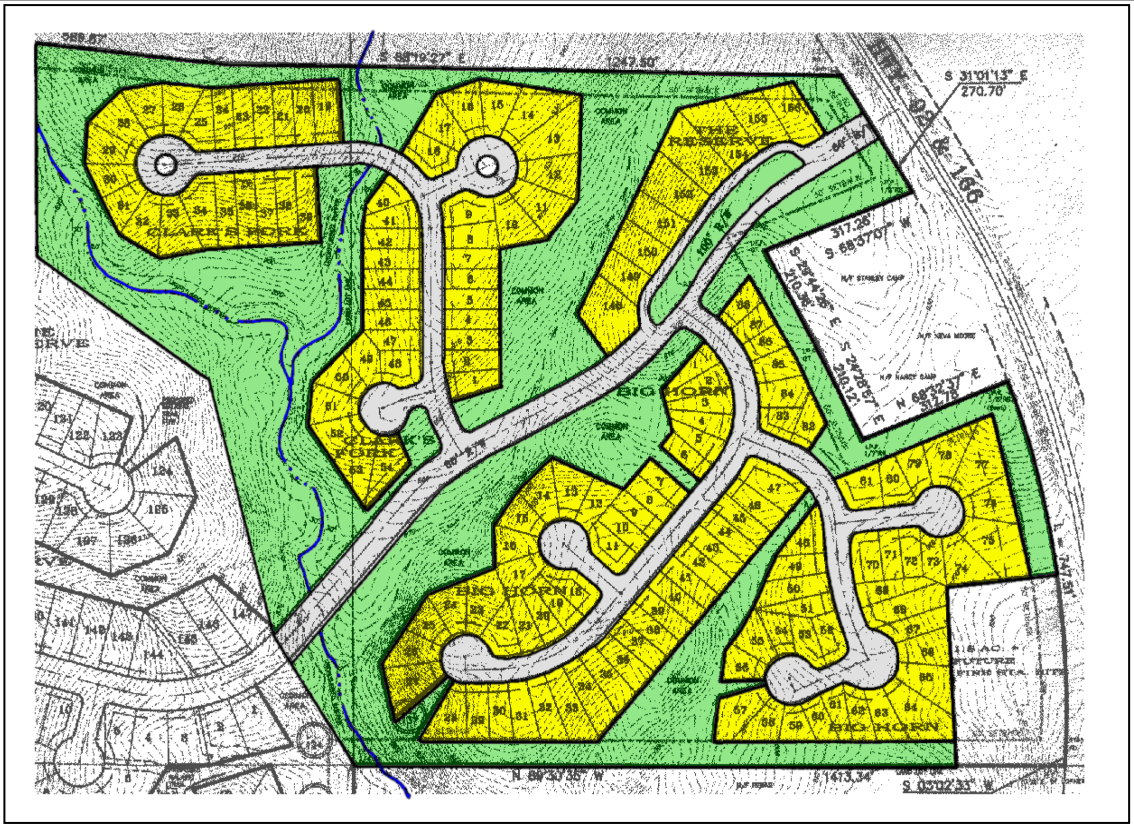


Figure 2.11 Subdivision Design for Hilly or Steep Terrain Utilizes Branching Streets from Collectors that Preserves Natural Drainageways and Stream Corridors

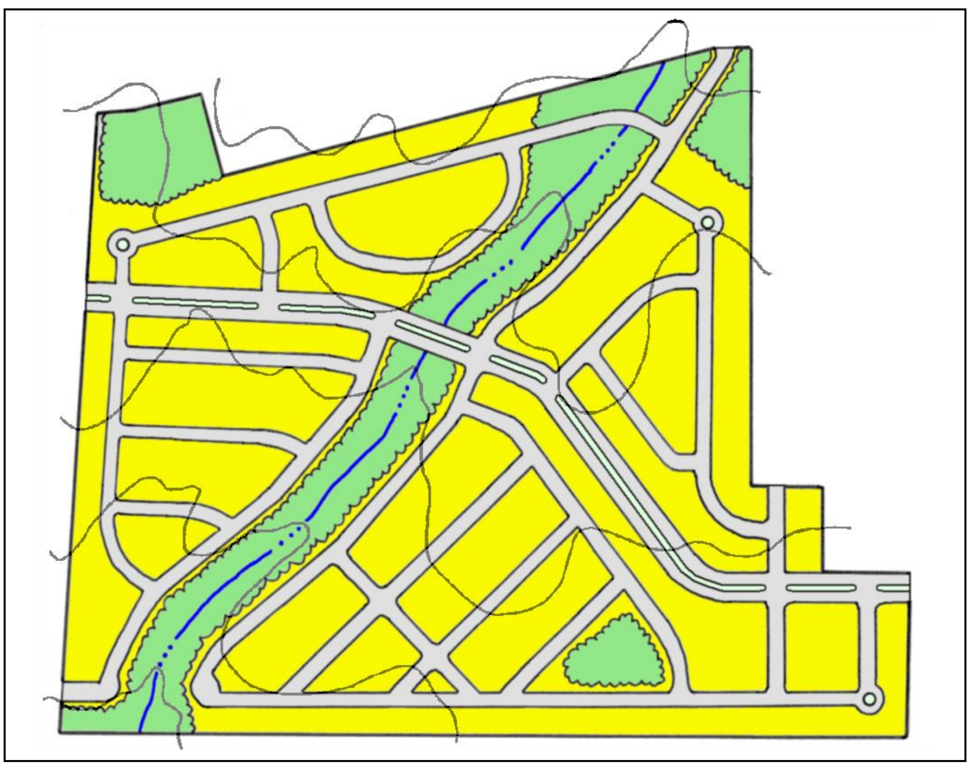


Figure 2.12 A Subdivision Design for Flat Terrain Uses a Fluid Grid Layout that is Interrupted by the Stream Corridor

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
▪ Helps to preserve the natural hydrology and drainageways of a site ▪ Makes most efficient use of natural site features for preventing and mitigating stormwater impacts ▪ Provides a framework for site design and 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 stormwater runoff infiltration zones. Buildings and impervious surfaces should be located in areas with less permeable soils.

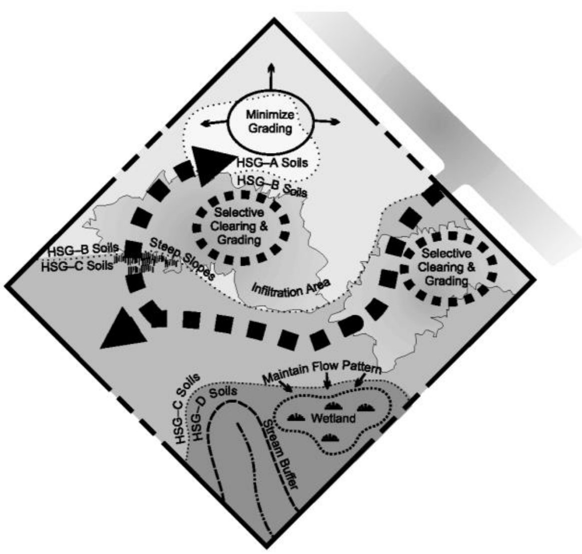


Figure 2.13 Guiding Development to Less Sensitive Areas of a Site
(Source: Prince George's County, MD, 1999)

- 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 2.13 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
▪ Preserves more undisturbed natural areas on a development site ▪ Techniques can be used to help protect natural 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 2.14 and 2.15.
- Fitting the site design to the terrain.
- Using special procedures and equipment which reduce land disturbance.

