Jasper County

Stormwater Management Design Manual

October 3, 2011

1.0 Introduction

1.1 Purpose of the Manual

Jasper County's Stormwater Management Design Manual (Manual) is a comprehensive tool for the application of stormwater management controls and stormwater Best Management Practices (BMP's) aimed at improving the water quality of stormwater. It contains the minimum requirements for the planning, design, construction, operation, and maintenance of drainage facilities within the County and is subject to the requirements of the Stormwater Management Article of the County's Land Development Regulations (LDR). Jasper County's current LDR can be found on the Jasper County website at www.jaspercountysc.org. Definitions, formulas, criteria, procedures, and data presented herein have been developed to support the LDR. If a conflict arises between the technical data and the LDR, the LDR shall govern.

The concepts and design elements described in this Manual, along with the requirements of the LDR, are intended to protect, maintain, and enhance the public health, safety, and general welfare by establishing requirements and procedures to control the adverse effects of increased stormwater runoff associated with future development, re-development, and existing developed land.

The intent of the County's Stormwater Management Program, including the pertinent articles of the LDR and this Manual, is to:

1. Ensure a balance between sustainable economic development and environmental protection.
2. Ensure a functional drainage system that reduces local flooding thereby minimizing damage to public and private property
3. Reduce the effects of development on land and stream channel erosion.
4. Attain and maintain water quality standards.
5. Enhance the local environment associated with the drainage system.
6. Reduce pollutant loading to the maximum extent practical.
7. Maintain pre-development runoff characteristics to the maximum extent practical.
8. Encourage prudent site planning, preservation of natural drainage ways and buffers, on-site stormwater retention and infiltration, effective and efficient storrmwater magement, and the use of structural and non-structural stormwater best management practices (BMPs).
9. Provide a mechanism for the review, approval, and inspection of the approach to be used for the management and control of stormwater for development or redevelopment.
10. This Ordinance is not in conflict with any development agreement to which the County is a party and does not prevent the development set forth in any development agreement.
11. This Ordinance is essential to the public health, safety and welfare and shall apply to any development that is subject to a development agreement.

1.2 Organization of the Manual

To enhance its utility and ease of use, this manual has been divided into six sections. Each section provides information that supports the implementation of an integrated, green infrastructure-based and low-impact approach to stormwater management and site design that can be used to protect valuable natural resources from the negative impacts of land development and nonpoint source pollution. The six sections presented in this document include:

Section 1.0: Section 1.0 provides an introduction to this manual. It describes the purpose of the document and summarizes all of the information presented within.

Section 2.0: Section 2.0 presents Jasper County's design and submittal requirements for stormwater management.

Section 3.0: Section 3.0 provides information on general design criteria and guidelines that can be used to calculate stormwater runoff conditions and design the various components of a stormwater management system.

Section 4.0: Section 4.0 provides detailed information about the green infrastructure practices (e.g., better site planning and design techniques, low impact development practices) that can be used to meet the stormwater management planning and design criteria. Each green infrastructure practice is described and information about its proper application, design, installation and maintenance is included.

Section 5.0: Section 5.0 provides detailed information about the traditional stormwater management practices, such as wet ponds, wetlands and swales, that can be used to meet the stormwater management planning and design criteria. Each stormwater management practice is described and information about its proper application, design, installation and maintenance is included.

Section 6.0: Section 6.0 provides a general approach that can be applied to conducting the necessary calculations and analysis to demonstrate compliance with the County's stormwater volume control and water quality treatment requirements.

1.3 Disclaimer

This manual is established to provide the County, its duly appointed representatives, property owners, developers, engineers, surveyors, and builders a better understanding of acceptable engineering methods and practices to meet the intent of the County's stormwater management requirements. Design of stormwater management for development requires the expertise and judgment of a licensed professional engineer. The County accepts no responsibility for any loss, damage or injury as a result of the use of this manual.

The application of the County's stormwater management requirements and the provisions expressed in this manual are the minimum stormwater management requirements and shall not be deemed a limitation or repeal of any other powers granted by statute. In addition, if site characteristics indicate that complying with the minimum stormwater management requirements will not provide adequate design or protection for local property or residents, the owner and operator of these facilities may be required to exceed the minimum stormwater management practices, control techniques design and engineering methods and such other programs and controls as necessary.

1.4 Updates to the Manual

This manual is subject to periodic updates. As design technology and criteria evolve or change or it becomes evident that additional measures are needed to ensure the public's general welfare, this manual will be updated as needed. Users of this manual are encouraged to provide comments on the content of this manual at any time. The current version of this manual can be found on the Jasper County website at www.jaspercountysc.org.

1.5 Acknowledgements

The Jasper County Stormwater Management Manual was developed under contract to the Jasper County Department of Planning and Building Services by Thomas & Hutton Engineering Company and the Horsley Witten Group. Individuals contributing to the development of the manual included:

- David Jirousek, AICP (Jasper County, Director of Planning and Building Services)
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- Jasper County Council
- Jasper County Planning Commission
- Jasper County Stormwater Advisory Group

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A special recognition is extended to the authors and collaborators of the Coastal Stormwater Supplement (CSS) to the Georgia Stormwater Management Manual (www.georgiastormwater.com), including the Center for Watershed Protection (www.cwp.org), Georgia Department of Natural Resources (www.gadnr.org) and the Chatham County-Savannah Metropolitan Planning Commission (www.thempc.org). The Jasper County Stormwater Management Manual is built on much of the work, concepts and procedures contained in the CSS.

2.0 Stormwater Management Standards and Permit Requirements

2.1 Design Requirements

This manual and the design criteria presented within represent engineering practices that may be utilized in the preparation of stormwater management plans. The criteria are intended to establish requirements, minimum standards, and methods for the sound planning, design, and review process of a stormwater management system. Alternative methods of design may be submitted to the County for its consideration if it can be demonstrated that the design meets the intent of the County's Land Development Regulations.

The design criteria shall be revised and updated as necessary to reflect advances in drainage engineering and stormwater management. The County and its duly appointed representatives will utilize the manual in the planning of new facilities and in their review of proposed work done by developers, private parties, and other governmental agencies.

2.1.1 Minimum Design Criteria

Each chapter contained in this manual illustrates and describes in detail the design criteria established for a particular element of a post-construction stormwater system. The design professional is referred to these chapters for further direction of the design criteria and its application.

The design and management of construction site runoff control measures for all developments subject to the County's stormwater management regulations shall be in accordance with SCDHEC NPDES General Permit for Stormwater Discharges from Large and Small Construction Activities, the SCDHEC Erosion and Sediment Reduction and Stormwater Management regulations and its most current version of standards, where applicable.

2.1.2 Scope of Stormwater Management Plan

For each development subject to the County's stormwater management regulations, a stormwater management plan shall be prepared and submitted to the County for approval. The stormwater management plan shall include a set of construction drawings and a drainage report with documentation that comprises all of the information and specifications for the drainage systems, structures, BMP's, concepts, and techniques for the management and treatment of stormwater runoff.

2.1.3 Minimum Runoff Control Requirements

2.1.3.1 General

The following outlines the general requirements for management of stormwater runoff:

a) Use site planning, design, construction, and maintenance strategies to maintain, to the maximum extent practicable, the pre-development hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

b) All development shall disconnect impervious surfaces with vegetative surfaces to the maximum extent practicable.

c) Limits the stormwater runoff interaction with potential pollutant sources that may become waterborne and create non-point source pollution.

d) Stormwater runoff shall be controlled in a manner that:

  i. Promotes positive drainage from structures resulting from development.
  ii. Causes no adverse impact to downstream and upstream properties.
  iii. Includes the use of vegetated conveyances, such as swales and existing natural channels to promote infiltration.
  iv. Promotes low runoff velocities and maintains sheet flow condition to prevent erosion and promote infiltration.

The County's stormwater management regulations are the following requirements:

2.1.3.2 Stormwater Design Requirements

a) Control the post-development peak runoff discharge rate for the 2-, 10-, and 25-year, 24-hour design storm events to pre-development discharge rates.
b) The 100-year, 24-hour storm event shall be accommodated through the development without causing damage to on-site and offsite structures.
c) Engineered stormwater collection, conveyance, and storage systems shall be designed using criteria established in this manual.

2.1.3.3 Water Quality Requirements

a) Stormwater Runoff Volume - The design of stormwater management facilities shall be based upon soil conditions. Information documenting the permeability of soils as well as the groundwater table elevations shall be provided as part of the design of stormwater management systems.

  i. The development shall maintain the pre-development hydrology of the site for the 85th percentile storm event.

  ii. A stormwater management system is presumed to comply with this criteria if:

    - It includes practices that provide for the interception, evapotranspiration, infiltration or capture and reuse of stormwater runoff, that have been selected, designed, constructed and maintained in accordance with the Stormwater Design Manual, sound engineering practice, and other information as approved by the DSR; and

    - It is designed to provide the amount of stormwater runoff reduction specified in the latest edition of this manual.

b) Stormwater Runoff Quality - Post-construction stormwater runoff shall be adequately treated before it is discharged from a development site.

  i. A stormwater management system is assumed to meet the stormwater runoff quality criteria by satisfying the stormwater runoff volume criteria above.

  ii. If any of the required stormwater runoff volume as defined above and in this manual cannot be reduced on the site (due to impractical site characteristics or constraints and provided a waiver is granted), it shall be intercepted and treated in one or more stormwater management practices. These practices shall provide at least an 80 percent reduction in total suspended solids loads, 30 percent reduction of total nitrogen load, and 60 percent reduction in bacteria load.

iii. A stormwater management system is presumed to comply with this criteria if:

- It intercept and treat stormwater runoff in stormwater management practices that have been selected, designed, constructed and maintained in accordance with this manual;

- Provide documentation to show that total suspended solids, nitrogen and bacteria removal were considered during the selection of the stormwater management practices that will be used to intercept and treat stormwater runoff on the development site; and

- It is designed to provide the amount of stormwater load reduction specified in the latest edition of this manual.

2.2 Submittal Requirements

2.2.1 Stormwater Plan Requirements

Stormwater management plans are an essential component of the County's development application and review process. Stormwater management plans are to be submitted to the County at the time of the development application. Plans shall include:

(a) Narrative**-** A narrative shall be included with the stormwater management plan submitted for review. This narrative shall detail, in addition to the items stated above, the general intent of the development highlighted on the proposed development plans. If the development is to be phased, a detailed description of the proposed phases should be included. The narrative should also describe the proposed stormwater management system detailing the measures included in the system such as detention, infiltration, or filtration controls and the function of each. Description of site conditions around points of all surface water discharge including vegetation and method of flow conveyance from the land disturbing activity shall be included in the narrative.

(b) Design Calculations- Drainage areas contributing to each inlet, pipe, culvert, ditch, swale or BMP shall be delineated and tabulated. Existing stormwater conveyance systems shall be shown on the drawings with details and capacities of each system included with the calculations. All engineering calculations needed to design the system and associated structures shall be submitted, including pre- and post-development flow velocities, peak rates of discharge, and inflow and outflow hydrographs of stormwater runoff at all existing and proposed points of discharge from the site.

In determining downstream effects from stormwater management structures and the development, hydrologic-hydraulic engineering studies may be extended downstream to a point as determined by the DSR. All stormwater management facilities and all major portions of the conveyance system through the proposed development (i.e., channels and culverts) will be analyzed, using the design and 100-year storms, for design conditions and operating conditions that can reasonably be expected during the life of the facility. The expected timing of flood peaks through the downstream drainage system should be assessed when planning the use of detention facilities. The results of the analysis shall be included in the hydrologic-hydraulic portion of the design study.

(c) Other-

1. Description of the existing and proposed topography of the development site.
2. Anticipated starting and completion dates of the various stages of land disturbing activities and the expected date the final stabilization will be completed.
3. Certification by the person responsible for the land disturbing activity that the activity will be accomplished according to the approved stormwater management plan and those responsible personnel will be assigned to the project.
4. Geotechnical data and/or information as required for the design of the stormwater management system.
5. Inspection and maintenance plan.

(d) Construction Plans

i. A vicinity map indicating a north arrow, scale, boundary lines of the site, and other information necessary to locate the development site.
ii. Site map of physical improvements on the site including both existing and proposed development.
iii. Location, dimensions, elevations, and characteristics of all stormwater management facilities.
iv. Identification of all areas within the site included in the land disturbing activities and documentation of the total disturbed area calculations.
v. The location of temporary and permanent vegetative and structural stormwater management control measures.
vi. Location of temporary and permanent vegetative and structural stormwater management control measures for each respective stage of construction.
vii. Designation of all easements (rights-of-way) needed for inspection and maintenance of the drainage systems and stormwater management facilities.
viii. BMPs to control the water quality of the runoff during the land disturbing activities and during the life of the development.
ix. Construction and design details for structural stormwater controls.
x. Outfall location of proposed stormwater system to existing downstream stormwater system, wetland, or waterbody.

When revised plans are submitted to the County, it is the responsibility of the applicant to clearly identify all changes made to the plans. Identification of changes can include providing a list showing the revisions with the re-submittal, “clouding” of changes on plan, or other similar measures.

2.3 Inspection and Maintenance Plan

The effectiveness of each of the BMPs and stormwater management facilities described in the proceeding sections depends upon appropriate application of design and regular maintenance. Many of the health and safety concerns that may arise when the BMPs or stormwater management facilities are installed can be addressed by a scheduled maintenance plan. Therefore, the stormwater management plan must contain an inspection and maintenance plan component, including a schedule, for each BMP and facility incorporated into the stormwater system. The inspection and maintenance plan must address both inspection and procedures and shall be in compliance with the LDR. The inspection and maintenance plan will become the basis for the inspection and maintenance agreement that must be executed between the applicant and the County.

2.4 Approvals

The stormwater management plan will not be considered approved without the inclusion of the DSR's approval stamp, signature, and date. The stamp of approval on the plans is solely an acknowledgement of satisfactory compliance with the requirements of these regulations. The approval stamp does not constitute a representation or warranty to the applicant or any other person concerning the safety, appropriateness or effectiveness of any provision, or omission from the stormwater management plan.

3.0 General Design Criteria and Guidelines

3.1 Hydrology and Runoff Determination

By definition, hydrology is the scientific study of water and its properties, distribution, and effects on the earth's surface, soil, and atmosphere. Hydrologic analyses include estimation of peak runoff rates, volumes, and time distribution of stormwater runoff flows and are fundamental in the design of stormwater management facilities. This chapter addresses the movement of water over land resulting directly from precipitation in the form of stormwater runoff.

Land development changes how a watershed responds to precipitation. The most common effects are reduced infiltration and decreased travel time. Increased impervious surfaces and runoff velocities increase peak flow discharge volumes and rates. Total runoff volume is determined by the total drainage area of the receiving watershed, its infiltration characteristics, and the amount of precipitation.

3.1.1 General Design Criteria

The following guidelines should be followed when selecting hydrologic computation standards:

- The design storm duration shall be the 24-hour rainfall event, using the National Resource Conservation Service (NRCS), formerly known as Soil Conservation Service (SCS), Type III rainfall distribution with a maximum 6-minute time increment.
- If the contributing drainage area is 20 acres or less, the design requires a single culvert or channel, and if no storage design or runoff volume is required, the Rational Method or the NRCS (SCS) Method of runoff calculation shall be acceptable.
- If the contributing drainage area is greater than 20 acres, or if storage or runoff volume design is required, only the NRCS (SCS) Method of runoff calculation shall be acceptable.

3.1.2 Drainage Area Characteristics

Drainage area (also referred to as watershed or drainage basin) is an area receiving precipitation, which generates runoff flow that drains into a single point of discharge. The use of contour maps is recommended for drainage area delineation. Identifying the area from which the runoff will be evaluated is one of the basic requirements for design of stormwater management facilities.

Watershed runoff discharge is determined by the following characteristics:

- Size
- Shape
- Slope
- Soils
- Land-Use
- Ponding/Storage
- Soil Moisture
- Groundwater Level

3.1.2.1 Size

Size of the watershed dictates how much of the precipitation will fall on the area contributing to the flow at the point of interest.

3.1.2.2 Shape

Shape of the basin influences the timing of the peak flow hydrograph (i.e.; how fast water is being transported from the edge of the watershed to the point of interest). Long, narrow or short, wide basins usually have larger runoff peak rates than basins which are approximately equal in length and width.

3.1.2.3 Slopes

Slope of a basin significantly impacts the runoff rate. Runoff from a drainage area with steep slopes will travel along its flow path faster and have larger peak runoff rates than an area with shallow, rolling topography.

3.1.2.4 Soils

Soil properties influence the relationship between rainfall and runoff with their various rates of infiltration. Based on the infiltration rates, the NRCS (SCS) has divided the soils into four hydrologic soil groups (HSG) A, B, C, and D. The soils in hydrologic group A have the most (0.30 – 0.45 in/hr) infiltration capacity while soils in the hydrologic group D have the least (less than 0.05 in/hr).