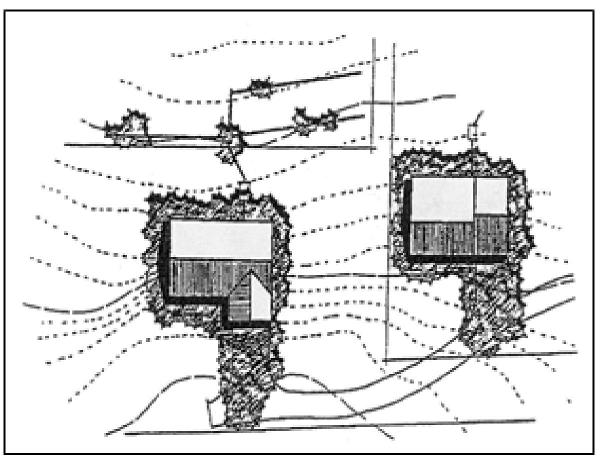


Figure 2.14 Establishing Limits of Clearing
(Source: DDNREC, 1997)

Figure 2.15 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
▪ Preserves conservation areas on a development site ▪ Can be used to preserve natural hydrology and drainageways ▪ Can be used to help protect natural conservation areas and other site features ▪ Reduces the need for grading and land disturbance ▪ Reduces infrastructure needs and overall 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, stormwater pollution, construction costs, and the need for grading and landscaping, while providing for the conservation of natural areas. Figures 2.16 and 2.17 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 stormwater 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.

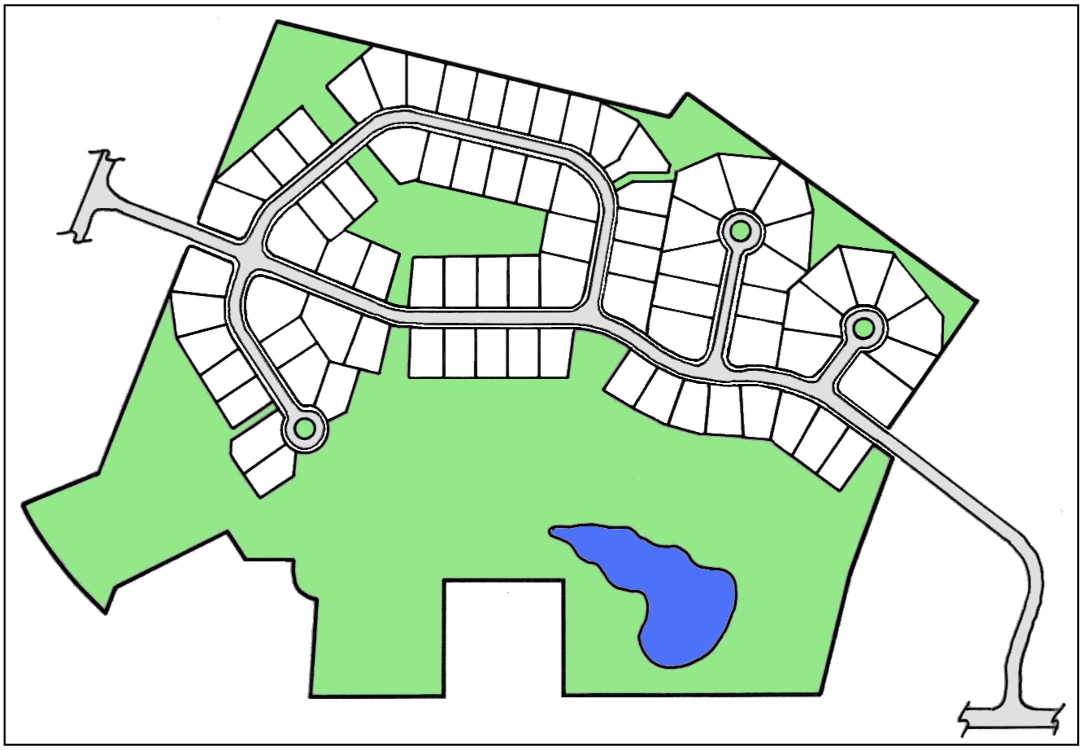


Figure 2.16 Open Space Subdivision Site Design Example

Figure 2.17 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 stormwater management and the protection of environmentally sensitive areas.

KEY BENEFITS	USING THIS PRACTICE
▪ Allows flexibility to developers to implement creative site designs which include *integrated* Site Design Practices ▪ May be useful for implementing an open space development	☑ Check with your local review authority to determine if the community supports PUDs ☑ 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 stormwater 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.

2.2.3 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 stormwater management. Increased impervious cover means increased stormwater 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 stormwater runoff and associated pollutants that are generated. It can also reduce the size and cost of necessary infrastructure for stormwater 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 Stormwater Islands

Figure 2.18 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 2.18 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
▪ Reduces the amount of impervious cover and associated runoff and pollutants generated ▪ Reduces the costs associated with road 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 2.19 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.

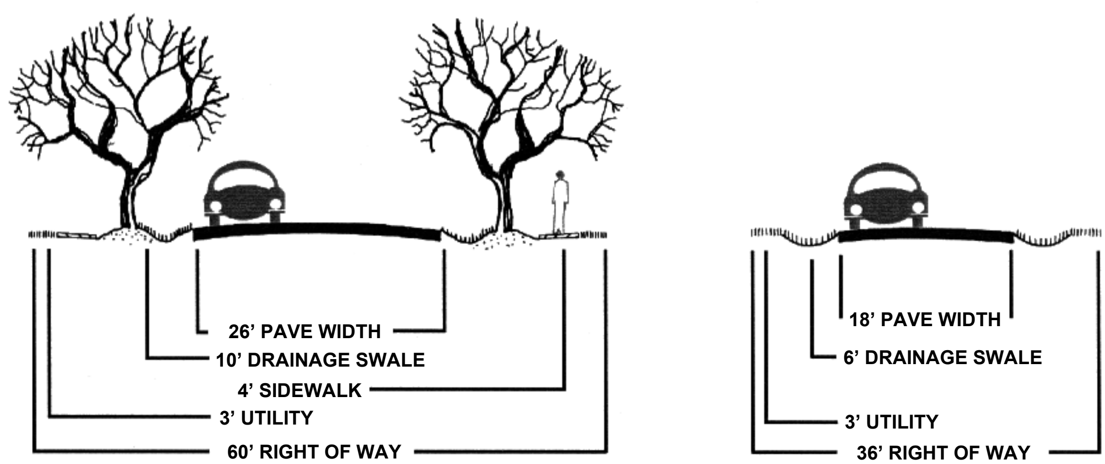


Figure 2.19 Potential Design Options for Narrower Roadway Widths
(Source: VPISU, 2000)

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
▪ Reduces the amount of impervious cover and 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 2.20 shows the reduction in impervious footprint by using a taller building design.