Group A	Soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well-drained sands and gravels.
Group B	Soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep and moderately well to well drained soils with moderately fine to moderately coarse textures.
Group C	Soils having a moderately high runoff potential due to slow infiltration rates. These consist primarily of either soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.
Group D	Soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a clay layer at or near the surface, and shallow soils over nearly impervious underlying material.

Soil Survey maps can be obtained from the local NRCS (SCS) office or downloaded on-line from the South Carolina Department of Natural Resources (SCDNR) at http://www.dnr.sc.gov/gis.html. Note: A/D and B/D indicate the drained/un-drained situation.

Consideration should be given to the effects of urbanization on the natural hydrologic soil group. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, appropriate changes should be made in the hydrologic soil group selection. Also runoff curve numbers (CN) vary with the antecedent soil moisture conditions (AMC). Average antecedent moisture conditions (AMC II) are recommended for all hydrologic analysis.

3.1.2.5 Land Cover

Land Cover represents the surface characteristic of the drainage area and consists of a combination of pervious and impervious surfaces.

Two widely used methods characterizing the land surface are Rational Method's "C" value and NRCS (SCS) method's curve number (CN). The surface identifying number of the drainage area may be calculated as a composite number from the sub-areas of the uniform land cover.

3.1.2.6 Ponding/Storage

If part (up to 5%) of the drainage area is available for the runoff retention/detention, this should be included in the peak runoff analysis. The Rational Method is not an appropriate hydrologic methodology for drainage areas with these considerations.

3.1.2.7 Soil Moisture

Antecedent moisture condition is the index of runoff potential before a storm event.

3.1.2.8 Groundwater Level

The groundwater level should be analyzed to understand the infiltration capabilities of the soils and aid in the selection of BMP and/or LID that best suites the site.

3.1.3 Precipitation Data

Rainfall is the primary form of precipitation in Jasper County. The period in which rainfall begins, intensifies, peaks, and subsides during one storm is categorized as a storm event. Individual storm events are generally defined, or separated, by a minimum 6-hour time interval without precipitation. Variants of an event may be complicated by tropical storm "bands". The storm magnitude is estimated from the storm event volume, duration, and intensity. Statistical calculations are used to establish the probability of a specific storm event. The following items characterize a storm event.

- Depth/Volume/Duration
- Intensity
- Spatial Distribution
- Recurrence Interval

3.1.3.1 Depth/Volume/Duration

The depth of precipitation over an area generates a certain volume. This volume can be derived from the rainfall intensity that falls during the storm duration (or time period) over the area. Rainfall depths are typically provided based on a return period or the period a certain magnitude will occur in any given year. Table 2-2 presents the 24-hour storm events within the County for return periods of 2-, 5-, 10-, 25-, 50-, and 100-year.

TABLE 3-1
RAINFALL DEPTH (Inches) FOR JASPER COUNTY, SOUTH CAROLINA

Return Period [years]					
2	5	10	25	50	100
4.2	5.4	6.4	7.8	9.0	10.2

Source: South Carolina DHEC Storm Water Management BMP Handbook, Appendix F, July 2005.

3.1.3.2 Intensity

Intensity represents the rate at which rainfall occurs. The average intensity for a period is the total rainfall event depth divided by the time over which the rainfall occurred. The rainfall intensity values may be also computed using the following equation:

$$i = a / (b + t_c)^c \qquad (3\text{-}1)$$

Where:

i = rainfall intensity, in inches per hour
t_c = time of concentration, in minutes
a , b, and c are coefficients

The coefficients for the 2-, 5-, 10-, 25-, 50-, and 100-year rainfalls and the intensity values for a time of concentration of 5, 10, and 15 minutes for Jasper County are listed in Table 2-3.

TABLE 3-2
RAINFALL INTENSITY COEFFICIENTS FOR JASPER COUNTY, SOUTH CAROLINA

Frequency (years)	**a**	**b**	**c**
2	252.6	33.7	1.02
5	263.4	32.0	1.01
10	271.2	30.9	1.01
25	282.3	29.2	0.99
50	290.4	28.0	0.99
100	297.5	26.9	0.98

Source: South Carolina Department of Transportation, September 1997 (Hilton Head values presented here.)

3.1.3.3 Spatial Distribution

Spatial distribution relates to whether the rainfall depth (volume or intensity) at various locations in a drainage basin are equal for the same event. In practice, spatial variations for a relatively small drainage area can be neglected.

3.1.3.4 Recurrence Interval

The probability that a rainfall event of a certain magnitude will occur in any given year is expressed in terms of recurrence interval (also called return period or event frequency). The recurrence interval is the average length of time expected to elapse between rainfall events of equal or greater magnitude. The recurrence interval is expressed in years, but is actually based on a storm event's exceedance probability. For example, the 100-year storm, also known as one percent annual chance storm, is the storm that has one percent chance of being equal or exceeded in any given year. The relationship between recurrence interval and exceedance probability is given by

$$T = 1/P \tag{3-2}$$

Where:

T = return period, in years
P = exceedance probability

Storms of different magnitude with different recurrence intervals will be set as design criteria for individual parts of stormwater management facilities. For example, a culvert under a freeway will be designed to safely carry flow from a 100-year storm event, but a culvert under residential flow is only required to carry flow from a 25-year storm event.

3.1.3.5 Form of Rainfall Data

Rainfall data for probable precipitation depths are based upon historical records. Calculation of resulting peak runoff flow or flow volume is a primary objective of data collection and analysis. Several forms of data useful for peak runoff flow calculation or computer simulation are shown below.

- Intensity-Duration-Frequency (IDF) Curves illustrate the average rainfall intensities corresponding to various durations and storm recurrence intervals, such as 100-, 50-, 25-, 10-, 2-year storms.
- NRCS (SCS) Peak Discharge Method produces a peak discharge and requires the 24-hour total rainfall depths for the selected recurrence interval.
- NRCS (SCS) Unit Hydrograph can be used with any rainfall distribution, however, the 24-hour total rainfall depths and 24-hour rainfall temporal distribution (Type III) will be used in this manual.

3.1.4 Runoff Determination

The travel time, or time of concentration, of the watershed is directly related to the slope, flow path length, depth of flow, and roughness of the flow surfaces due to the type of ground cover. The time of concentration is used in Rational as well as NRCS (SCS) Methods for the peak flow determination.

3.1.4.1 Time of Concentration (T_c)

The TR-55 method (Natural Resource Conservation Service (NRCS), Urban Hydrology for Small Watersheds, Technical Release No. 55, June 1986) is used to compute T_c by summing all the travel times of consecutive flow segments of the drainage conveyance system along the path extending from the hydraulically most distant point of the drainage area to the point of interest within this area.

$$T_c = T_1 + T_2 + T_3 + \ldots + T_n \qquad (3\text{-}3)$$

Where:

T_1 = time of travel through one segment, in hours
N = number of segments

Water moves through the drainage area as sheet flow, shallow concentrated flow, open channel, or a combination of these.

a) Sheet Flow

Sheet flow is the flow of water over a plane surface usually taking place in the headwater of the basin. The sheet flow occurs over a distance of up to 300 feet before it forms rills or paths. A maximum of 100 feet shall be used for the design of stormwater systems.

$$T_t = [0.007\ (nL)^{0.8} / (P_2)^{0.5}\ (s)^{0.4}] \qquad (3\text{-}4)$$

Where:
T_t = travel time, in hours
n = Manning's roughness coefficient for shallow depths of about 0.1 foot
L = flow length, in feet
P_2 = 2-year 24-hour rainfall, in inches
s = land slope, in feet per foot

b) Shallow Concentrated Flow

Average velocities for estimating travel time for shallow concentrated flow can be computed from the following equations. These equations can also be used for slopes less than 0.005 ft/ft.

$$V = 16.1345(S)^{0.5} \text{ for unpaved surface} \qquad (3\text{-}5)$$
$$V = 20.3282(S)^{0.5} \text{ for paved surface} \qquad (3\text{-}6)$$

Where:

V = average velocity, in feet per second
S = slope of hydraulic grade line (watercourse slope), in feet per foot

These two equations are based on the solution of Manning’s Equation with different assumptions for "n" (Manning's roughness coefficient) and "r" (hydraulic radius, in feet). For unpaved areas "n" is 0.05 and "r" is 0.4 feet; for paved areas, "n" is 0.025 and "r" is 0.2 feet.

After determining average velocity, travel time for the shallow concentrated flow segment can be estimated by dividing the flow length by the velocity.

c) Open Channel Flow

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's Equation for water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull elevation. Manning's Equation for this is:

$$V = 1.49 / n\ (R)^{2/3}\ (s)^{1/2} \tag{3-7}$$

Where:

V = average velocity, in feet per second
n = Manning's roughness coefficient
s = slope of the hydraulic grade line, in feet per foot
R = hydraulic radius, in feet and is defined by the equation

$$R = a/p_w \tag{3-8}$$

Where:

a = cross sectional flow area, in square feet
p_w = wetted perimeter, in feet

After average velocity is computed using above equation, T_t for the channel segment can be estimated by dividing the flow length by the velocity. Velocity in channels should be calculated from Manning's Equation. Cross sections from all channels that have been field checked should be used in the calculations. This is particularly true of areas below dams or other flow control structures.

3.1.4.2 Flow Determination Methods

This section describes the recommended procedures for calculating the runoff generated from a project site. Correct utilization of these procedures should result in the best available estimation of existing and projected runoff. All hydrologic computational methods shall be accomplished using a method acceptable by Jasper County.

The following guidelines should be followed when selecting hydrologic computation standards:

- The design storm duration shall be the 24-hour rainfall event, using the NRCS (SCS) Type III rainfall distribution with a maximum 6-minute time increment.
- If the contributing drainage area is 20 acres or less, the design requires a single culvert or channel, and if no storage design or runoff volume is required, the Rational Method or the NRCS (SCS) Method of runoff calculation shall be acceptable.
- If the contributing drainage area is greater than 20 acres, or if storage or runoff volume design is required, only the NRCS (SCS) Method of runoff calculation shall be acceptable.

3.1.4.3 Rational Method

a) General

The Rational Method formula is utilized to determine peak flow rates in urban areas and small watersheds for the following situations:

- Total drainage area of 20 acres or less.
- No storage or volume design required.
- Design involves only the sizing of a single culvert or channel.

The Rational Method allowed only for small, highly impervious drainage areas such as parking lots and roadways draining into inlets and gutters with individual outfall pipes. The Rational Method calculates peak discharge only as opposed to developing a runoff hydrograph for an area. It makes a basic assumption that the design storm has constant rainfall intensity for a time period equaling the drainage area time of concentration (T_c), the time required for water to flow from the most remote point of the basin to the point of interest.

$$Q = C\,i\,A \tag{3-9}$$

Where:

Q = maximum rate of runoff, in cubic feet per second
C = runoff coefficient representing a ratio of runoff to rainfall
i = average rainfall intensity for a duration equal to the T_c, in inches per hour
A = drainage area contributing to the design location, in acres

b) Less Frequent Storms

The runoff coefficients for the Rational Method are generally applicable for storms equal to or frequent than the 10-year frequency (such as 2-, 5-, and 10-year storms). Less frequent, higher intensity storms, such as 25-, 50-, and 100-year storms require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on the runoff. Adjustment of the Rational Method for use with major storms can be made by multiplying the runoff coefficient by a frequency factor, C_f.

For infrequent storm events, the rational equation is then expressed as:

$$Q = C\,C_f\,i\,A \tag{3-10}$$

Where:

Q = maximum rate of runoff, in cubic feet per second
C = runoff coefficient based on 5- to 10-year storms
C_f = frequency factor based on recurrence interval (dimensionless)
i = average rainfall intensity, in inches per hour
A = drainage area contributing to the design location, in acres

c) Runoff Coefficient

The runoff coefficient "C" is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the design professional. While engineering judgment will always be required in the selection of runoff coefficients, recommended runoff coefficients for the Rational Method representing the integrated effects of many drainage basin parameters may be obtained from various references including Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22 (HEC-22), available on-line at http://www.fhwa.dot.gov/engineering/hydraulics/.

d) Composite Coefficients

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surfaces in the drainage areas. Composites can be made with values for homogeneous land uses by using percentages of different land uses. In addition, more detailed composites can be made with coefficients for different surface types such as roofs, asphalt and concrete streets, drives and walks. The composite procedure can be applied to an entire drainage area or to typical sample block as a guide to the selection of reasonable values of the coefficient for an entire area.

Composite runoff coefficients can be determined using the following equation:

$$\text{Composite C} = \frac{\sum(C_{\text{Sub-Area}})(A_{\text{Sub-Area}})}{A_{\text{Total Area}}} \qquad (3\text{-}11)$$

It should be remembered that the Rational Method assumes that all land uses within a drainage area are uniformly distributed throughout the area. If it is important to locate a specific land use within the drainage area then another hydrologic method should be used where hydrographs can be generated and routed through the drainage system.

e) Rainfall Intensity

Rainfall intensity is the average rainfall rate (typically reported in inches per hour) for duration equal to the time of concentration for a selected return period. Once a return period has been selected for design and a time of concentration calculated, the rainfall intensity can be determined from Rainfall-Intensity-Duration data, refer to Equation 3-1 and Table 3-2.

3.1.4.4 NRCS Curve Number Method

a) General

The NRCS (formerly SCS) hydrologic method requires basic data similar to the Rational Method: drainage area, a runoff factor, time of concentration, and rainfall. Details of the methodology can be found in the NRCS (SCS) TR-55 and the NRCS Engineering Field Manual for Conservation Practices.

The NRCS (SCS) curve number method begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff CN that is based on soil type, plant cover, impervious areas, interception, and surface storage.

Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed. The NRCS (SCS) Method is used to determine stormwater runoff peak flow rates, runoff volumes, and the generation of hydrographs for the routing of storm flows in urban areas and project sites. The following are requirements of its use:

- NRCS (SCS) CN Method is required for total drainage areas greater than 20 acres.
- NRCS (SCS) CN Method may be used for total drainage areas less than 20 acres.
- Runoff volume.
- Routing.
- Design of storage facilities and outlet structure.

The NRCS (SCS) method includes the following basic steps:

- Determination of CN representing different land uses within the drainage area.
- Calculation of T_c to the study point.
- Selection of design storm event.
- Use of the Type III rainfall distribution to determine the total and excess rainfall quantity.
- Use of the unit hydrograph approach including development of triangular and composite hydrographs for the drainage area.

The NRCS (SCS) method applicable to the County is based on a storm event, which has a Type III time distribution. To use this distribution, the user has to obtain the 24-hour rainfall volume. A relationship between accumulated rainfall and accumulated runoff was derived by NRCS (SCS) from experimental plots for numerous soils and vegetative cover conditions. The following NRCS (SCS) runoff equation is used to estimate direct runoff from a 24-hour storm event. The equation is:

$$Q = (P - 0.2S)^2 / (P + 0.8S) \qquad (3\text{-}12)$$

Where:

Q = total runoff volume for the specified storm event, in inches
P = rainfall volume for the specified storm event, in inches from Table 3-1.
S = potential maximum retention after runoff begins, in inches and is defined by the following equation:

$$S = (1000/CN) - 10 \qquad (3\text{-}13)$$

Where:

CN = NRCS (SCS) curve number

Initial Abstractions (I_a) are all losses in the watershed before runoff begins. These abstractions include water retained in surface depressions, water intercepted by vegetation, evaporation and infiltration. I_a is highly variable but is generally correlated with soil and cover parameters. Through the study of many small agricultural watersheds, I_a is approximated by the following empirical equation:

$$I_a = 0.2S \tag{3-14}$$

CNs represents the combined hydrologic effect of the soil type, land use, hydrologic soil group (HSG), and antecedent moisture condition. It may be necessary to create a composite CN by weighting distinct land use-HSG combinations and summing them for the total drainage area. The CN indicates the runoff potential of soil which is not frozen. Higher CN reflects a higher runoff potential. Typical CN values are included in TR-55, available on-line at http://www.cpesc.org/reference/tr55.pdf.

CN is similar to the Rational Method's "C" coefficient in that it is based on the surface condition of the drainage area. Another factor of consideration is whether impervious areas are directly connected to the system or if the system is unconnected and flows from impervious areas spread over pervious areas before reaching the outfall point. The NRCS (SCS) TR-55 presents a method for analyzing unconnected impervious areas.

b) Urban Modifications

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CNs for urban areas.

It is possible that CN values from urban areas could be reduced through the use of structural stormwater BMPs and strategic placement of vegetated areas to disconnect impervious surfaces for infiltration of runoff.

An impervious area is considered connected if runoff from it flows directly into the storm drainage system. It is also considered connected if runoff from the area occurs as concentrated shallow flow that runs over a pervious area and then into a drainage system.