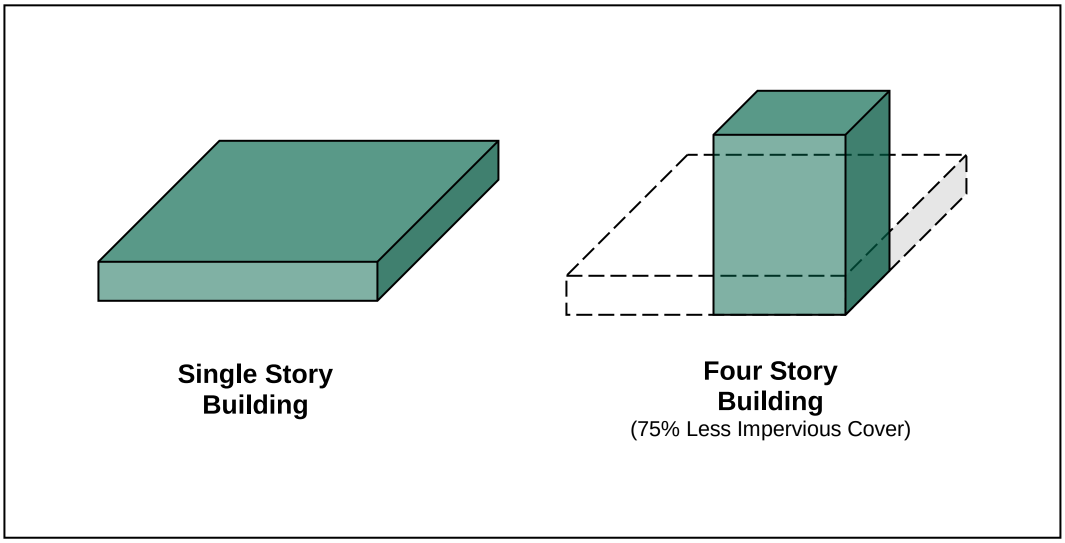


Figure 2.20 Building Up Rather Than Out Can Reduce the Amount of Impervious Cover

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
▪ Reduces the amount of impervious 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 2.2 provides examples of conventional parking requirements and compares them to average parking demand.

Table 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 2.21 shows a parking deck used for a commercial development.

Figure 2.21 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 2.22 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 the *Site Development Controls Technical Manual* on (Modular Porous Paver Systems) and (Porous Concrete). These surfaces can only be used if the soils allow for adequate infiltration.

Figure 2.22 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
▪ Reduces the amount of impervious cover 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 2.23).

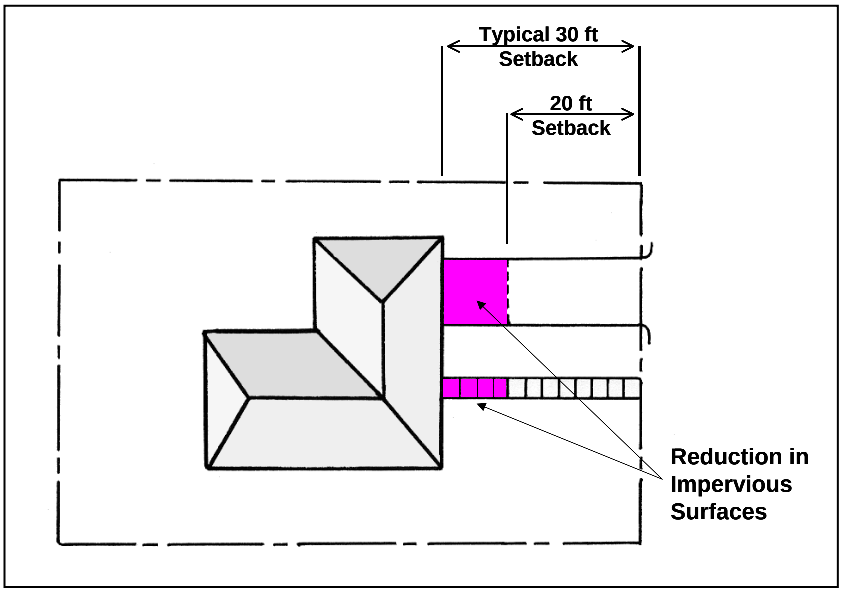


Figure 2.23 Reduced Impervious Cover by Using Smaller Setbacks
(Adapted from: MPCA, 1989)

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 2.24 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 2.25 illustrates various nontraditional lot designs.

Figure 2.24 Examples of Reduced Frontages and Side Yard Setbacks

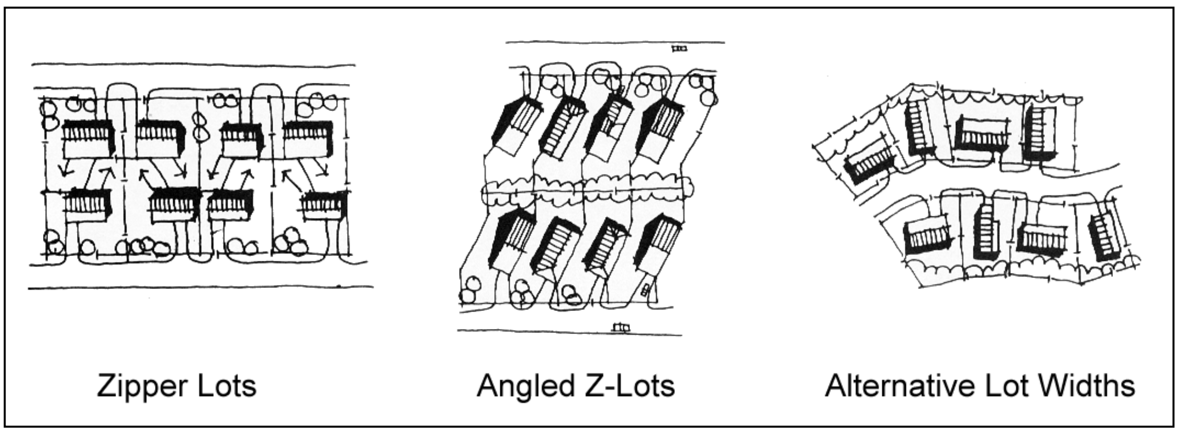


Figure 2.25 Nontraditional Lot Designs
(Source: ULI, 1992)

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
▪ Reduces the amount of impervious cover 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 stormwater 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 2.26).

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.

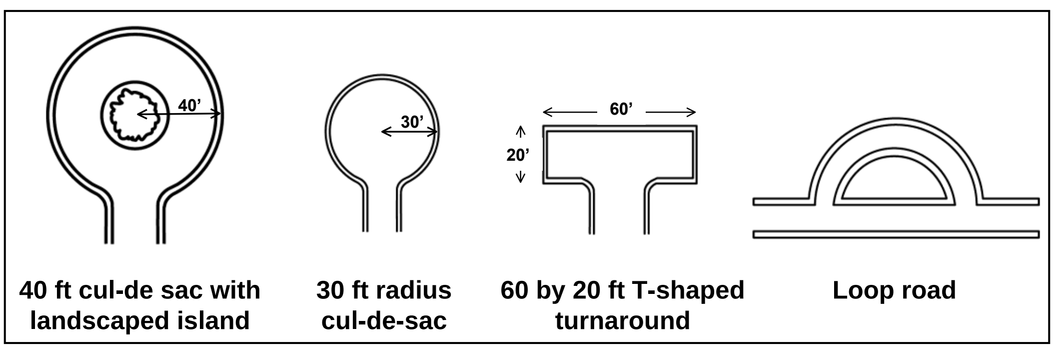


Figure 2.26 Four Turnaround Options for Residential Streets
(Source: Schueler, 1995)

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

Reduction of Impervious Cover

Description: Provide stormwater 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
▪ Reduces the amount of impervious cover and associated runoff and pollutants generated ▪ Provides an opportunity for the siting of structural control facilities ▪ Trees in parking lots provide shading for cars and are more visually appealing	☑ 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 stormwater management "islands" which reduce the overall impervious cover of the lot as well as provide for runoff treatment and control in stormwater 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. Stormwater is directed into these landscaped areas and temporarily detained. The runoff then flows through or filters down through the bed of the facility and is infiltrated into the subsurface or collected for discharge into a stream or another stormwater facility. These facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of filter strips, enhanced swales and bioretention areas, refer to the *Site Development Controls Section of the Technical Manual*.

Figure 2.27 Parking Lot Stormwater "Island"

2.2.4 Utilization of Natural Features for Stormwater Management

Traditional stormwater drainage design tends to ignore and replace natural drainage patterns and often results in overly efficient hydraulic conveyance systems. Structural stormwater 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 stormwater filtering of pollutants and sediment; recycle nutrients; and maximize on-site storage of stormwater. 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* stormwater 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.

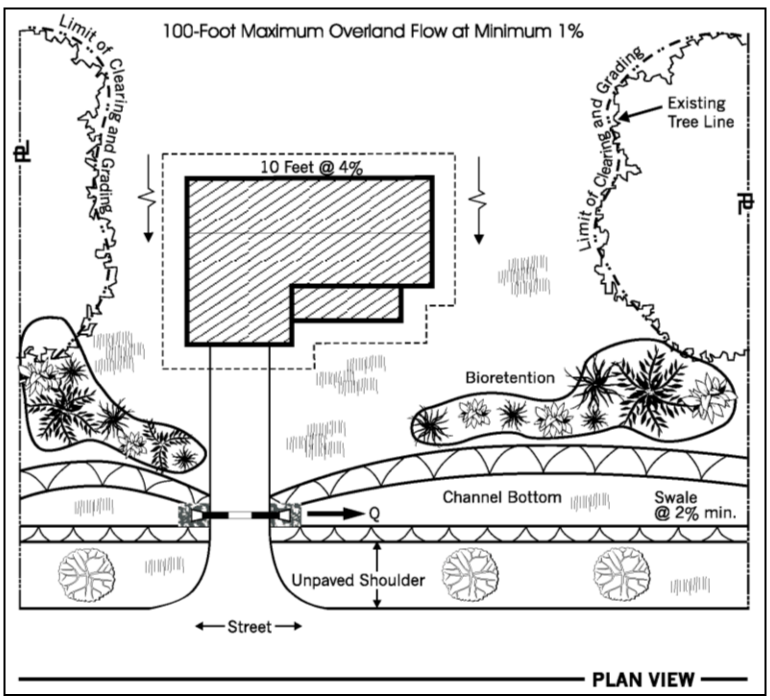


Figure 2.28 Residential Site Design Using Natural Features for Stormwater Management
(Source: Prince George's County, MD, 1999)

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

Utilization of Natural Features for Stormwater Management

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

KEY BENEFITS	USING THIS PRACTICE
▪ Riparian buffers and undisturbed vegetated areas can be used to filter and infiltrate stormwater runoff ▪ Natural depressions can provide inexpensive storage and detention of stormwater flows ▪ A stormwater site design credit can be taken 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 stormwater 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 2.29. 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 under *Site Development Controls Technical Manual* with a similar goal.

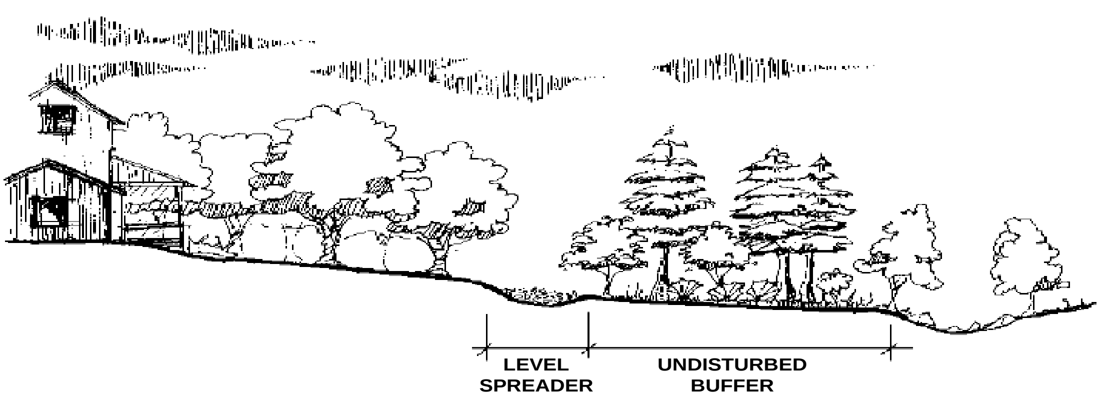


Figure 2.29 Use of a Level Spreader with a Riparian Buffer
(Adapted from NCDENR, 1998)

integrated Site Design Practice #18:

Use Natural Drainageways Instead of Storm Sewers

Utilization of Natural Features for Stormwater Management

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

KEY BENEFITS	USING THIS PRACTICE
▪ Use of natural drainageways reduces the cost of constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading ▪ Natural drainage paths are less hydraulically efficient than man-made conveyances, resulting in longer travel times and lower peak discharges ▪ Can be combined with buffer systems to allow for stormwater filtration and infiltration	☑ 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 stormwater from a site; however, in doing so, these systems tend to increase peak runoff discharges, flow velocities and the delivery of pollutants to downstream waters. An alternative is the use of natural drainageways and vegetated swales (where slopes and soils permit) to carry stormwater flows to their natural outlets, particularly for low-density development and residential subdivisions.