If runoff from unconnected impervious areas is spread over a pervious area as sheet flow, then all or part of the impervious area is not directly connected to the drainage system. Use NRCS TR-55 Chapter 2 for reference in determining a modified CN for the disconnected impervious areas.

c) Hydrograph Generation

In addition to estimating the peak discharge, the NRCS (SCS) method can be used to estimate the entire hydrograph from a drainage area. The NRCS (SCS) has developed a Tabular Hydrograph procedure that can be used to generate the hydrograph for small drainage areas (less than 2,000 acres). The Tabular Hydrograph procedure uses unit discharge hydrographs that have been generated for a series of time of concentrations. In addition, NRCS (SCS) has developed hydrograph procedures to be used to generate composite flood hydrographs.

For the development of a hydrograph from a homogeneous developed drainage area or from drainage area which is not homogeneous where hydrographs need to be generated from sub-areas and then routed and combined at a point downstream, the engineer is referred to the procedures outlined by the NRCS (SCS) in TR-55 available on-line at: http://www.cpesc.org/reference/tr55.pdf.

3.2 Storm Sewer Collection System

Effective drainage of roadway pavements is essential to the maintenance of roadway service level and to traffic safety. Water on the pavement can interrupt traffic, reduce skid resistance, increase potential for hydroplaning, limit visibility due to splash and spray, and cause difficulty in steering a vehicle when the front wheels encounter puddles.

Pavement drainage requires consideration of surface drainage, gutter flow, inlet capacity, and storm sewer capacity. The design of these elements is dependent on storm frequency and the allowable inundation of stormwater on the pavement surface. This chapter presents guidance for the design of these elements. Most of the information presented in this chapter was originally published in HEC-12, Drainage of Highway Pavements, available on-line at http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec12.pdf; and AASHTO's Model Drainage Manual (American Association of State Highways Transportation Officials, available for purchase on-line at https://bookstore.transportation.org/Item_details.aspx?id=131.

3.2.1 General Design Criteria

Design criteria for the collection and conveyance of runoff on public roadways are typically based on roadway classification and reasonable frequency of traffic interference. Depending on the roadway classification, certain lanes can incur more inundation of standing water on each side of an inlet (spread) and still pass traffic safely with minor interference.

3.2.1.1 Inlets

- Spread Limits
    i. The maximum allowable spread in the roadway shall be based on the 25-year design storm and shall be limited to no more than six (6) feet of spread in the roadway gutter. Catch basins shall be located along the roadway at sufficient intervals to intercept flows before they exceed the maximum spread limit. In no instance shall inlet spacing exceed three hundred (300) feet.
    ii. The formulas for gutter flow shall be used to determine the spread in the roadway.
    iii. At sag locations, the roadway shall have a minimum of 0.5% longitudinal slope within fifty (50) feet of the level point in the sag. For large flows, flanking inlets may be required on either side of the low point to prevent exceeding the spread limit.
- Capture Efficiency
    i. For the 25-year design storm, the capture efficiency for inlets on grade shall be no less than 90%, and the capture efficiency for inlets at sump locations shall be 100%.
    ii. At sump locations, the capacity of the catch basin shall be determined using the weir equation unless precast boxes with special inlets are used, which may be designed with the orifice equation. The minimum curb transition/apron length on either side of the basin shall be six (6) feet for catch basins open on three (3) sides.
    iii. Catch basins shall not be allowed in the radius section at intersections, except where flows are very small, road grades are very flat, or the entire intersection is in a sag.
    iv. Within a piped drainage system, an adequate number of manholes or inlets shall be constructed to provide for cleaning and maintenance of the stormwater system. In no instance shall spacing exceed three hundred (300) feet between structures.
- Weir Opening Height
    i. For catch basins, the minimum allowable weir opening height shall be four (4) inches and the maximum allowable weir opening height shall be eight (8) inches.

3.2.1.2 Storm Sewers

a) The Manning equation shall be used for pipe design, assuming pipe flowing full.
b) The orifice equation shall be used to check the required headwater depths at all catch basins, junction boxes or pipe inlets along the system to predict and prevent surcharge conditions.
c) Alternatively, a computer model using the Standard Step method or other approved energy-based method may be used to compute the hydraulic profile.
d) For complex systems, computation of the hydraulic profile is required.
e) No pipe less than 15" in diameter will be allowed, except for subsurface drainage systems.
f) Maximum tail water conditions and associated tidal influences shall be considered when designing a stormwater system.
g) Minimum maintenance easement widths shall be as specified in Jasper County's Land Development Regulations.

If the storm sewer system is part of a roadway to be accepted by the South Carolina Department of Transportation (SCDOT), the system design is governed by SCDOT design criteria.

3.2.2 Collection System

The roadway collection system is comprised of roadway sections including gutters, and inlets. Gutters collect runoff from the roadway and direct it to the inlets for capture. The inlets collect part of the gutter flow for transport to a subsurface conveyance system. The inlet design and location limit the amount of inundation on a roadway. This inundation is commonly referred to as spread. The control of spread is an important consideration for the minimization of interference to traffic and the safe passage of emergency-response vehicles.

3.2.2.1 Gutter Capacity and Types

There are various types of gutter sections available for use in roadway drainage design today. The gutter geometry may be determined by the need for additional carrying capacity or the requirement for safe passage of pedestrian traffic. The gutter may have a straight transverse slope (uniform), a composite transverse slope, or transverse slope composed of two straight lines (V-shape). When the allowable spread for the roadway has been determined, the gutter capacity (and part of the roadway that may also be used to convey runoff) can be computed using a modified version of Manning's Equation. The equation is modified because the hydraulic radius term does not adequately describe the spread flow cross section, especially when the top width of flow is significantly larger than the depth.

a) Standard Gutter Sections

A straight transverse slope section has uniform cross slope for the roadway and gutter. These gutter sections, or standard gutter, as they are commonly known, usually resemble a triangle with the curb forming the vertical leg. For standard gutters, the modified version of the Manning's Equation may be used to calculate gutter flow properties.

b) Composite Gutter Sections

To increase the capacity of a gutter, the gutter cross slope may be steepened with respect to the cross slope of the roadway. These gutters are termed composite gutters. For composite gutters, the capacity is determined for the depressed section and the area above the depressed section separately.

c) Valley Gutter Sections

Gutters with transverse slopes composed of two straight lines (V-shape) are commonly referred to as valley gutters. The valley gutters may also be composed of a smooth parabolic cross section. The smooth parabolic gutters are commonly referred to as roll back or mountable types. The capacity for all valley type gutters is approximated by the same methodology. For valley gutters an adjusted cross slope of the gutter section is calculated and then a modified version of the Manning's Equation may be used to calculate gutter flow properties.

Gutter calculations can be determined easily using available software packages. The Federal Highway Administration's HY-22 and Visual Urban HY-22 (for Windows) are free of charge, downloadable software packages that perform this and other calculations presented in this chapter.

3.2.2.2 Inlet Capacity and Types

Gutter inlets can be divided into the following three major classes, each with many variations: (1) curb-opening inlets, (2) grate inlets, and, (3) combination inlets. The placement of two inlets side by side is referred to as a double inlet and is acceptable.

Brief descriptions of the approved inlet types follow:

- Curb-Opening inlets. These inlets are vertical openings in the curb covered by a top slab.
- Grate inlets. These inlets consist of an opening in the gutter covered by one or more grates.
- Combination inlets. These units consist of both a curb-opening and a grate inlet acting as a single unit.

Other inlets deemed practical and technically sound to meeting the criteria of this chapter may be submitted prior to design commencement for approval by the DSR on a case by case basis. Additional design consideration may be required where safe passage for bicycle and pedestrian traffic is an important factor. The designer should consult SCDOT for guidance.

Curb Opening Inlet

Factors affecting gutter flow also affect inlet interception capacity. Interception capacity of a curb-opening is largely dependent on flow depth at the curb and curb-opening length. Curb-opening inlet interception capacity and efficiency are increased by the use of a gutter depression at the curb-opening or a depressed gutter to increase the proportion of the total flow adjacent to the curb. The amount of the depression has more effect on the capacity than the arrangement of the depressed area with respect to the inlet.

Figure 3-1
Source: Roanoke, VI

The interception capacity of a grate inlet depends on the amount of runoff flowing over the grate, the size and configuration of the grate, and the velocity of flow in the gutter. The efficiency of a grate is dependent on the same factors and total flow in the gutter.

Grate Inlet

The interception capacity of a combination inlet consisting of a grate and a curb-opening does not differ materially from that of a grate. Interception capacity and efficiency are dependent on the same factors which affect grate capacity and efficiency. However, as the depth of water in the gutter increases, the curb-opening becomes a major factor in the interception capacity. Curb-opening inlet interception capacity and efficiency are increased by the use of a gutter depression at the curb-opening or a depressed gutter to increase the proportion of the total flow adjacent to the curb. The amount of the depression has more effect on the capacity than the arrangement of the depressed area with respect to the inlet.

Figure 3-2
Source: East Jordan Iron Works

A combination inlet, consisting of a curb-opening inlet placed upstream of a grate, has a capacity equal to that of the curb-opening length upstream of the grate plus that of the grate, taking into account the reduced spread and depth of flow over the grate because of the interception by the curb-opening. This inlet configuration has the added advantage of intercepting debris that might otherwise clog the grate and deflect water away from the inlet.

Combination Inlet

A combination inlet consisting of a slotted inlet upstream of a grate might appear to have advantages when 100-percent interception is necessary. However, grates intercept little more than frontal flow and would usually need to be more than 3 feet wide to contribute significantly to the interception capacity of the combination inlet. A more practical solution would be to use a slotted inlet of sufficient length to intercept total flow.

Most investigators have pointed out that the capacity of an inlet is greatly increased by allowing a small percentage of the flow to bypass the inlet. For a given gutter discharge, the catch of each additional increment of width declines rapidly.

Figure 3-3
Source: East Jordan Iron Works

3.2.2.3 Inlet Clogging

All types of inlets are subject to clogging. Attempts to simulate clogging tendencies in the laboratory have not been successful, except to demonstrate the importance of parallel bar spacing in debris handling efficiency. Grates with wider spacing of longitudinal bars pass debris more efficiently. Problems with clogging are largely local since the amount of debris varies significantly from one neighborhood to another. Some neighborhoods may contend with only a small amount of debris while others experience extensive clogging of drainage inlets. Clogging shall be considered in the design of all grate and combination inlets in sag conditions.

The width of the grate should be adjusted to account for clogging. Common practice has been to apply a 25 percent reduction to the width of the inlet. Therefore, a 2-foot by 3-foot grate whose unclogged effective perimeter is 7 feet (2 feet +3 feet +2 feet) would be reduced to 6 feet (1.5 feet + 3 feet +1.5 feet) under clogged conditions. Notice only the width (2-feet) is reduced by 25 percent. In sags on arterials and multi-lane connectors where ponding may cause violation of spread depth requirements, it is advised to design flanking inlets on either side located 0.2 feet above the invert elevation of the sag inlet to promote drainage.

a) Curb Opening Inlets

Curb-opening inlets may be located for roadway drainage where the expected flow depth at the curb is sufficient for the inlet to perform efficiently. Curb-openings are relatively free of clogging tendencies and offer little interference to traffic operation.

Curb-opening is commonly constructed with a depression beginning W feet away from the curb, where W is the width of the curb inlet, and dropping 1-inch per foot below the plane of the pavement. Transitions at the two ends extend W feet from the end of the opening.

b) Grate Opening Inlets

Grate inlets intercept all of the gutter flow passing over the grate (frontal flow) if the grate is sufficiently long and the gutter flow velocity is low. Only a portion of the frontal flow is intercepted if the velocity is high or the grate is short and splash-over occurs. Part of the flow along the side of the grate will also be intercepted, dependent on the cross slope of the pavement, the length of the grate, and flow velocity.

c) Combination Opening Inlets

The interception capacity of combination inlets where the curb opening and the grate are placed side-by-side does not increase appreciably over the capacity of a grate alone. The combination inlet capacity is computed by neglecting the capacity of the curb opening in this situation. A curb opening at combination inlets is sometimes placed upstream of the grate. The curb opening of such design intercepts debris which might otherwise clog the grate. This type of combination inlet where the curb opening (or slotted drain) is upstream of the grate has an interception capacity equal to the sum of the interception capacities of two inlets except that the frontal flow, and thus the interception capacity of the grate, is reduced by interception by the curb opening.

Combination inlets consisting of a grate and a curb opening are favorable in sags where clogging of grates can create ponding that is hazardous to traffic. The interception capacity of the combination inlet is essentially equal to that of a grate alone in weir flow. In orifice flow, the capacity is equal to the capacity of the grate plus the capacity of the curb opening.

3.2.3 Conveyance System

It is the purpose of this section to consider the significance of the storm sewer's hydraulic elements and appurtenances to a storm drainage system. Hydraulically, storm drainage systems consist of conduits (opened or closed) which convey unsteady and non-uniform free flowing stormwater. Steady flow conditions may or may not be uniform.

All storm sewer systems shall be designed by the application of Manning's Equation when flowing in open channel conditions. The hydraulic grade line shall be checked to determine if the open channel flow assumption is valid. In the preparation of hydraulic designs, a thorough investigation shall be made of all existing structures and their performance on the waterway of interest.

The design of a storm drainage system shall be governed by the following seven conditions:

a) The system must accommodate the surface runoff resulting from the selected design storm with no damage to physical facilities and minimum interruption of normal traffic.
b) Runoff resulting from major storms must be anticipated and discharged free from impedance without damage to physical facilities (such as conveyance past finished floor elevations of buildings and under roadways without washing out embankments and subgrades).
c) The storm drainage system must have a maximum reliability of operation with respect to being structurally sound to its environment where it is placed and performing hydraulically to its intended function for the entire life of design.
d) The construction costs of the system must be reasonable with relationship to the importance of the facilities it protects.
e) The storm drainage system must require minimum maintenance (cleaning and clearing obstructions) and must be accessible for maintenance operations.
f) The storm drainage system must be adaptable to future expansion with minimum additional cost and designed to accommodate build-out conditions in the upstream reaches of the drainage area.
g) Site design, swales and natural flow features should be utilized to reduce the need for extensive storm sewer systems whenever possible.

3.2.3.1 Storm Sewer Pipe System

All lines will be laid in accordance with the “Permanent Pipe Culverts” section in the SCDOT Specifications SC-M-714, latest edition. Strict compliance to backfilling and compaction restrictions and regulations are required.

a) Storm drain pipe shall conform to the following standards:
    i. Reinforced Concrete Pipe (RCP) - shall be Class III or better, as specified in the SCDOT Specifications.
    ii. High Density Polyethylene Pipe (HDPE)-shall be smooth bore HDPE pipe which complies with the SCDOT Qualified Product Listing 30.
b) Design Loading: As a minimum, all pipe materials shall be capable of supporting H-20 loading under minimum cover. All HDPE pipe shall also be of sufficient thickness to meet the design load requirements for the proposed cover height. Greater design loadings shall apply to industrial, commercial, or special situations as appropriate.

c) Minimum Cover: Two (2) feet minimum cover shall be required for all pipe materials in the right of way, measured from the outside top of the pipe to the finished subgrade at the lowest point. Minimum cover requirements may be reduced at the discretion of the DSR only if extenuating circumstances exist. In these cases, Class V RCP will be required.
d) Grade: The design engineer should make all efforts not to design pipe over a 10% slope, especially in the road right of way. In cases where steep slopes are inevitable, the design engineer should use concrete anchors or other factory recommended anchor systems. These details will be required on the construction plans.
e) Minimum Size: No pipe less than 15" in diameter will be allowed.
f) Installation: All storm drain lines shall be installed in accordance with SCDOT Specifications. A vibratory roller, trackhoe-mounted sheepsfoot roller, or other mechanical tamping device must be used for compacting all utility trenches in the right-of-way. In the case, due to cover restrictions, dual pipes (double barrel) must be used, headwalls will be required. No more than two (2) pipes will be allowed at a crossing if a larger pipe or structure cannot be installed due to cover restrictions. The design engineer should make every effort to provide alternatives to dual piped systems.
g) Catch basins shall conform to the following standards:
    i. Catch basins and aprons shall be constructed in accordance with SCDOT Standards.
    ii. Construction materials for catch basins shall be as specified in SCDOT Specifications.
    iii. All catch basins deeper than four (4) feet must be constructed with steps.
    iv. The minimum drop from the edge of the roadway to the throat of the basin shall be six (6) inches for the standard two (2) feet offset from the road. Greater offsets shall require greater drops to achieve the desired 25% cross-slope for the apron.
    v. All catch basins must have manhole lids.