The use of natural open channels (see Figure 2.30) allows for more storage of stormwater flows on-site, lower stormwater peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of stormwater pollutants. 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.

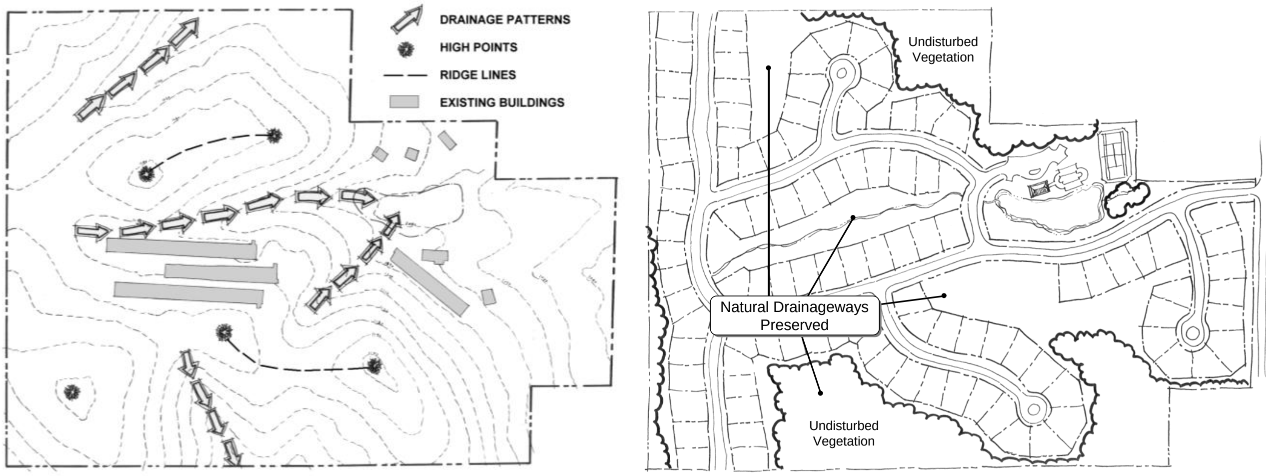


Figure 2.30 Example of a Subdivision Using Natural Drainageways for Stormwater Conveyance and Management

integrated Site Design Practice #19:

Use Vegetated Swales Instead of Curb and Gutter

Utilization of Natural Features for Stormwater 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 stormwater runoff from roadways.

KEY BENEFITS	USING THIS PRACTICE
▪ Reduces the cost of road and storm sewer construction ▪ Provides for some runoff storage and infiltration, as well as treatment of stormwater ▪ A stormwater site design reduction credit can be 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 stormwater runoff

Discussion

Curb and gutter and storm drain systems allow for quicker transport of stormwater 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 stormwater that is often polluted from vehicle emissions, pet waste, lawn runoff and litter.

Open vegetated channels along a roadway (see Figure 2.31) 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 stormwater 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 the *Site Development Controls Section of the Technical Manual*.

Figure 2.31 Using Vegetated Swales Instead of Curb and Gutter

integrated Site Design Practice #20:

Drain Runoff to Pervious Areas

Utilization of Natural Features for Stormwater 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 stormwater conveyance system.

KEY BENEFITS	USING THIS PRACTICE
▪ Sending runoff to pervious vegetated areas increases overland flow time and reduces peak flows ▪ Vegetated areas can often filter and infiltrate stormwater runoff ▪ A stormwater site design credit can be taken if allowed by the local review authority	☑ Minimize directly connected impervious areas and drain runoff as sheet flow to pervious vegetated areas

Discussion

Stormwater 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 stormwater 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 2.32)
- 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 the *Site Development Controls Section of the Technical Manual.*

for more design information and specifications on filter strips and vegetated channels.

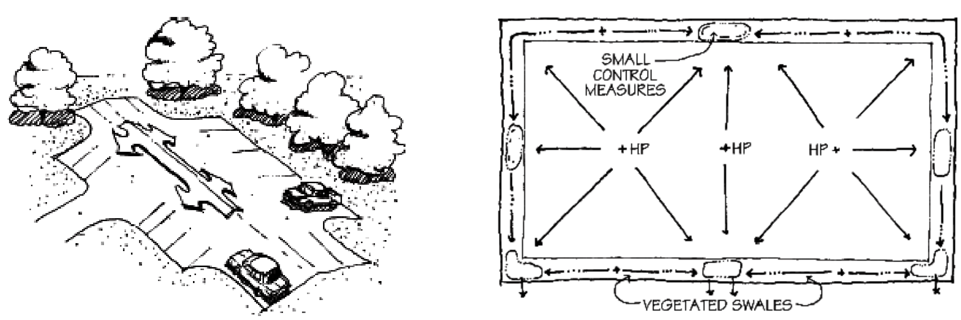


Figure 2.32 Design Paved Surfaces to Disperse Flow to Vegetated Areas
Source: NCDENR, 1998

2.3 *integrated* Site Design Examples

2.3.1 Residential Subdivision Example 1

A typical residential subdivision design on a parcel is shown in Figure 2.33 (a). The entire parcel except for the subdivision amenity area (clubhouse and tennis courts) is used for lots. The entire site is cleared and mass graded, and no attempt is made to fit the road layout to the existing topography. Because of the clearing and grading, all of the existing tree-cover, vegetation and topsoil are removed dramatically altering both the natural hydrology and drainage of the site. The wide residential streets create unnecessary impervious cover and a curb and gutter system that carries stormwater flows to the storm sewer system. No provision for non-structural stormwater treatment is provided on the subdivision site.

A residential subdivision employing *integrated* Site Design Practices is presented in Figure 2.33 (b). This subdivision configuration preserves a quarter of the property as undisturbed open space and vegetation. The road layout is designed to fit the topography of the parcel, following the high points and ridgelines. The natural drainage patterns of the site are preserved and are utilized to provide natural stormwater treatment and conveyance. Narrower streets reduce impervious cover and grass channels provide for treatment and conveyance of roadway and driveway runoff. Landscaped islands at the ends of cul-de-sacs also reduce impervious cover and provide stormwater treatment functions. 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.

2.3.2 Residential Subdivision Example 2

Another typical residential subdivision design is shown in Figure 2.34 (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 flood mitigation storm 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 2.34 (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.

2.3.3 Commercial Development Example

Figure 2.35 (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. Stormwater 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 2.35 (b). Here the retail buildings are dispersed on the property, providing more of an “urban village” feel with pedestrian access between the buildings. The parking is broken up, and bioretention areas for stormwater treatment are built into parking lot islands. A large bioretention area which serves as open green space is located at the main entrance to the shopping center. A larger undisturbed buffer has been preserved on the site. Because the bioretention areas and buffer provide water quality treatment, only a dry extended detention basin is needed for water quantity control.

2.3.4 Office Park Example

An office park with a conventional design is shown in Figure 2.36 (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 2.36 (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.

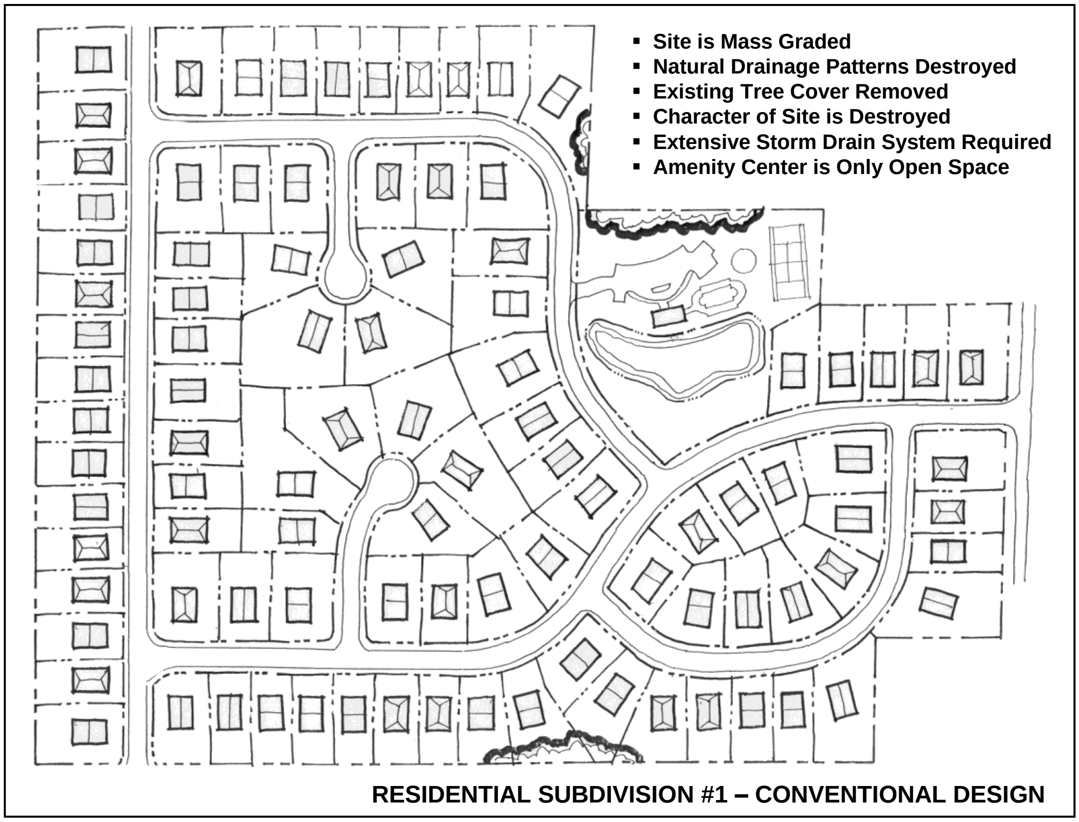


Figure 2.33 Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).

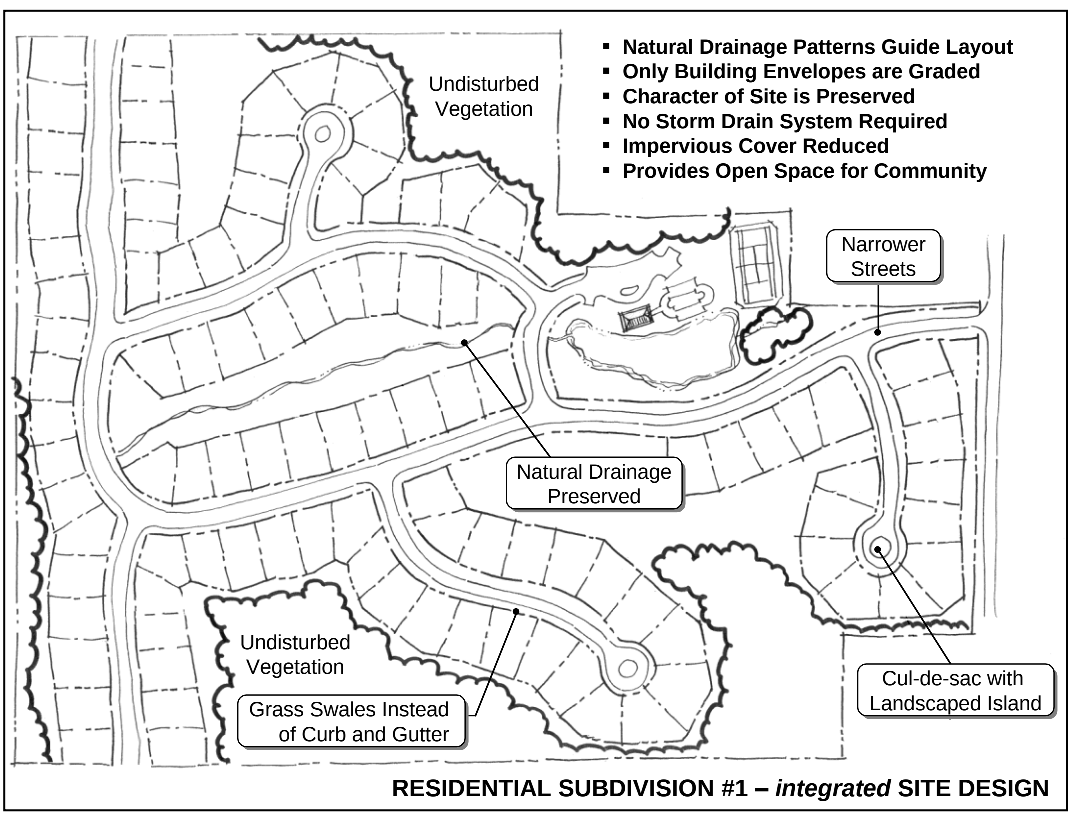
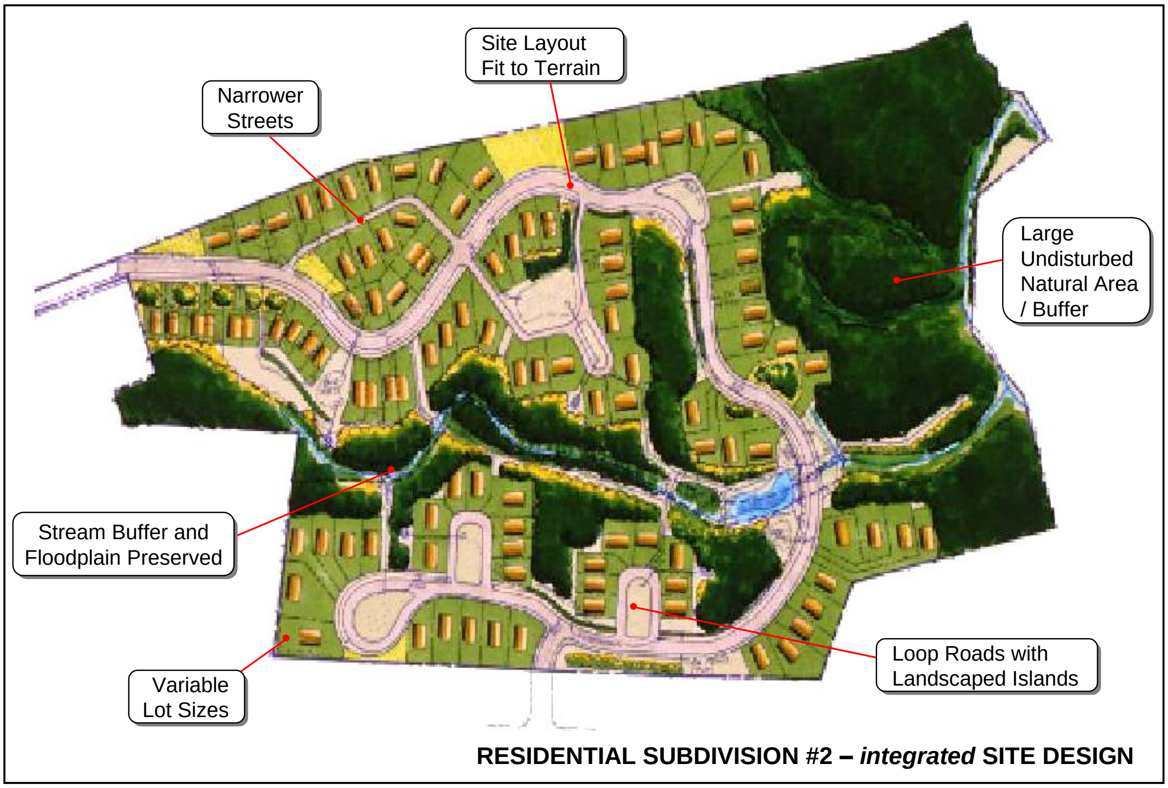