The pipe design life is a key consideration in selection of pipe material. Pipe design life shall be a minimum 50 years as certified by the manufacturer. The engineer must meet all manufacturers' requirements on which the design life is based. For example, bedding requirements are critical to meeting the pipe design life.

In selecting a roughness coefficient, "n", consideration shall be given to the average conditions during the useful life of the structure. An increased "n" value shall be used primarily in analyzing old conduits where alignment is poor and joints have become rough. If, for example, concrete pipe is being designed for a location and there is reason to believe that the roughness would increase due to erosion or corrosion of the interior surface, slight displacement of joints, or entrance of foreign material, a roughness coefficient should be selected which, in the judgment of the designer, will represent the average condition.

3.2.3.2 Underdrains

The following construction requirements shall apply to pipe underdrains:

a) Underdrains shall be constructed in accordance with the manufacturer's recommendations.
b) Underdrains shall be installed within 2 1/2' of the back of the curb and shall be properly connected to a permanent drainage structure such as a catch basin, or daylighted to a suitable location off the right-of-way.
c) All underdrains shall have a minimum of two (2) feet of cover.
d) Underdrains shall be installed prior to the base course.
e) Underdrains are required on both sides of the street where mucking out and backfilling have been done, or where the water table is within two (2) feet of the road centerline elevation.

f) Underdrains must be inspected and approved by the DSR during installation.
g) Additional underdrains may be required as determined by the DSR.

3.2.3.3 Manhole Location

Manholes shall be located at pipe junctions; changes in alignment, size, and slope; and ends of curved sections. Manholes shall be located at intervals not to exceed 300 feet for pipe 30 inches in diameter or smaller.

Manholes for pipe larger than 30 inches in diameter, along straight alignments, shall be located at points where design requirements indicate entrance into the conduit is desirable. In no case shall the distance between openings or entrances to the storm sewer system be greater than 1,000 feet.

3.2.3.4 Alignment

In general, storm sewer alignment between manholes shall be straight. Long radius curves may be allowed to conform to street alignment. Short radius curves may be used on larger pipes in order to reduce head losses at junctions. Curves may be produced by angling the joints or by fabricating beveled ends. Angled joints shall be kept at a minimum to maintain a tight joint. Pipe deflection shall not exceed manufacturers' recommendations, unless precast or cast-in-place bends are specifically designed for deflection. All curved alignments must be approved by the County prior to installation.

3.2.3.5 Minimum Grades

Storm sewers should operate with flow velocities sufficient to prevent excessive deposition of solid material, which would result in clogging. The controlling velocity occurs near the bottom of the conduit and is considerably less than the mean velocity. Storm sewers shall be designed to have a minimum mean velocity flowing full of 2.0 feet per second, the lower limit of scouring velocity. Outlets of pipes on minimum grade should be designed to avoid sedimentation at the outfall. Maximum velocities in conduits are important mainly because of the possibilities of excessive erosion on the storm sewer inverts. Energy dissipaters shall be required at outfalls when pipe flow velocities exceed channel scour velocities.

3.2.3.6 Flow in Storm Sewers

All storm sewers shall be designed by the application of the continuity Equation and Manning's Equation, either through the appropriate charts and nomographs or by direct solutions of the equations as follows:

$$Q = AV \qquad (3\text{-}15)$$

$$Q = \frac{1.49}{n} A\, R^{2/3}\, S_f^{\,1/2} \qquad (3\text{-}16)$$

Where:

Q = pipe flow, in cubic feet per second
A = cross-sectional area of pipe, in square feet
V = velocity of flow, in feet per second
n = Manning's roughness coefficient of pipe
R = hydraulic radius = A/P, in feet
P = wetted perimeter, in feet
S_f = friction slope of pipe, in feet per foot

There are several general rules to be observed when designing storm sewer sections. These rules are as follows:

- Select pipe size and slope so that the velocity of flow will increase progressively, or at least not appreciably decrease, at inlets, bends, or other changes in geometry or configuration.
- Design system so that the contents of a larger pipe do not discharge into a smaller one, even though the capacity of the smaller pipe may be greater due to steeper slope.
- Match the inside top surface of the soffits rather than the flow lines of the pipes at points where pipe size changes from a smaller to a larger pipe
- Check conduits during the design with reference to critical slope. If the slope of the energy line is greater than critical slopes, the unit will likely be operating under entrance control instead of the originally assumed normal flow. Conduit slope should be kept below critical slope if at all possible. This also removes the possibility of a hydraulic jump within the line.

3.2.3.7 Energy Gradient and Profile of Storm Sewers

When using Bernouilli's Equation in the hydraulic design of storm sewers, all energy losses must be accounted for. These losses are commonly referred to as head losses, and are classified as either friction losses or minor losses. Friction losses are due to forces between the fluid and the boundary material, while minor losses are a result of the geometry of sewer appurtenances such as manholes, bends, and either expanding or contracting transitions. Minor losses can constitute a significant portion of the total head loss.

When storm sewer systems are designed as flowing full, the designer shall establish the head losses caused by flow resistance in the conduit, changes of momentum, and interference at junctions and structures. This information is then used to establish the design water surface elevation at each structure.

It is not necessary to compute the energy grade line of a conduit section if all three of the following conditions are satisfied:

- The slope(s) and the pipe size(s) are chosen so that the slope is equal to or greater than the friction slope.
- The inside top surfaces (soffit) of successive pipes are lined up at size changes.
- The water surface at the point of discharge will not rise above the top of the outlet.

In such cases, the pipe should not operate under pressure and the slope of the water surface under capacity discharge will approximately parallel the slope of the pipe invert, assuming the minor losses are reasonable.

In the absence of these conditions or when it is desired to check the system against a larger flood than that used in sizing the pipes, the hydraulic and energy grade lines shall be computed and plotted. The friction head loss shall be determined by direct application of Manning's Equation. Minor losses due to turbulence at structures shall be determined. If there is a possibility that the storm sewer system will be extended at some future date, present and future operation of the system must be considered.

The final hydraulic design of a system should be based on the procedures set forth in this Manual and accepted engineering practices. The conduits are treated as either open channel flow or pipe flowing full flow, as the case may be. For open channel flow, the energy grade line is used as a base for calculation, while the hydraulic grade line is used for pipe flowing full flow.

3.2.4 Outlet Protection

The function of outlet protection is to dissipate the energy of concentrated stormwater flows thereby reducing erosion or scouring at stormwater outlets and paved channel sections. In addition, outlet protection lowers the potential for downstream erosion. This type of protection can be achieved through a variety of techniques, including permanent turf reinforcement mats, stone or rip rap, concrete aprons, paved sections, or other structural measures.

3.2.4.1 Design Criteria for Outlets

The outlet design for pipes and channel sections applies to the immediate outlet area or reach below the pipe or channel and does not apply to continuous lining and protection of channels or streams. Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10 percent should not be protected using just outlet protection. This causes re-concentration of the flow when the flow eaves the protection area resulting large velocities.

Rip-rap shall be installed around the top and sides of all outfall pipes. On steep slopes, the last joint of pipe on a plain end outlet shall be a full eight (8) foot joint. A precast headwall or an approved reinforced concrete headwall is required for all pipe outfalls 36 inches and over. Where a drainage outfall is an appreciable distance above the bottom of a stream or ditch into which it empties, a junction box with a rip-rapped stub will be required.

Energy dissipation measures shall be installed at all pipe outlets to prevent downstream channel erosion. Rip-rap aprons shall be designed in accordance with OCRM and SCDOT guidelines or other approved method.

Precast manhole sections may be adapted for use as energy dissipaters at outfalls. The energy dissipater shall be designed so as not to adversely affect the hydraulic capacity of the system.

Grouted rip-rap may be used in high velocity conditions or where safeguarding of the material is needed.

a) Flow Velocity

The flow velocity at the outlet when flowing at design capacity shall not exceed the permissible velocity of the receiving unprotected grass-lined channel.

b) Tailwater Depth

The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. If the tailwater depth is less than half the outlet pipe diameter, it should be classified as a minimum tailwater condition. If the tailwater depth is greater than half the outlet pipe diameter, it should be classified as a maximum tailwater condition.

c) Protection Length

The required protection length, L_a, according to the tailwater condition, should be determined from the appropriate graphs.

d) Protection Width

When the pipe discharges directly into a well-defined channel, the protection should extend across the channel bottom and up the channel banks to an elevation one foot above the maximum tailwater depth or to the top of the bank, whichever is less.

If the outlet discharges onto a flat area with no defined channel, the width of the protection should be determined as follows:

i. The upstream end of the protection, adjacent to the outlet, should have a width three times the diameter of the outlet pipe (3D).
ii. For a minimum tailwater condition, the downstream end of the protection should have a width equal to the pipe diameter plus the length of the required apron.
iii. For a maximum tailwater condition, the downstream end of the protection should have a width equal to the pipe diameter plus 0.4 times the length of the required apron.

e) Bottom Grade

The protection shall be constructed with no slope along its length (0 percent grade) where applicable. The downstream invert elevation of the protection should be equal to the elevation of the invert of the receiving channel. There shall be no overfalling at the end of the protection.

f) Side Slopes

If the outlet discharges into a well-defined channel, the receiving side slopes of the channel should not be steeper than 3:1 (H:V).

g) Alignment

The protection should be located so there are no bend in the horizontal alignment.

3.3 Culverts and Bridges

The function of a culvert or bridge is to safely pass the peak flow generated by the design storm under a roadway, railroad, or other feature. The culvert or bridge design shall not cause excessive backwater or velocities. The design of a culvert must take into account the different engineering and technical aspects of the culvert site and adjacent areas which may be impacted by the design.

3.3.1 Design Criteria

The following design criteria apply for bridge and culvert design crossings.

3.3.1.1 General Design Requirements

a) Roadway culverts refer to structures installed under the roadway which convey flows from existing creeks, live streams, or drainage channels that originate upstream of the site and carry offsite flows through the site.
b) The design of all roadway culverts shall comply with SCDOT and Federal Emergency Management Agency (FEMA) guidelines.
c) The 100-year average return frequency storm shall be used for the design of all roadway culverts.
d) The permanent impoundment of water on the upstream side of the culvert (i.e., dams) is not permitted.

3.3.1.2 Discharge Velocities

Inlet and outlet flow velocities shall not impact channel stability. Scour analyses shall be performed for critical culvert and bridge structures, as identified by the DSR, municipality, state or, federal jurisdictions to determine necessary channel and structure protection. At a minimum, all inlet and outlet locations and other locations impacted by flow velocities near structures shall include design of channel protection where erosive flow velocities occur.

Culverts shall be designed to have a minimum mean velocity flowing full of 2.0 feet per second, the lower limit of scouring velocity.

3.3.1.3 Culvert Material Types

Material for culverts under roadways or under driveways within right-of-way shall consist of reinforced concrete pipe (RCP). RCP shall be Class III or better, as specified by SCDOT specifications.

Material for culverts for installations in grassed areas, in areas that do not have traffic bearing loads, or that do not have surcharge loads from embankment may consist of high density polyethylene (HDPE) pipe with smooth interior liner. HDPE pipe connections shall be watertight in areas where either elevated seasonal high ground water may be evident or where hydraulic surcharge of the system will occur. HDPE pipe shall comply with SCDOT specifications.

3.3.1.4 Geometry

The culvert shall be of adequate length to join or match required headwalls, sloping of embankments, and wall treatments, and any other inlet/outlet protection improvements. The longitudinal slope shall conform to existing naturalized channel slope. The culvert invert shall not impeded flows along the bottom of the open channel. Culvert skew shall not exceed approximately 30 degrees. The minimum pipe diameter (round or arch) shall be 15 inches; the minimum box dimension shall be 3 by 6 feet. Bridge passages shall be designed not to substantially impact flow characteristics.

3.3.1.5 Culvert End Treatments

Culvert headwalls shall be used at pipe inlets larger than 36 inches in diameter or rise. Design of inlets should not impact embankment stability or erosion. A combination of headwall and wingwalls may be allowed where limiting the length of embankment side slopes, property impacts, or other conditions necessitate their use. Exposure of end treatment configurations should not have adverse effect upon adjacent activities or uses. Barriers, buffers, or other means of access restriction shall be designed as necessary.

Hardened concrete inlet aprons may be utilized to provide inlet channel protection. The apron shall extend a minimum length of one pipe diameter along the flow channel and conform to the channel bottom. If the exit velocity is high and/or receiving channel conditions are prone to erosion and destabilization of the channel, the outfall energy dissipaters for culverts or channel armor shall be required. Materials may include properly sized stone riprap on geotextile, stilling basins, hardened control devices, or natural structures, design in accordance with FHWA HEC No. 14, Hydraulic Design of Energy Dissipaters for Culverts and Channels, 1983 or as otherwise approved by DSR.

3.3.1.6 Hydraulic Considerations

If the project location is in the area of a mapped 100-year frequency base flood elevation shown on the FEMA Flood Insurance Rate Map (FIRM), the design must follow the National Flood Insurance Program guidelines.

a) Headwater Limitations

Headwater (HW) is the depth of water above the culvert invert at the upstream (entrance) end of the culvert. The allowable headwater elevation is determined from an evaluation of land use upstream, roadway or embankment elevation, and acceptable elevation for flood passage. Culverts with a rise of 42 inches or smaller shall not be subjected to an HW of greater than 1.6 times the rise of the culvert for up to a 25-year storm event. Culverts with a rise of 48 inches and larger shall not be subjected to an HW of greater than 0.8 times the rise of the culvert for a 25-year storm event and not greater than 1.25 times the rise of the culvert for a 50-year storm event. Resulting HW of culverts shall not increase, adversely impact, or result in a surface water elevation increase that is unacceptable or greater than 1 foot at areas upstream of the culvert. Design shall demonstrate that flow passes safely around the culvert and that headwater or tailwater elevations from the culvert do not endanger property or overtop the roadway for all events including a 100-year storm event.

b) Tailwater Considerations

Tailwater is the depth of water above the culvert invert at the downstream (outfall) of the culvert. The tailwater depth for a range of discharges must be determined by way of hydraulic evaluation. There may be a need for calculating backwater curves to establish the tailwater conditions. The following site conditions must be considered.

- If the culvert outlet is operating with a free outfall, the critical depth and equivalent hydraulic grade line should be determined.
- If the culvert discharges to an open channel, the stage-discharge curve for the receiving channel must be determined.
- If the culvert discharges to a lake, pond, or other major water body, the expected high water elevation of the particular water body may establish the culvert tailwater. For tidal

culverts discharging into an ocean, the mean high and mean low tide elevations must be considered with the mean high tide elevation occurring at the time of peak flow for the stormwater system.

- If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert may establish the design tailwater depth for the upstream culvert.

c) Storage

If area upstream of the culvert will be utilized as storage during the design storm, the following must be considered:

- The total area of inundation by design storm, and
- The freeboard and bankfull elevation design criteria for open channels shall be considered.

3.3.1.7 Culvert Weep Holes

Weep holes are installed to relieve hydrostatic pressure resulting in uplift forces on the culvert structure and shall be included as necessary. The weep holes should be used in conjunction with filter materials in order to intercept the flow and prevent the formation of piping channels. The filters should be designed as under-drain filter structures to prevent clogging.

3.3.1.8 Environmental Considerations

Selected culvert design and location should cause the least impact on the stream, wetlands, and wildlife habitat. This selection analysis shall consider the entire impacted site, including any inlet and outlet channels where the stormwater design substantially impacts the existing hydraulic capacity or surface water elevation.

3.3.1.9 Regulated Floodway Requirements

The culvert/bridge design must be in compliance with National Flood Insurance Program. It is necessary to consider the 100-year frequency flood at the local identified special flood hazard areas. The design professional should review floodway regulations applicable for the project and impacted area.

3.3.2 Culvert Flow

Culverts shall be selected based on hydraulic performance, site conditions and economy. It is necessary to know the design culvert flow regime to properly access its impact. Culvert selection shall include analysis of both inlet and outlet control.

The culvert flow controls for a straight, uniformly shaped culvert are divided into two basic classes depending on the control section: inlet control and outlet control. For each type of control, different factors and equations are used to compute the hydraulic capacity of the culvert. Inlet control is restricted due to the opening efficiency and opening size. Conversely, outlet control is restricted by friction and by tailwater effects. Both the inlet flow capacity and the outlet flow capacity must be calculated to compare the values and select which condition is most restrictive.

3.3.2.1 Inlet Control

For a culvert operating under inlet control, the culvert barrel is capable of conveying a greater discharge than the inlet will accept. The flow control section is just inside the culvert barrel at its entrance. The flow profile passes through critical depth at this location and flow in the barrel is supercritical. Conditions downstream of the entrance have no effect on culvert capacity. The barrel flows partially full over its length and the flow approached normal depth at the outlet end.

Under inlet control, only the headwater and the inlet configuration affect the hydraulic performance. The headwater elevation at the culvert entrance supplies the energy necessary to force flow through a culvert.