Figure 2.34 Comparison of a Traditional Residential Subdivision Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



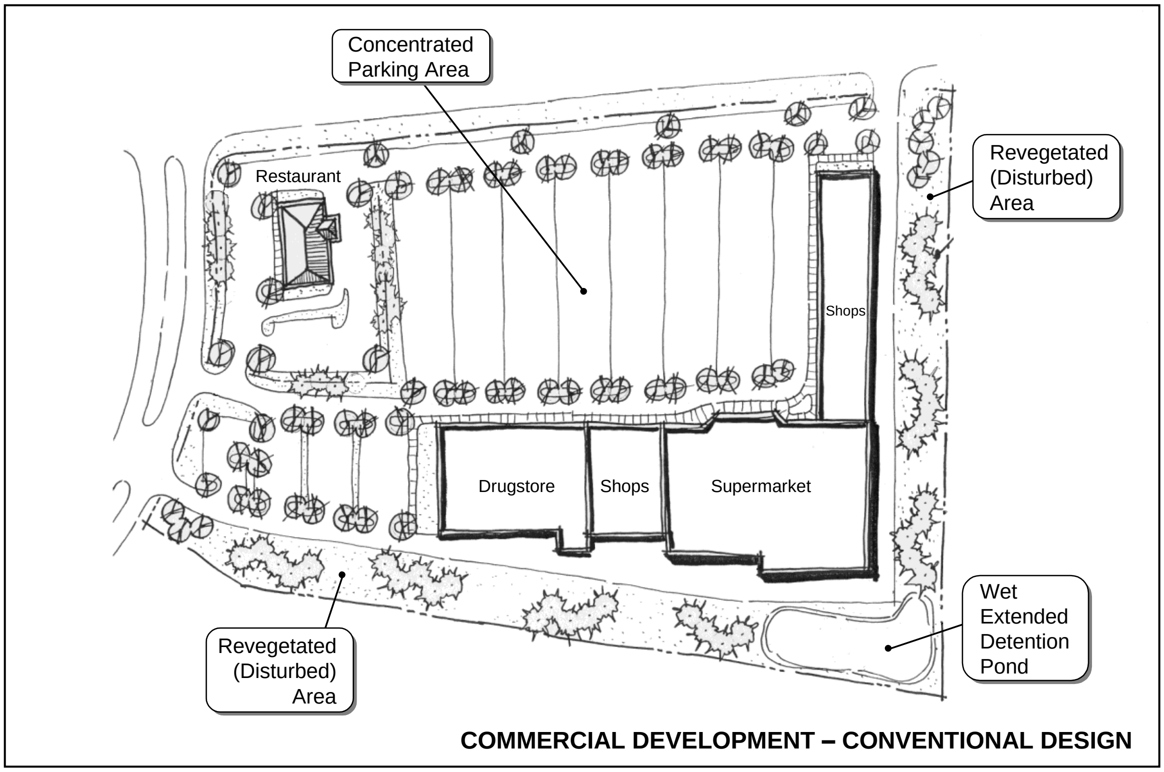
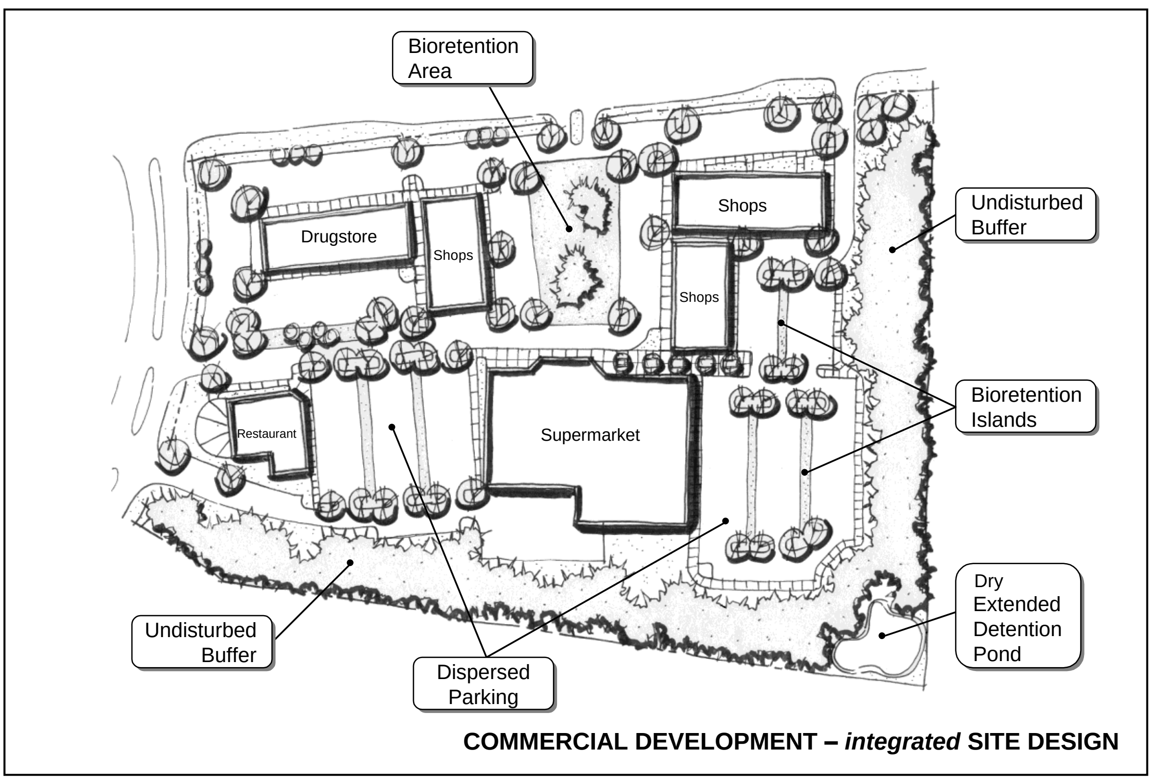