The maximum discharge through a culvert flowing partially full occurs when flow is at critical depth for a given energy head. To assure that flow passes through critical depth near the inlet, the culvert must be laid on a slope equal to or greater than critical slope for the design discharge. Placing culverts which are to flow partially full on slopes greater than critical slope will increase the outlet velocities but will not increase the discharge capacity. The section near the inlet at which critical flow occurs limits the discharge.

3.3.2.2 Outlet Control

All the factors affecting the hydraulic performance of a culvert in inlet control also influence culverts in outlet control. In addition, the barrel characteristics (roughness, area, shape, length, and slope) and the tailwater elevation affect culvert performance in outlet control.

The barrel roughness is a function of the culvert material and is represented by Manning's "n" coefficient. The barrel length is the total length extending from the entrance to the exit of the culvert. The barrel slope is the actual slope of the culvert and is often equivalent to the slope of the stream. The tailwater elevation is based upon the downstream water surface elevation measured from the outlet invert. Backwater calculations or normal depth approximations, when appropriate, are two methods used to determine the tailwater elevation.

Most culverts flow with free outlet but, depending on topography or downstream constraint, a tailwater elevation sufficient to submerge the outlet may form at some instances. For an outlet to be submerged, the depth at the outlet must be equal to or greater than the diameter of the culvert. The capacity of a culvert flowing full with a submerged outlet is governed by the following equation when the approach velocity is considered zero. Outlet velocity is based on full-pipe flow at the outlet.

3.3.2.3 Critical Depth

When the sum of kinetic energy plus potential energy for a specified discharge is at a minimum, critical flow occurs. During critical flow, the maximum discharge through the culvert occurs with any specified total energy head. For a given flow rate, the depth of flow and slope associated with critical flow define the critical depth and critical slopes. If a culvert has an unsubmerged outlet, the maximum capacity of the culvert is established when critical flow occurs.

3.3.3 Culvert Selection and Design

Culvert selection techniques can range from solving empirical formulas, to using nomographs and charts, to comprehensive mathematical analysis for specific hydraulic conditions. The many hydraulic factors involved make precise evaluation time consuming and difficult without the help of computer programs and models. The actual models used for these calculations shall be at the discretion of the design professional with approval from the DSR. Applicable computer models for culvert design include, but are not limited to the following:

- HY8
- Hydraflow Storm Sewers
- XPSWMM
- HEC-RAS
- Culvert Master
- ICPR

The simple empirical and nomograph methods do not account for all of the factors that impact flow through culverts, but they can be easily used to estimate flow capacities for the conditions they represent.

3.4 Open Channel

Open channel is frequently an integral component of an urban drainage system design. The drainage system may include the following types of channels or combination:

- Natural Channel
- Constructed Channel
- Ditch
- Swale

These types of channel are ruled by common open channel design procedure. A stable open channel brings several advantageous features to the design:

- Relatively low construction cost,
- Potential flood control (instream storage attenuating downstream peak),
- Potential groundwater recharge,
- Improved water quality,
- A habitat for native vegetation and wildlife,
- Areas for recreation, and
- An aesthetically pleasing environment adding social benefits.

The implementation of an open channel into the design requires careful planning and accounting for potential right-of-way constraints, utility conflicts, maintenance cost, and safety issues.

This section provides the necessary criteria and methodology for selection and design of open channels.

3.4.1 General Design Criteria

3.4.1.1 Design Storm Frequency

Open channels shall be designed to convey the 10-year event below its freeboard height and the 25-year event below its bankfull elevation. The 100-year design storm shall be routed through the channel system to determine that the finished floor of residential dwellings, public, commercial, and industrial buildings will be 2 feet above the 100-year flood water surface elevation.

3.4.1.2 Geometry

The channel geometry design depends on site conditions and conveyance needs. The channel cross section may be trapezoidal, parabolic, V-shaped, or combination of those geometric shapes. Most desirable and commonly used is trapezoidal channel cross section.

a) Channel side slopes shall be stable throughout the entire length. The channel side slopes shall be a maximum 2:1 (H:V).
b) Channels with bottom widths greater than 10 feet shall be designed with a minimum bottom cross-slope of 12:1 (H:V).
c) If relocation of a stream channel is unavoidable, the geometry, meander pattern, roughness, and slope should conform to the existing conditions, as practicable. Some means of energy dissipation may be necessary when existing conditions cannot be duplicated.

3.4.1.3 Freeboard

Freeboard is extra height of channel lining above the design storm depth where overflow is expected to occur and potentially cause damage. This additional range of inundation creates a safety factor should unexpected obstructions or additional runoff create a rise in the design water surface elevation.

a) For channels three feet or less in depth, one half of foot of freeboard shall be provided.
b) For channels deeper than three feet and up to five feet in depth, one foot of freeboard shall be provided.
c) For channels deeper than five feet in depth, freeboard that is at least equal to 20 percent of the total channel depth shall be provided.

3.4.1.4 Velocity Limitations

The final design of an open channel should be consistent with the velocity limitations for the selected channel lining to satisfy the condition of non-erosive velocity in the channel.

3.4.1.5 Channel Lining

Channel linings include vegetative and engineered materials, further divided into flexible materials (grass, riprap, articulated concrete, and gabions), and rigid materials (paving blocks and concrete). The channel lining design criteria require that two primary conditions are satisfied:

a) The channel system with the lining in place must have capacity for the peak flow expected from the design storm, and
b) The channel lining must be resistant to erosion for the design velocity.

3.4.1.6 Maintenance Corridors and Easements

a) For minor ditches with open channel flow, the required easement width shall be determined from the equivalent pipe size required to carry the flow and the easement width (listed below) corresponding to that calculated pipe size.

Pipe Size	Required Easement Width
15 inches – 48 inches	20 feet
Over 48 inches	30 feet

b) For major ditches or channels, the easement width shall be centered on the ditch or channel and be equal to the maximum top width of the ditch plus twenty (20) feet.

c) The following statement shall be included on the construction plans and Final Plat: "There is a ten (10) foot drainage and utility easement along either side of all side and rear lot lines except where otherwise noted."

3.4.2 Channel Discharge

Designing a stable channel under dynamic channel conditions requires an understanding of sediment transport, stream channel response, and erosive forces which are at work. Unlined channels must be designed to minimize excessive scour while lined channels must be designed to prevent deposition of sediments. Details of methodology specific to protection from erosive forces can be found in the Federal Highway Administration, Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Circular No. 14 (HEC-14), 1983.

All variables used in fluid mechanics and hydraulics fall into one of three classes: those describing the boundary geometry, those describing the flow, and those describing the fluid. Various combinations of these variables define parameters that describe the state of flow in open channels.

3.4.2.1 Manning's "n" Values

The Manning's "n" value is an important variable describing material roughness in open channel flow computations. Changes in this variable can significantly affect flow discharge, depth, and velocity estimates. Since Manning's "n" values depend on many physical characteristics of channel surface, care and good engineering judgment must be exercised in the selection process. The composite "n" value should be calculated where the lining material, and subsequently the Manning's "n" value, changes within a cross section.

For natural channels, Manning's "n" values should be estimated using the procedures presented in the publication *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains,* (FHWA-TS-84-204, 1984).

3.4.3 Channel Design

The drainage channel design has to provide adequate capacity for flow resulting from the design storm. The hydraulic characteristics of open channels shall be determined by using Manning's and continuity equations. Manning's Equation is commonly expressed as:

$$V = 1.49/n\ R^{2/3}\ S^{1/2} \tag{3-17}$$

Where:

V = average flow velocity, in feet per second
n = Manning roughness coefficient

S = channel slope, in feet per foot
R = hydraulic radius, in feet, calculated as

$$R = A/P \tag{3-18}$$

Where:

A = flow cross sectional area, in square feet
P = wetted perimeter, in feet (length of boundary between water and channel)

For prismatic channels, in the absence of backwater conditions, the slope of the energy grade line, water surface and channel bottom are equal.

The continuity equation is commonly expressed as:

$$Q=VA \tag{3-19}$$

Where:

Q = average flow through a cross section, in cubic feet per second
V = average flow velocity over a cross section, in feet per second
A = area of cross section, in square feet

The continuity and Manning's Equations together may be solved for channel flow:

$$Q = 1.49/n\ A\ R^{2/3}\ S^{1/2} \tag{3-20}$$

Area, wetted perimeter, hydraulic radius, and channel top width for standard channel cross-sections can be calculated from geometric dimensions. Irregular channel cross sections (i.e., those with a narrow deep main channel and a wide, shallow overbank flow area) must be subdivided into segments so that the flow can be computed separately for the main channel and overbank portions. This same process of subdivision may be used when different parts of the channel cross section have different roughness coefficients as previously mentioned. When computing the hydraulic radius of the subsections, the water depth common to the two adjacent subsections is not counted as wetted perimeter.

3.4.3.1 Permissible Velocity

Permissible nonerosive velocity of a channel is dependent upon stability of lining materials and channel vegetation. In stable channels, the flow velocities generated by the design storm event shall not exceed the permissible velocity of the channel liner.

To satisfy this condition it is necessary to calculate the velocity in the design channel for the design storm event and compare it with the permissible velocity for the selected channel lining.

A temporary lining may be required to stabilize the channel until the vegetation is established. If a channel requires temporary lining, the designer should analyze shear stress in the channel to select an appropriate liner that provides protection and promotes vegetation establishment.

The channel outfall has to be evaluated for stability and the receiving channel for carrying capacity. If discharge velocities exceed allowable velocities for the receiving stream, an outlet protection design will be required.

3.4.3.2 Tractive Force

The design of riprap lined channels and temporary linings are based on shear stress/tractive force analysis. This method assumes that the design flow is uniform and does not vary with time. Since actual flow conditions change through the length of the channel, it is necessary to subdivide the channel into design reaches with uniform flow and work within the tractive force method limitations.

a) Shear Stress

The critical shear stress or critical tractive force determines a soil's resistance to the shearing forces of concentrated flows. When the shearing forces of the flow exceed the critical tractive force of the soil, erosion takes place.

The slope, flow depth (normal depth, dn) calculated for the design flow, and other channel design characteristics are important variables in shear stress calculation.

b) Permissible Shear Stress

Permissible shear stress is the force required to initiate movement of the lining material and is not related to the erodibility of the underlying soil. However, if the lining is eroded or broken, the bed material will be exposed to the erosive force of the flow.

Permissible shear stress for the lining materials can be determined from appropriate resources. If a calculated shear stress is less than the permissible sheer stress, the proposed riprap or temporary lining is considered acceptable. If the lining is unacceptable, lining with a higher permissible shear stress is necessary. In some cases it may be necessary to alter channel dimensions to reduce the shear stress to the level below the permissible value.

c) Normal Depth

Normal depth is unique for each channel with a particular slope and discharge and can be calculated using Manning's Equation. This generally requires a trial-and-error solution. The trial-and-error method for normal depth calculation is described in the section below. It is recommended that normal depth should be calculated for the following conditions:

- Bare matting with no vegetation,
- Matting with maintained vegetation, and
- Matting with un-maintained vegetation.

d) Iterative Method for Normal Depth Calculation

The use of Manning's procedure includes iterative calculations to calculate the normal depth of flow in a uniform channel when the channel shape, slope, roughness and design discharge are known.

Using Manning's equation and the continuity equation, and solving for flow, the following ratio is desired:

$$A R^{2/3} = n Q / (1.49 S^{1/2}) \qquad (3\text{-}21)$$

To calculate the normal depth of flow (dn) by the trial and error process, trial values of depth (dn) are selected to calculate a corresponding flow area (A), wetted perimeter (P), and hydraulic radius (R). For each trial depth selected, a corresponding $AR^{2/3}$ value is calculated. Trial values of the depth are selected until the $AR^{2/3}$ value equals the known ratio calculated by using the known roughness, design discharge, and channel slope.

e) Computing Shear Stress around a Channel Bend

Computing shear stress around a channel bend requires special considerations because the change in flow direction imposes higher shear stress on the channel bottom and banks. The length of channel requiring protection downstream from a bend is a function of the roughness of the lining material and the hydraulic radius.

The design channels usually exhibit high stress around bends and therefore these areas should be carefully evaluated. The channel may be protected by change in cross sectional area that would decrease the shear stress, or upgrade the protective channel lining so it withholds the shear forces.

3.5 Storage Facilities

Urban stormwater storage facilities are often referred to as either detention or retention facilities. Detention facilities are those permanent stormwater management structures whose primary purpose is to temporarily store stormwater and release the stored stormwater at controlled rates. Therefore, detention facilities are designed to reduce the peak discharge and only detain runoff for some short period of time. These facilities are designed to completely drain or drain back to a normal pool elevation after the design storm has passed. Retention facilities are those permanent structures that permanently store a given volume of stormwater. These facilities typically store an additional volume of stormwater for release by infiltration and/or evaporation. They do not pass stormwater purposely but reduce it completely through other means. The term storage facilities will be used in this chapter to include detention and retention facilities.

Storage facilities can range from small facilities in parking lots or other onsite facilities to large lakes and reservoirs. This chapter provides general design criteria for promoting onsite storage where possible.

It should be noted that the location of storage facilities is very important as it relates to the effectiveness of these facilities to control downstream flooding. Small individual storage facilities generally have only minimal regional flood control benefits, as the localized benefits quickly diminish as the flood wave moves away from the facility and travels downstream. Multiple storage facilities located in the same drainage basin will affect the timing of the runoff through the conveyance system which could decrease or increase flood peaks in different downstream locations. Therefore careful consideration to downstream effect should be exercised in large or complex watersheds.

3.5.1 General Design Criteria

The R.72-300 South Carolina *Standards for Stormwater Management and Sediment Reduction* provides performance criteria for design and operation of storage facilities. The criteria have been compiled and outlined below based on their function in controlling stormwater.

3.5.1.1 Storage

a) Storage volume shall be adequate to attenuate the post-development peak discharge rates to predevelopment discharge rates for the 2-, 10- and 25-year storms.
b) Development projects shall use a calculated natural ground cover and vegetated surface condition for the determination of predevelopment discharge rates from the site.
c) The stored detention volume shall be released within 24 to 48 hours and normal pool elevations returned, unless otherwise specified.

3.5.1.2 Release Rate

a) Control structure release rates shall be less than or equal to predevelopment peak runoff rates for the 2-, 10- and 25-year storms, with emergency overflow adequately designed for the 100-year discharge.
b) Design calculations must demonstrate that the facility will limit runoff from the 2-, 10- and 25-year post-development discharge rates to predevelopment peak discharge rates.
c) Outlet structures that draw water from or near the normal pool surface of the storage facility shall be used
d) Discharge velocities shall be non-erosive for the design storm.

3.5.2 Design Recommendations

The sizing of a storage facility depends on the amount of storage, its location within the system, and its operational characteristics. An analysis of storage facilities should consist of comparing the design flow at a location downstream of the proposed storage site both with and without storage. Flow in excess of the design storm flow is expected to pass through or around the storage facility safely (i.e., 100-year flood). Additional design recommendations for storage facilities should include:

- Storage volume
- Grading and depth requirements
- Safety considerations and landscaping
- Outlet works
- Location

The same hydrologic procedure shall be used to determine pre- and post-development hydrology.

3.5.2.1 Storage

Routing calculations must be used to demonstrate that the storage volume is adequate. If sedimentation during construction causes loss of detention volume, design dimensions shall be restored before completion of the project.

3.5.2.2 Grading and Depth

This section presents a discussion of the general grading and depth criteria for storage facilities followed by criteria related to dry detention basins and wet detention ponds.

The construction of storage facilities usually requires excavation or placement of earthen embankments to obtain sufficient storage volume. Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 3:1 (H:V). Riprap protected embankments shall be no steeper than 1:2 (H:V). Geotechnical slope stability analysis is required for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. Procedures for performing slope stability evaluations can be found in most soil engineering textbooks.

Final side slopes for storage facilities shall be a maximum of 2:1 (H:V) and shall extend three feet below the permanent pool water level. Side slopes shall be stabilized with grass or other natural vegetation. During construction, if side slopes do not meet the above requirements then the permanent pool shall be surrounded with a fence of a minimum height of 6 feet until such time as the final side slope is established.

Impoundment depths greater than 25 feet or storage volume greater than 10 acre-feet are subject to the requirements of the South Carolina Safe Dams Act (SDA) unless the facility is excavated for the depth. Other considerations when setting depths include flood elevation requirements, public safety, land availability, land value, present and future land use, water table fluctuations, soil characteristics, maintenance requirements, vegetation maintenance and/or control, and required freeboard. The feature's pleasing aesthetical characteristics are also important in urbanized areas.

3.5.2.3 Outlet Works

Outlet works selected for storage facilities typically include a principal outlet works and an emergency spillway. These structures are sized to accomplish the design functions of the storage facility. Outlet works can include risers, drop inlets, pipes, various weirs, orifices, and combinations. The clogging factor of these structures has to be considered in the outlet works structure design.

The outlet works are designed to convey the design storm. The emergency spillway shall safely convey the 100-year flood determined by using a fully developed land use conditions, and with the outlet located above the pond's 25-year water surface elevation.

For large storage facilities under the jurisdiction of the SDA, Dams and Reservoirs Safety Act Regulations (DRSAR) guidelines must be followed for selecting a design flood magnitude. The sizing of the emergency outlet should be always consistent with the potential threat to downstream life and property damage in a case of embankment failure. The hydrologic routing calculations are the only means accepted by County for sizing the outlet works.

Where the discharge structure consists of a single pipe outlet, the pipe shall have a minimum inside diameter of 15 inches since maintenance of outlets smaller than 15 inches is likely to be a problem. If design release rates call for outlets smaller than 15 inches, release structures such as perforated risers or flow control orifices shall be incorporated.

a) Principal Outlet Works

Discharge for various headwater depths can be controlled by crests (weir control), riser, barrel opening, low orifice control, or barrel pipe (outlet control). Each of these flow controls shall be evaluated when determining the rating curve of the principal outlet. The following weir, orifice, and pipe flow equations can be used to evaluate a single opening outlet structure. Outlet works design shall consider weir flow, and pipe flow where appropriate.

b) Emergency Spillways

All detention basins shall include a stabilized emergency spillway designed to convey the 100-year storm event. The County may require the design professional to evaluate a more stringent design requirement including a breach analysis if there is a potential for loss of life or significant downstream property damage. The elevation of the 100-year storm event also shall be reviewed to ensure that area structures are not impacted. Certain embankments may be classified as dams and are required to meet applicable rules.

The emergency spillway shall be constructed using undisturbed native (in-situ) soils. The geologic and topographic features of a site determine the design features of the spillway, such as position, profile, and length. The cross section dimensions are governed by required hydraulic capacity and are determined by reservoir routing of the design storm. Emergency spillways for detention ponds are often designed as stabilized open channels with linings selected to resist erosion.

Discharge from the emergency spillway shall be directed to the receiving channel without causing erosion along the downstream toe of the dam. An emergency spillway proposed for the protection of an earthen embankment shall be in undisturbed soil, if possible, to avoid flow-imposed stress against a constructed fill. The side slopes of the excavated earth channel shall be no steeper than 3:1 (H:V) and shall be stabilized in accordance with procedures for open channels. Where the site limitations prevent a full channel cut, a wing dike shall be provided to direct spillway flows away from the downstream toe of the dam. Ready access to the emergency spillway system is required.

The configuration of the entrance channel from the reservoir to the control section of the emergency spillway shall provide a smooth transition to avoid turbulent flow over the spillway crest. The outlet of the emergency spillway shall transition to the channel without causing erosion. The slope of the exit channel usually follows the configuration of the abutment. In cases of highly erodible soils, it may be necessary to use structural or vegetative protective lining. As an alternative, increased detention storage reduces the frequency and/or duration of emergency spillway operation and therefore reduces potential erosion problems.

3.5.2.4 Location

In addition to controlling the peak discharge from the outlet works, storage facilities will change the timing of the entire hydrograph. If several storage facilities are located within a particular basin, it is important to determine what effects a particular facility may have on combined hydrographs in downstream locations. The DSR may request an analysis of the potential for adverse impacts downstream. At the request of the County, channel routing calculations should be performed proceeding downstream to a confluence point where the drainage area being analyzed represents ten percent of the total drainage area. For example, if the proposed development occupies a drainage area of seven acres then the analysis must be performed far enough downstream that the resulting contributing drainage of analysis is equal to or greater than seventy (70) acres (seven acres being ten percent of seventy acres). At this point, the effect of the hydrograph routed through the proposed storage facility on the downstream hydrograph should be assessed to ensure detrimental effects on downstream hydrographs are not present.

3.5.2.5 Dams and Reservoirs Safety Act Regulations

Under the SDA, a regulated dam is an artificial barrier that does or may impound water and that is 25 feet or greater in height or has a maximum storage volume of 50 acre-feet or more. A number of exemptions are allowed from the SDA and any questions concerning a specific design or application should be addressed to the South Carolina Department of Health and Environmental Control (SCDHEC).

According to SDA, all dams and reservoirs subject to regulation shall be classified according to their size and hazard potential. Classifications shall be made in accordance with the Section 72-2. of DRSAR and are subject to final approval by the SCDHEC. It may be necessary to reclassify dams overtime in accordance with changes in DRSAR regulations.

Size classification may be determined by either storage or height, whichever gives the larger size capacity. The hazards potential classification pertains to potential loss of human life or property damage in the event of failure or improper operation of the dam or appurtenant works.

3.6 Onsite Detention

Potential advantages and disadvantages of onsite detention structures should be considered by the design professional in the early stages of development. Discharge rates and outflow velocities are regulated to conform to the capacities and physical characteristics of downstream drainage systems. Energy dissipation and flow attenuation resulting from onsite storage can reduce soil erosion and pollutant loading. By controlling release flows, the impacts of pollutant loading of stored runoff on receiving water quality can be minimized.

The onsite detention structures listed in this section shall be designed for the temporary storage of stormwater. The design professional should ensure that all detained stormwater is emptied in the specified duration to avoid creating hazardous and unsightly conditions, or more importantly, to prevent jeopardizing the future function of the structure itself. Onsite detention systems shall also be designed to provide positive overflow and drainage relief in the event that blockage of primary release locations occurs.

3.6.1 Hydraulic Design Methods

3.6.1.1 Hydrograph Procedure for Storage Analysis

The unit hydrograph procedure develops a hydrograph which provides a more reliable solution for detention storage effects by providing the design professional greater flexibility for the representation of actual conditions to be modeled. This procedure can be used for any size drainage area. For detention basin design, 24-hour design storm duration should be used.

3.6.1.2 Modified Puls Routing Procedure

A flood routing procedure may be used to determine the required volume of the detention basin. Several flood routing procedures are available in published texts. One commonly used method is the Modified Puls Routing Procedure. The data needed for this routing procedure are:

a) Inflow hydrograph
b) Physical dimensions of the storage basin
c) Maximum outflow allowed
d) Hydraulic characteristics of the outlet structure or spillway

To perform the Modified Puls procedure, the inflow hydrograph, depth-storage relationship, and depth-outflow relationship must be determined and further combined in a routing routine. The results of the routing are the ordinate of the outflow hydrograph, the depth of storage, and the volume of storage at each point in time of the flood duration.

The routing period, or time interval, Δt, should be small enough so that there is a good definition of the hydrograph and the change in the hydrograph during the period Δt is approximately linear. This may be accomplished by setting Δt = 5 or 10 minutes, depending on size of watershed and hydrograph time to peak.

Several assumptions are made in this procedure and include the following:

a) The entire inflow hydrograph is known
b) The storage volume is known at the beginning of the routing
c) The outflow rate is known at the beginning of the routing
d) The outlet structures are such that the outflow is uncontrolled and the outflow rate is dependent only on the structure's hydraulic characteristics.

3.6.2 Debris and Sedimentation

The performance and reliability of detention facilities can be reduced by natural and man-made debris. Naturally occurring sedimentation can, over a period of time, reduce the storage capacity of a detention basin and thereby reduce the degree of flood protection provided. The obstruction of low flow conduits by debris can reduce outlet capacity and cause the premature filling of the detention basin with stormwater, again reducing the flood protection provided by the structure. Consequently, adequate care must be exercised in design to provide for protection of the outlet work from debris and for the control and removal of sedimentation in the basin.

3.6.2.1 Trash Racks

All outlet works and low flow conduits shall be provided with a trash rack for debris control. The trash rack shall provide a maximum bar spacing not to exceed two-thirds of the outlet opening or diameter. The total area of the trash rack shall allow for passage of the design flow with 50 percent of the trash rack blocked. Calculations for head losses through a trash rack shall be included in the hydraulic evaluation of the outlet. The trash rack should have an area equal to 10 times the area of the outlet to maintain low velocities through the trash rack.

3.6.2.2 Sedimentation

Sediment removal within a detention facility may be facilitated by the use of a sediment trap at the inlet, which concentrates the majority of the incoming sediment bed load to a small portion of the facility. Sediment traps should be provided in conjunction with all detention facilities. The following list provides guidelines for the design of efficient sediment traps:

a) Sedimentation volume should be provided at an elevation below the invert of the inflow channel.
b) The length/width ratio of the sediment trap should be a minimum of 2:1, with the length measured along a line between the inlet and outlet.
c) The basin shape should be configured to prevent flow short-circuiting from the inlet to the outlet. This can be accomplished by placing the inlet at the opposite end or installing flow baffles. This is to allow the finer sediments the maximum residence time to settle out.
d) Provisions for total drainage and accumulated sediment removal of the sediment trap shall be provided. Maintenance access should also be provided and designed to accommodate dump trucks and other equipment necessary for removal of accumulated sediment.

4.0 Green Infrastructure Practices

4.1 Overview

Green infrastructure practices are natural resource protection and stormwater management practices and techniques that can be used to help prevent increases in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. The term green infrastructure practices has been succinctly defined as the combination of three complementary, but distinct, groups of natural resource protection and stormwater management practices and techniques:

- Better Site Planning Techniques: Techniques that are used to protect natural resources from the direct impacts of the land development process.
- Better Site Design Techniques: Techniques that are used to minimize land disturbance and the creation of new impervious and disturbed pervious cover.
- Low Impact Development Practices: Small-scale stormwater management practices that are used to disconnect impervious and disturbed pervious surfaces from the storm drain system and reduce post-construction stormwater runoff rates, volumes and pollutant loads.

Together, these green infrastructure practices can be used to not only help protect natural resources from the direct impacts of the land development process, but also help maintain pre-development site hydrology and reduce post-construction stormwater runoff rates, volumes and pollutant loads.

This section provides additional information about using these green infrastructure practices to help satisfy Jasper County's stormwater management requirements. Together with stormwater management practices, which can be used to manage post-construction stormwater runoff rates, volumes and pollutant loads, green infrastructure practices can be used to help control and minimize the negative impacts of land development and nonpoint source pollution.

4.2 Recommended Green Infrastructure Practices

The green infrastructure practices recommended for use in Jasper County include:

4.2.1 Better Site Planning Techniques

- Protect Primary Conservation Areas
- Protect Secondary Conservation Areas

4.2.2 Better Site Design Techniques

- Reduce Clearing and Grading Limits
- Reduce Roadway Lengths and Widths
- Use Fewer or Alternative Cul-de-Sacs
- Reduce Parking Lot Footprints
- Create Landscaping Areas in Parking Lots
- Reduce Driveway Lengths and Widths
- Reduce Sidewalk Lengths and Widths
- Reduce Building Footprints
- Reduce Setbacks and Frontages

4.2.3 Low Impact Development Practices

The low impact development practices recommended for use in Jasper County have been divided into three groups: (1) alternatives to disturbed pervious surfaces; (2) alternatives to impervious surfaces; and (3) receiving low impact development practices. Each of these groups is briefly described below:

4.2.3.1 Alternatives to Disturbed Pervious Surfaces

These low impact development practices can be used to help restore disturbed pervious surfaces to their pre-development conditions, which decreases post-construction stormwater runoff rates, volumes and pollutant loads. They can be used alone or in combination with one another to restore soils and native vegetative cover in areas that have been or will be disturbed by clearing, grading and other land disturbing activities. The alternatives to disturbed pervious surfaces recommended for use in Jasper County include:

a) Soil Restoration
b) Site Reforestation/Revegetation

4.2.3.2 Alternatives to Impervious Surfaces

These low impact development practices can be used to reduce the amount of effective impervious cover found on a development site. They can be used in place of traditional impervious surfaces, such as rooftops, parking lots and driveways, to reduce the post-construction stormwater runoff rates, volumes and pollutant loads that these surfaces create. The alternatives to impervious surfaces recommended for use in Jasper County include:

a) Green Roofs
b) Permeable Pavement

4.2.3.3 Receiving Low Impact Development Practices

These low impact development practices can be used to receive and reduce the post-construction stormwater runoff generated on a development site. They are designed to slow and temporarily store stormwater runoff, subjecting it to the runoff reducing hydrologic processes of interception, evapotranspiration, infiltration and capture and reuse, before directing it into the stormwater conveyance system. The low impact development practices that can be used to receive post-construction stormwater runoff on a development site include:

a) Undisturbed Pervious Areas
b) Vegetated Filter Strips
c) Grass Channels
d) Simple Downspout Disconnection
e) Rain Gardens
f) Stormwater Planters
g) Dry Wells
h) Rainwater Harvesting
i) Bioretention Areas
j) Infiltration Practices
k) Dry Swales

The remainder of this Section provides additional information about all of these green infrastructure practices, including information about their proper application and design and information about how they can be used to help satisfy Jasper County's stormwater management requirements.

4.3 Other Green Infrastructure Practices

4.3.1 New and Innovative Green Infrastructure Practices

The use of new and innovative green infrastructure practices is encouraged in Jasper County, provided that their applicability and functionality has been sufficiently documented. At its discretion, the DSR may allow for the use of a green infrastructure practice that is not discussed in this manual.

4.4 Green Infrastructure Practice Selection

In general, the following information should be considered when deciding what green infrastructure practices to use on a development site:

- Ability to Help Satisfy the Stormwater Management Criteria
- Overall Feasibility
- Site Applicability

In addition, site planning and design teams should consider how the following site characteristics and constraints, which are commonly encountered in Jasper County, will influence the use of green infrastructure practices on a development site:

- Poorly drained soils, such as hydrologic soil group C and D soils
- Well drained soils, such as hydrologic soil group A and B soils
- Flat terrain
- Shallow water table
- Tidally-influenced drainage

Each green infrastructure practice can be evaluated for its ability to help satisfy the post-construction stormwater management criteria that apply to a development site. Additional information about each of the green infrastructure practices is included in the matrix (Table 4.1, pages 4-52 to 4-56) as described below.

- Stormwater Runoff Reduction: This column indicates the stormwater management credit that can be applied toward the stormwater runoff reduction criteria if the green infrastructure practice is used on the development site.
- Water Quality Protection: This column indicates the stormwater management credit that can be applied toward the water quality protection criteria if the green infrastructure practice is used on the development site.

The overall feasibility of applying each of the green infrastructure practices on a development site should be evaluated. Additional information about each of the evaluation categories included in the evaluation matrix (Table 4.2, pages 4-57 and 4-59) is described below.

- Drainage Area: This column describes how large of a contributing drainage area each green infrastructure practice can realistically handle. It indicates the maximum size of the

contributing drainage area that each green infrastructure practice should be designed to receive stormwater runoff from.
- Area Required: This column indicates how much space the green infrastructure practice typically consumes on a development site.
- Slope: This column describes the influence that site slope can have on the performance of the green infrastructure practice. It indicates the maximum or minimum slope on which the green infrastructure practice can be installed.
- Minimum Head: This column provides an estimate of the minimum amount of elevation difference needed within the green infrastructure practice, from the inflow to the outflow, to allow for gravity operation.
- Minimum Depth to Water Table: This column indicates the minimum distance that should be provided between the bottom of the green infrastructure practice and the top of the water table.
- Soils: This column describes the influence that the underlying soils (i.e., hydrologic soil groups) can have on the performance of the green infrastructure practice.

The applicability of each of the green infrastructure practices on a particular development site should be evaluated. Additional information about each of the applicability categories included in the applicability matrix (Table 4.3, pages 4-60 and 4-61) is described below.

- Rural Use: This column indicates whether or not the green infrastructure practice is suitable for use in rural areas and on low-density development sites.
- Suburban Use: This column indicates whether or not the green infrastructure practice is suitable for use in suburban areas and on medium-density development sites.
- Urban Use: This column identifies the green infrastructure practices that are suitable for use in urban and ultra-urban areas where space is at a premium.
- Construction Cost: This column assesses the relative construction cost of each of the green infrastructure practices.
- Maintenance: This column assesses the relative maintenance burden associated with each green infrastructure practice. It is important to note that nearly *all* green infrastructure practices require some kind of routine inspection and maintenance.

4.5 Better Site Planning Techniques

This section contains information about the better site planning techniques that are recommended for use in Jasper County.

4.5.1 Protect Primary Conservation Areas

4.5.1.1 Description

Primary conservation areas, which include, but are not limited to, perennial and intermittent streams, freshwater wetlands, tidal creeks, coastal marshlands, maritime forests, marsh hammocks, aquatic buffers and shellfish harvesting areas, should be considered for protection, from the direct impacts of the land development process.