Figure 2.35 Comparison of a Traditional Commercial Development (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



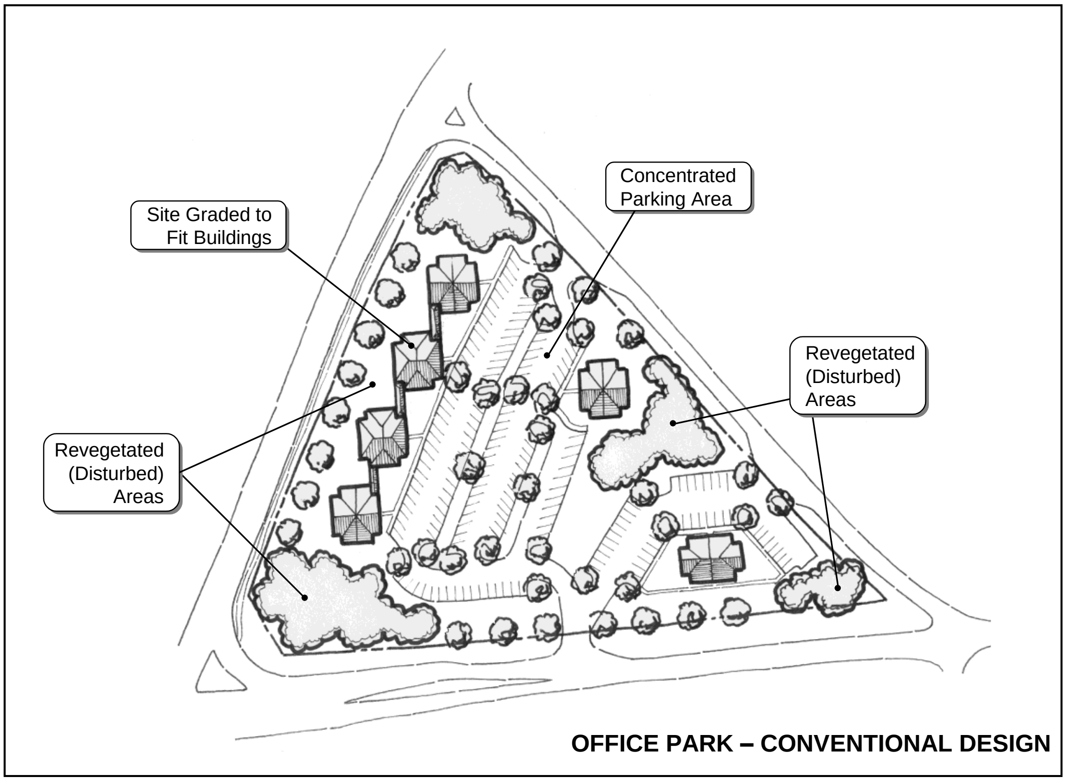
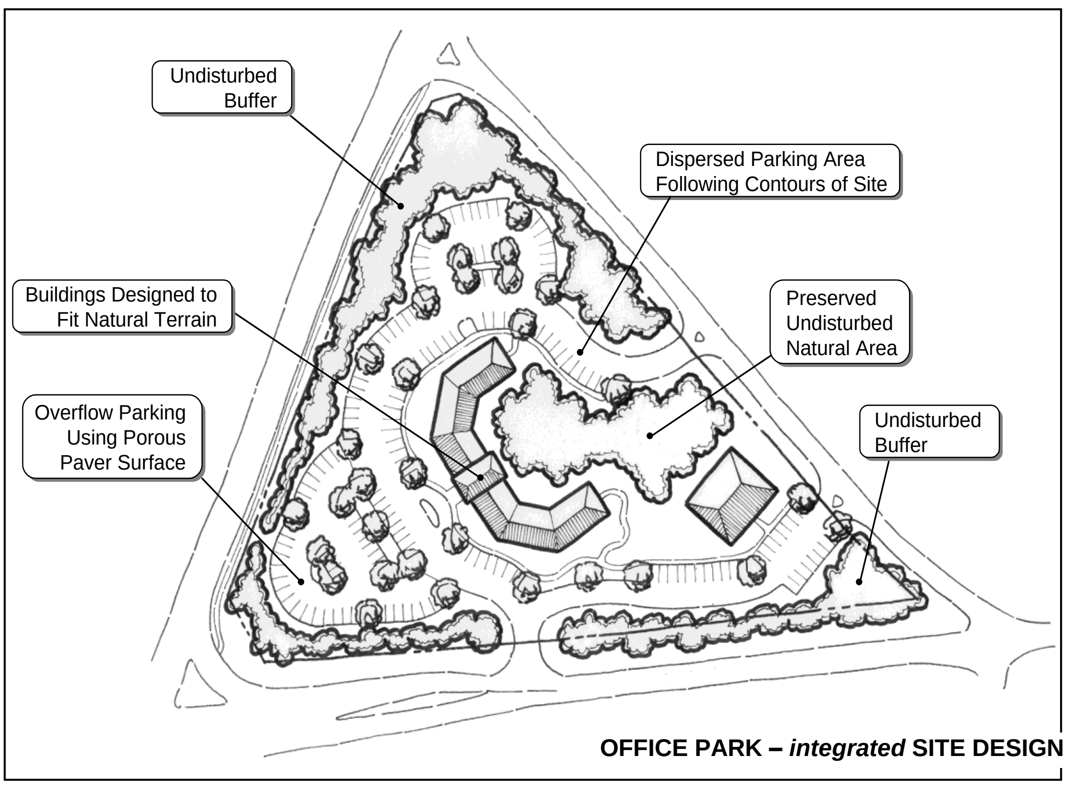


Figure 2.36 Comparison of a Traditional Office Park Design (above) with an Innovative Site Plan Developed Using *integrated* Site Design Practices (below).



2.4 *integrated* Site Design Credits

2.4.1 Introduction

Non-structural stormwater control practices are increasingly recognized as a critical feature in every site design. As such, a set of stormwater "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 stormwater 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.

Refer to *Section 3.2.2 of the Criteria Manual* for more detail on the credits allowed for *integrated* Site Design Practices and the incentives allowed by the local municipality.