4.5.1.2 Discussion

Protecting primary conservation areas such as perennial and intermittent streams, freshwater wetlands, tidal creeks, coastal marshlands, maritime forests, marsh hammocks, aquatic buffers and shellfish harvesting areas, helps preserve important habitats for Jasper County's high priority plant and animal species and helps maintain pre-development site hydrology by reducing post-construction stormwater runoff rates, volumes and pollutant loads. It also helps prevent soil erosion and provides areas that can be used to receive stormwater runoff generated elsewhere on the development site.

The potential primary conservation areas found on a development site should be identified and mapped during the initial phases of a project. The identification and subsequent preservation and/or restoration of these natural resources helps reduce the negative impacts of the land development process by design.

It is recommended that the following primary conservation areas, which provide habitat for high priority plant and animal species, be protected from the direct impacts of the land development process:

a) Aquatic Resources
    i. Rivers
    ii. Perennial and Intermittent Streams
    iii. Freshwater Wetlands
    iv. Tidal Rivers and Streams
    v. Tidal Creeks
    vi. Coastal Marshlands
    vii. Tidal Flats
    viii. Scrub-Shrub Wetlands
    ix. Near Coastal Waters
    x. Beaches

b) Terrestrial Resources
    i. Dunes
    ii. Maritime Forests
    iii. Marsh Hammocks
    iv. Evergreen Hammocks
    v. Canebrakes
    vi. Bottomland Hardwood Forests
    vii. Beech-Magnolia Forests
    viii. Pine Flatwoods
    ix. Longleaf Pine-Wiregrass Savannas
    x. Longleaf Pine-Scrub Oak Woodlands

c) Other Resources
    i. Aquatic Buffers
    ii. Shellfishing Areas
    iii. Other High Priority Habitat Areas
    iv. Wildlife Corridors
    v. Contiguous and Connected Open Space/Habitat

Primary conservation areas that will be protected from the direct impacts of the land development process should be clearly identified on all development plans. They should be protected during construction, preferably with temporary construction fencing, and should be protected in perpetuity through a legally enforceable conservation instrument (e.g., conservation easement, deed restriction). Once established, primary conservation areas should be maintained in an undisturbed, natural state over time.

4.5.1.3 Stormwater Management Credits

Although protecting primary conservation areas can be thought of as a self-crediting stormwater management technique (i.e., protecting them *implicitly* reduces post-construction stormwater runoff rates, volumes and pollutant loads), it is important not to overlook the valuable stormwater management and other environmental benefits that this better site planning technique provides. Therefore, it has been assigned quantifiable stormwater management credits as follows:

a) Stormwater Runoff Reduction: Subtract any *primary conservation areas* from the total site area when calculating the runoff reduction volume that applies to a development site.
b) Water Quality Protection: Subtract any *primary conservation areas* from the total site area when calculating the runoff reduction volume that applies to a development site.

In order to be eligible for these credits, primary conservation areas must satisfy the criteria outlined below.

4.5.1.4 Planning and Design Criteria

Primary conservation areas must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Primary conservation areas should have a contiguous area of 10,000 square feet or more.
b) Primary conservation areas should not be disturbed before, during or after construction (except for temporary disturbances associated with incidental utility construction, restoration activities or removal of invasive vegetation).
c) Primary conservation areas should be clearly identified on all development plans. Limits of disturbance around all primary conservation areas should be clearly marked on all development plans and should be delineated with temporary fencing prior to the start of any land disturbing activities.
d) Primary conservation areas should be protected, in perpetuity, from the direct impacts of the land development process by a legally enforceable conservation instrument (e.g., conservation easement, deed restriction).

4.5.2 Protect Secondary Conservation Areas

4.5.2.1 Description

Secondary conservation areas, which include, but are not limited to, natural drainage features, trees and other existing vegetation and groundwater recharge areas, should be considered for protection from the direct impacts of the land development process.

4.5.2.2 Discussion

Protecting secondary conservation areas, such as natural drainage features, trees and other existing vegetation and groundwater recharge areas, helps maintain pre-development site hydrology by reducing post-construction stormwater runoff rates, volumes and pollutant loads. It also helps prevent soil erosion and provides areas that can be used to receive stormwater runoff generated elsewhere on the development site.

The potential secondary conservation areas found on a development site should be identified and mapped during the initial phase of a project. The identification and subsequent preservation and/or restoration of these natural resources helps reduce the negative impacts of the land development process by design.

It is recommended that consideration be given to protecting the following secondary conservation areas from the direct impacts of the land development process:

a) General Resources
    i. Natural Drainage Features (e.g., Swales, Basins, Depressional Areas)
    ii. Erodible Soils
    iii. Steep Slopes (i.e., Areas with Slopes Greater Than 15%)
    iv. Trees and Other Existing Vegetation

b) Aquatic Resources
    i. Groundwater Recharge Areas
    ii. Wellhead Protection Areas

c) Other Resources
    i. Floodplains

Secondary conservation areas that will be protected from the direct impacts of the land development process should be clearly identified on all development plans. They should be protected during construction, preferably with temporary construction fencing, and should be protected in perpetuity through a legally-enforceable conservation instrument (e.g., conservation easement, deed restriction). Once established, secondary conservation areas should be maintained in an undisturbed, natural state over time.

4.5.2.3 Stormwater Management Credits

Although protecting secondary conservation areas can be thought of as a self-crediting stormwater management technique (i.e., protecting them *implicitly* reduces post-construction stormwater runoff rates, volumes and pollutant loads), it is important not to overlook the valuable stormwater management benefits that this better site planning technique provides. Thus, it has been assigned quantifiable stormwater management credits:

a) Stormwater Runoff Reduction: Subtract any *secondary conservation areas* from the total site area when calculating the runoff reduction volume that applies to a development site.
b) Water Quality Protection: Subtract any *secondary conservation areas* from the total site area when calculating the runoff reduction volume that applies to a development site.

In order to be eligible for these credits, secondary conservation areas must satisfy the planning and design criteria outlined below.

4.5.2.4 Planning and Design Criteria

Secondary conservation areas must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Secondary conservation areas should have a contiguous area of 10,000 square feet or more.

b) Secondary conservation areas should not be disturbed before, during or after construction (except for temporary disturbances associated with incidental utility construction, restoration activities or removal of invasive vegetation).
c) Secondary conservation areas should be clearly identified on all development plans. Limits of disturbance around all primary conservation areas should be clearly marked on all development plans and should be delineated with temporary fencing prior to the start of land disturbing activities.
d) Secondary conservation areas should be protected, in perpetuity, from the direct impacts of the land development process by a legally-enforceable conservation instrument (e.g., conservation easement, deed restriction).

4.6 Better Site Design Techniques

This section contains information about the better site design techniques that are recommended for use in Jasper County.

4.6.1 Reduce Clearing and Grading Limits

4.6.1.1 Description

Reduced clearing and grading limits should be used to help minimize the creation of new disturbed pervious cover on development sites.

4.6.1.2 Discussion

After construction, cleared and graded areas are typically seeded with turf and turned into lawns, parks and other managed open spaces. At one time, these disturbed pervious areas where thought to provide significant stormwater management benefits. However, recent research has shown that clearing, grading and other land disturbing activities can significantly reduce the ability of disturbed pervious areas to reduce post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Unless efforts are made to restore them to their pre-development conditions, these disturbed pervious areas provide few of the environmental benefits (e.g., stormwater runoff reduction, wildlife habitat, urban heat island mitigation) that comparable undisturbed pervious areas provide.

Therefore, the amount of clearing and grading that takes place on a development site should be limited. Doing so will help preserve pre-development site hydrology and reduce post-construction stormwater runoff rates, volumes and pollutant loads. Methods that can be used to reduce clearing and grading limits on a development site include:

a) Protecting primary and secondary conservation areas.
b) Preserving smaller undisturbed natural areas, including stands of trees and other vegetation.
c) Using construction equipment and techniques that will help reduce land disturbance.
d) Delineating, on all development plans, the smallest possible area that requires clearing and grading on the development site; all delineated limits of disturbance should reflect the needs of the construction equipment and techniques that will be used on the development site.

4.6.1.3 Stormwater Management Credits

Although reducing clearing and grading can be thought of as a self-crediting stormwater management technique (i.e., it *implicitly* reduces post-construction stormwater runoff rates, volumes and pollutant loads), it is important not to overlook the valuable stormwater management benefits that this better site design technique provides. Therefore, it has been assigned quantifiable stormwater management credits:

a) Stormwater Runoff Reduction: Subtract 50% of any *undisturbed pervious areas* from the total site area when calculating the runoff reduction volume that applies to a development site.
b) Water Quality Protection: Subtract 50% of any *undisturbed pervious areas* from the total site area when calculating the runoff reduction volume that applies to a development site.

In order to be eligible for these credits, undisturbed pervious areas must satisfy the planning and design criteria outlined below.

4.6.1.4 Planning and Design Criteria

Undisturbed pervious areas must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Undisturbed pervious areas should not be disturbed before, during or after construction (except for temporary disturbances associated with incidental utility construction, restoration activities or removal of invasive vegetation).
b) Undisturbed pervious areas should be clearly identified on all development plans. Limits of disturbance around all undisturbed pervious areas should be clearly marked on all development plans and should be delineated with temporary fencing prior to the start of land disturbing activities.

4.6.2 Reduce Roadway Lengths and Widths

4.6.2.1 Description

Reduced roadway lengths and widths should be used to help reduce the creation of new impervious cover on development sites.

4.6.2.2 Discussion

Reduced roadway lengths and widths can be used to help minimize the creation of new impervious cover and reduce post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Consequently, roadway lengths and widths on a development site should be minimized where practical.

Since there is no single site design technique that is guaranteed to minimize street length on a development site, alternative site layouts should be considered to see how much total roadway pavement they require. Generally, compact site designs that make use of smaller lot sizes and reduced setbacks and frontages help reduce overall street lengths on development sites. Site designs that include a large number of small lots located off of a few main roadways, rather than a small number of large lots located off of a complex network of local roads are encouraged.

In addition to minimizing street length on development sites, street widths should be reduced to the minimum needed to support travel, on-street parking and emergency, maintenance and service vehicle access.

If roadway lengths and widths cannot be minimized on a development site, grass channels or swales should be used to receive roadway runoff. In addition, the use of alternative paving surfaces, such as pervious concrete and permeable pavers, for roadway construction should be considered.

4.6.2.3 Stormwater Management Credits

Reducing roadway lengths and widths on a development site can be thought of as a self-crediting stormwater management technique. Therefore, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

a) Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower volumetric runoff and, consequently, a lower runoff reduction volume on a development site.
b) Water Quality Protection: Self-crediting, in that minimizing the creation of new impervious cover results in lower volumetric runoff and, consequently, a lower runoff reduction volume on a development site.

4.6.3 Use Fewer or Alternative Cul-de-Sacs

4.6.3.1 Description

Fewer or alternative cul-de-sacs should be used to help minimize the amount of new impervious cover created on development sites. The dimensions of cul-de-sacs and alternative turnarounds should be reduced to the minimum needed to accommodate emergency, maintenance and service vehicles.

4.6.3.2 Discussion

A cul-de-sac is a type of turnaround commonly used on dead-end streets on residential, commercial and industrial development sites. Many cul-de-sacs have radii of 40 feet or more, which means that they are responsible for a significant amount of the impervious cover found on a development site. Consequently, fewer or alternative cul-de-sacs are encouraged to help minimize the creation of new impervious cover and reduce post-construction stormwater runoff rates, volumes and pollutant loads.

Alternative cul-de-sac designs include cul-de-sacs with landscaping islands, cul-de-sacs with reduced radii, hammerheads and loop roads. Landscaping islands located within cul-de-sacs can be used to receive stormwater runoff generated elsewhere on the development site, and make ideal locations for bioretention areas and other low impact development practices.

Providing sufficient turnaround area is an important factor to consider during the design of cul-de-sacs and dead-end streets. In particular, the types of vehicles, such as fire trucks, service vehicles and school buses that will have to enter the cul-de-sac should be considered. Although these vehicles are thought to have very large turning radii, some newer fire trucks have been designed with relatively small turning radii, and many newer service vehicles have been designed with tri-axles, which allow them to make tighter turns. Although school bus access is a concern, many school bus drivers choose not to enter individual cul-de-sacs and instead choose to stay on the main roadways that pass through residential developments, which altogether alleviate any concerns over school bus access.

4.6.3.3 Stormwater Management Credits

Using fewer or alternative cul-de-sacs on a development site can be thought of as a self-crediting stormwater management technique. Therefore, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

a) Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower volumetric runoff and, consequently, a lower runoff reduction volume on a development site.
b) Water Quality Protection: Self-crediting, in that minimizing the creation of new impervious cover results in lower volumetric runoff and, consequently, a lower runoff reduction volume on a development site.

4.6.4 Reduce Parking Lot Footprints

4.6.4.1 Description

Consider reducing the amount of new impervious cover created on development sites by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, using structured parking facilities and using alternative paving surfaces (e.g., permeable pavement) in parking lots.

4.6.4.2 Discussion

Parking lots are typically responsible for a significant amount of the impervious cover found on commercial and industrial development sites. Consequently, parking lot footprints should be reduced to help minimize the creation of new impervious cover and reduce post-construction stormwater runoff rates, volumes and pollutant loads.

Techniques that can be used to reduce parking lot footprints on development sites include:

- Rethinking parking lot design
- Minimizing parking stall dimensions
- Providing compact car parking spaces
- Using structured parking
- Using shared parking
- Using alternative paving surfaces (e.g., permeable pavement)

Each of these techniques is briefly described below.

a) Rethinking Parking Lot Design

Parking lots are often designed to provide far more parking spaces than are actually needed on a daily basis. This problem is exacerbated by the common practice of designing parking lots to provide enough parking spaces to accommodate the highest parking demand experienced during the peak shopping season. By using average parking demand as a basis for parking lot design, instead of peak parking demand, fewer parking spaces (which will still accommodate the parking demand for almost the entire year) and less impervious cover will be created on development sites.

b) Minimizing Parking Stall Dimensions

Another technique that can be used to reduce parking lot footprints is to minimize the dimensions of parking spaces. This can be accomplished by reducing both the length and width of parking stalls by 6 to 12 inches on a development site. Parking lot footprints can be even further reduced if compact car parking spaces are provided within parking lots.

c) Using Structured Parking

Structured parking decks are another technique that can be used to reduce parking lot footprints on a development site. Although costly, parking decks can be used to replace traditional surface parking lots, which frees up additional land for additional living, shopping or office space.

d) Using Shared Parking

Shared parking is another technique that can be used to reduce parking lot footprints on a development site. A shared parking arrangement might include usage of the same parking lot by an office building that experiences peak parking demand during week days with a church that experiences peak parking demands during weekends and evenings.

e) Using Alternative Paving Surfaces

If parking lot footprints cannot be minimized using any of the techniques described above, the use of alternative paving surfaces, such as pervious concrete and permeable pavers, for parking lot construction should be considered. Permeable pavements can be used to reduce the amount of effective impervious cover found on a development site, since they allow stormwater runoff to pass through the surface course (i.e., pavement surface) into an underlying stone reservoir, where it is temporarily stored and allowed to infiltrate into the surrounding soils or conveyed back into the storm drain system using an underdrain system. Although permeable pavement is generally more expensive to install than conventional pavement (e.g., asphalt, concrete), it can provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads, which can reduce the need for larger and more costly stormwater management practices, such as wet ponds and stormwater wetlands, on a development site.

4.6.4.3 Stormwater Management Credits

Reducing parking lot footprints on a development site can be thought of as a self-crediting stormwater management technique. Therefore, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

a) Stormwater Runoff Reduction : Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.
b) Water Quality Protection: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.

4.6.5 Create Landscaping Areas in Parking Lots

4.6.5.1 Description

Consider reducing the amount of new impervious cover created on development sites by distributing landscaping areas, such as landscaping islands and buffer strips, throughout parking lots. In many cases, these landscaping areas can be designed to function as low impact development practices, such as vegetated filter strips and bioretention areas, that can be used to receive stormwater runoff from other parts of the development site.

4.6.5.2 Discussion

Parking lots with numerous landscaping areas, such as islands and buffer strips are encouraged to help reduce the amount of new impervious cover created on development sites. In many cases, these landscaping areas can be designed to function as low impact development practices, such as vegetated filter strips, bioretention areas and dry swales, that can be used to receive stormwater runoff from other parts of the development site. Whenever practical, landscaping islands and buffer strips should be planted with shade trees and shrubs.

During the site planning and design process, it is important to keep in mind that a small number of large landscaping areas will sustain healthier vegetation than a large number of very small ones. One of the most effective ways to design landscaping areas that will support healthy plant communities is to use landscaping areas that are at least 6 feet wide and are filled with relatively porous soils that contain enough organic matter and nutrients to support plant growth.

4.6.5.3 Stormwater Management Credits

Creating landscaping areas in parking lots can be thought of as a self-crediting stormwater management technique. Consequently, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

a) Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.
b) Water Quality Protection: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.

4.6.6 Reduce Driveway Lengths and Widths

4.6.6.1 Description

Reduced driveway lengths and widths should be used to help reduce the creation of new impervious cover on development sites.

4.6.6.2 Discussion

Given that as much as 20% of the impervious cover found in a typical residential subdivision consists of sidewalks and driveways, driveway lengths and widths should be minimized. Methods that can be used to reduce driveway lengths and widths include:

a) Evaluating alternative site layouts to see how much total driveway pavement they will require
b) Reducing setbacks and frontages
c) Using shared driveways
d) Using narrower driveway widths

If driveway lengths and widths cannot be minimized using the methods described above, alternative or permeable surfaces, such as crushed rock, crushed shells or permeable pavement should be considered for driveway construction.

4.6.6.3 Stormwater Management Credits

Reducing driveway lengths and widths on a development site can be thought of as a self-crediting stormwater management technique. Consequently, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

a) Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.
b) Water Quality Protection: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.

4.6.7 Reduce Sidewalk Lengths and Widths

4.6.7.1 Description

Reduced sidewalk lengths and widths should be used to help reduce the creation of new impervious cover on development sites.

4.6.7.2 Discussion

Given that as much as 20% of the impervious cover found in a typical residential subdivision consists of sidewalks and driveways, sidewalk lengths and widths should be minimized. Methods that can be used to reduce sidewalk lengths and widths include:

a) Evaluating alternative site layouts to see how much total sidewalk pavement they will require
b) Reducing setbacks and frontages
c) Locating sidewalks on only one side of the street
d) Using sidewalk widths of six feet in areas that will see high foot traffic and sidewalk widths of four feet in areas that will see less use

If sidewalk lengths and widths cannot be minimized using the methods described above, alternative or permeable surfaces, such as crushed rock, crushed shells or permeable pavement should be considered for sidewalk construction.

4.6.7.3 Stormwater Management Credits

Reducing sidewalks lengths and widths on a development site can be thought of as a self-crediting stormwater management technique. Therefore, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

a) Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.
b) Water Quality Protection: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.

4.6.8 Reduce Building Footprints

4.6.8.1 Description

Consider using taller building designs to reduce the amount of impervious cover created by commercial buildings, multi-family residential buildings (e.g., apartment buildings) and other structures on development sites.

4.6.8.2 Discussion

The amount of new impervious cover created on development sites can be reduced by designing taller commercial and multi-family residential buildings (e.g., apartment buildings) that have the same amount of livable space as shorter building designs consolidating multiple buildings to create single structures that have smaller impervious footprints should be considered.

4.6.8.3 Stormwater Management Credits

Reducing building footprints on a development site can be thought of as a self-crediting stormwater management technique. Therefore, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

a) Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volumes and, consequently, a lower runoff reduction volume on a development site.
b) Water Quality Protection: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volumes and, consequently, a lower runoff reduction volume on a development site.

4.6.9 Reduce Setbacks and Frontages

4.6.9.1 Description

Consider using smaller setbacks and narrower frontages in order to reduce roadway, driveway and sidewalk lengths and help minimize the creation of new impervious cover on development sites.

4.6.9.2 Discussion

Smaller building setbacks and narrower frontages can be used to reduce roadway, driveway and entry sidewalk lengths and help minimize the creation of new impervious cover on development sites. A smaller front yard setback of 20 feet (which is more than sufficient to allow a car to park in a driveway without encroaching into the public right-of-way) can be used to reduce the required length of driveways and entry sidewalks by more than 30 percent on development sites.

Smaller side yard setbacks and narrower frontages can also help minimize the creation of new impervious cover on development sites. Both of these techniques can be used help create more compact site designs that require smaller amounts of roadway, driveway and sidewalk pavement.

Smaller setbacks and narrower frontages also allow for flexible lot shapes and create conservation developments, which provide for environmental benefits that are typically more difficult to achieve on more conventional development projects. Conservation developments, also known as open space developments or cluster developments, provide for better natural resource protection on development sites and inherently limit increases in site imperviousness, sometimes by as much as 40 to 60 percent.

4.6.9.3 Stormwater Management Credits

Reducing setbacks and frontages on a development site can be thought of as a self-crediting stormwater management technique. Therefore, it has not been assigned any additional stormwater management credits beyond the implicit credits outlined below:

- Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.
- Stormwater Runoff Reduction: Self-crediting, in that minimizing the creation of new impervious cover results in lower runoff volume and, consequently, a lower runoff reduction volume on a development site.

4.7 Low Impact Development Practice Profiles

This section contains information about the low impact development practices that are recommended for use in Jasper County.

4.7.1 Soil Restoration

4.7.1.1 Description

Soil restoration refers to the process of tilling and adding compost and other amendments to soils to restore them to their pre-development conditions, which improves their ability to reduce post-construction stormwater runoff rates, volumes and pollutant loads. The soil restoration process can be used to improve the hydrologic conditions of pervious areas that have been disturbed by clearing, grading and other land disturbing activities. It can also be used to increase the reduction in stormwater runoff rates, volumes and pollutant loads provided by other low impact development practices.

Figure 4-1
Soil Restoration
Source: Iowa Stormwater Management Manual

4.7.1.2 Discussion

Soil restoration is ideal for use on lawns and other pervious areas that have been disturbed by clearing, grading and other land disturbing activities. Organic compost and other amendments can be tilled into soils in these areas to help create healthier, uncompacted soil matrices that have enough organic matter to support a diverse community of native trees, shrubs and other herbaceous plants.

Soil restoration can also be used to increase the stormwater management benefits provided by other low impact development practices, such as site reforestation/revegetation, vegetated filter strips, grass channels and simple downspout disconnection, on sites that have soils with low permeabilities (i.e., hydrologic soil group C or D soils). The soil restoration process can be used to help increase soil porosity and improve soil infiltration rates on these sites, which improves the ability of these and other low impact development practices to reduce post-construction stormwater runoff rates, volumes and pollutant loads.

4.7.1.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 50% of any restored pervious areas from the total site area and re-calculate the runoff reduction volume that applies to the development site.
b) Water Quality Protection: Subtract 50% of any restored pervious areas from the total site area and re-calculate the runoff reduction volume that applies to the development site.

In order to be eligible for these credits, restored pervious areas must satisfy the planning and design criteria outlined below.

If any type of vegetation other than managed turf can be planted on a restored pervious area, the combination of soil restoration with site reforestation/revegetation is encouraged to further reduce post-construction stormwater runoff rates, volumes and pollutant loads. When soil restoration is used to enhance the performance of other low impact development practices (e.g., site reforestation/revegetation, vegetated filter strips, grass channels), it may be credited as described in the appropriate low impact development practice.

4.7.1.4 Planning and Design Criteria

The soil restoration process used on a development site shall meet all of the following criteria to be eligible for the stormwater management credits described above:

a) To avoid damaging existing root systems, soil restoration should not be performed in areas that fall within the drip line of existing trees.
b) Compost should be incorporated into existing soils, using a rototiller or similar equipment, to a depth of 18 inches and at an application rate necessary to obtain a final average organic matter content of 8%-12%. Required application rates should be determined.
c) Only well-aged composts that have been composted for a period of at least one year should be used to amend existing soils. Composts should be stable and show no signs of further decomposition.
d) Composts used to amend existing soils should meet the following specifications (most compost suppliers will be able to provide this information):

  i. Organic Content Matter: Composts should contain 35%-65% organic matter.
  ii. Moisture Content: Composts should have a moisture content of 40%-60%.
  iii. Bulk Density: Composts should have an "as-is" bulk density of 40-50 pounds per cubic foot (lb/cf). In composts that have a moisture content of 40%-60%, this equates to a bulk density range of 450-800 pounds per cubic yard (lb/cy), by dry weight.
  iv. Carbon to Nitrogen (C:N) Ratio: Composts should have a C:N Ratio of less than 25:1.
  v. pH: Composts should have a pH of 6-8.
  vi. Cation Exchange Capacity (CEC): Composts should have a CEC that exceeds 50 milliequivalents (meq) per 100 grams of dry weight.
  vii. Foreign Material Content: Composts should contain less than 0.5% foreign materials (e.g., glass, plastic), by weight.
  viii. Pesticide Content: Composts should be pesticide free.

e) The use of biosolids and composted animal manure to amend existing soils is not allowed.
f) Composts used to amend existing soils shall be provided by a member of the U.S. Composting Seal of Testing Assurance program.
g) Vegetation commonly planted on restored pervious areas includes turf, shrubs, trees and other herbaceous vegetation. Although managed turf is most commonly used, the use of trees, shrubs and/or other native vegetation to help establish mature native plant communities (e.g., forests) in restored pervious areas is encourages.
h) Methods used to establish vegetative cover within a restored pervious area should achieve at least 75 percent vegetative cover one year after installation.
i) To help prevent soil erosion and sediment loss, landscaping should be installed immediately after the soil restoration process is complete. Temporary irrigation may be needed to quickly establish vegetative cover on a restored pervious area.

4.7.1.5 Construction Considerations

To help ensure that the soil restoration process is successfully completed on a development site, the following are recommended:

a) To help minimize compaction, heavy vehicular and foot traffic should be kept out of all restored pervious areas during and after construction. This can typically be accomplished by clearly delineating soil restoration areas on all development plans and, if necessary, protecting them with temporary construction fencing.
b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used on restored pervious areas that exceed 2,500 square feet in size. If the restored pervious areas will receive any stormwater runoff from other portions of the development site, measures should be taken (e.g., silt fence, temporary diversion berm) to prevent it from compromising the soil restoration effort.
c) Test pits or a rod penetrometer can be used to verify that soil amendments have reached a depth of 18 inches.
d) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted on a restored pervious area.

4.7.2 Site Reforestation/Revegetation

4.7.2.1 Description

Site reforestation/revegetation refers to the process of planting trees, shrubs and other native vegetation in disturbed pervious areas to restore them to their pre-development conditions. The process can be used to help establish mature native plant communities in pervious areas that have been disturbed by clearing, grading and other land disturbing activities, which improves their ability to reduce post-construction stormwater runoff rates, volumes and pollutant loads.

4.7.2.2 Discussion

Mature plant communities intercept rainfall, increase evaporation and transpiration rates, slow and filter stormwater runoff and help improve soil porosity and infiltration rates, which leads to reduced post-construction stormwater runoff rates, volumes and pollutant loads.

Areas that have been reforested or revegetated should be maintained in an undisturbed, natural state over time. These areas should be designated as secondary conservation areas and protected in perpetuity through a legally enforceable conservation instrument (e.g., conservation easement, deed restriction). If properly maintained over time, these areas can help improve aesthetics on development sites, provide passive recreational opportunities and create valuable habitat for high priority plant and animal species.

To help create contiguous, interconnected green infrastructure corridors on development sites, reforested or revegetated areas should be connected with one another and with other primary and secondary conservation areas.

4.7.2.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: Subtract 50% of any *reforested/revegetated areas* from the total site area and re-calculate the runoff reduction volume that applies to the development site.
b) Water Quality Protection: Subtract 50% of any *reforested/revegetated areas* from the total site area and re-calculate the runoff reduction volume that applies to the development site.

Reforested/revegetated areas can only be assumed to be in fair hydrologic condition (as used in common curve number calculations) due to the fact that it will take many years for them to mature and provide full stormwater management benefits.

If site reforestation/revegetation can be combined with soil restoration on a development site, the following stormwater management credits can be used to help satisfy Jasper County's stormwater management requirements:

c) Stormwater Runoff Reduction: Subtract 100% of any restored and reforested/ revegetated areas from the total site area and re-calculate the runoff reduction volume that applies to the development site.
d) Water Quality Protection: Subtract 100% of any restored and reforested/revegetated areas from the total site area and re-calculate the runoff reduction volume that applies to the development site.

In order to be eligible for these credits, reforested/revegetated areas must satisfy the planning and design criteria outlined below.

4.7.2.4 Planning and Design Criteria

The reforestation/revegetation process used on a development site must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Reforested/revegetated areas should have a contiguous area of 10,000 square feet or more.
b) Reforested/revegetated areas should not be disturbed after construction (except for disturbances associated with landscaping or removal of invasive vegetation).
c) Reforested/revegetated areas should be protected, in perpetuity, from the direct impacts of the land development process by a legally enforceable conservation instrument (e.g., conservation easement, deed restriction).
d) A landscaping plan should be prepared for all reforested/revegetated areas. The landscaping plan should be reviewed and approved by the Administrator prior to construction.
e) Landscaping commonly used in site reforestation/revegetation efforts includes native trees, shrubs and other herbaceous vegetation. Because the goal of the site reforestation/revegetation process is to establish a mature native plant community (e.g., forest), managed turf cannot be used to landscape reforested/revegetated areas.
f) Methods used for site reforestation/revegetation should achieve at least 75 percent vegetative cover one year after installation.

4.7.2.5 Construction Considerations

To help ensure that the site reforestation/revegetation process is successfully completed on a development site, the following are recommended:

a) Document the condition of the reforested/revegetated area before, during and after the completion of the site reforestation/revegetation process.
b) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of all reforested/revegetated areas before, during and after construction. This can typically be accomplished by clearly delineating reforested/revegetated areas on all development plans and, if necessary, protecting them with temporary construction fencing.
c) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used on reforested/revegetated areas that exceed 2,500 square feet in size. If the reforested/revegetated areas will receive any stormwater runoff from other portions of the development site, measures should be taken (e.g., silt fence, temporary diversion berm) to prevent it from compromising the reforestation/revegetation effort.
d) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted on the reforested/revegetated area.

4.7.3 Green Roofs

4.7.3.1 Description

Green roofs represent an alternative to traditional impervious roof surfaces. They typically consist of underlying waterproofing and drainage materials and an overlying engineered growing media that is designed to support plant growth. Stormwater runoff is captured and temporarily stored in the engineered growing media, where it is subjected to the hydrologic processes of evaporation and transpiration before being conveyed back into the storm drain system. This allows green roofs to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites.


Figure 4-2
Green Roof
Source: Florida Department of Environmental Protection

4.7.3.2 Discussion

There are two different types of green roof systems: intensive green roof systems and extensive green roof systems. Intensive green roof systems (also known as *rooftop gardens*) have a thick layer of engineered growing media (i.e., 12 to 24 inches) that supports a diverse plant community that may even include trees. Extensive green roof systems typically have a much thinner layer of engineered growing media (i.e., 2 to 6 inches) that supports a plant community that is comprised primarily of drought tolerant vegetation (e.g., sedums, succulent plants).

Extensive green roof systems, which can cost up to twice as much as traditional impervious roof surfaces, are much lighter and are less expensive than intensive green roof systems. Therefore, it is recommended that the use of extensive green roof systems be considered prior to the use of intensive green roof systems in Jasper County.

Extensive green roof systems typically contain multiple layers of roofing materials, and are designed to support plant growth while preventing stormwater runoff from ponding on the roof surface. Green roof systems are designed to drain stormwater runoff vertically through the engineered growing media and then horizontally through a drainage layer towards an outlet. They are designed to require minimal long-term maintenance and, if the right plants are selected to populate the green roof, should not need supplemental irrigation or fertilization after an initial vegetation establishment period.

When designing a green roof, not only should stormwater storage capacity of the green roof be considered, but also the structural capacity of the rooftop itself. To support a green roof, a rooftop might be designed to support an additional 15 to 30 pounds per square foot (psf) of load. Consequently, a structural engineer should be involved with the design of a green roof to ensure that the rooftop itself has enough structural capacity sufficient to support the green roof system.

4.7.3.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Reduce the runoff reduction volume conveyed through a *green roof* by 60%.
b) Water Quality Protection: Reduce the runoff reduction volume conveyed through a *green roof* by 60%.

In order to be eligible for these credits, green roofs must satisfy the planning and design criteria outlined below.

4.7.3.4 Planning and Design Criteria

Green roofs must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) All green roofs should be designed in accordance with the ASTM International Green Roof Standards (ASTM, 2005a, ASTM, 2005b, ASTM, 2005c, ASTM, 2005d, ASTM, 2006).
b) Green roofs should only be used to replace traditional impervious roof surfaces. They should not be used to receive any stormwater runoff generated elsewhere on the development site.
c) Although green roofs may be installed on rooftops with slopes of up to 25%, it can be difficult to install them on rooftops with slopes of greater than 10%. Supplemental measures, such as battens, may be needed to ensure stability against sliding on rooftops with slopes of greater than 10%.
d) Green roof systems should be designed to provide enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event.
e) During the design of a green roof system, site planning and design teams should consider not only the storage capacity of the green roof, but also the structural capacity of the rooftop itself. A structural engineer should be involved with the design of a green roof to ensure that the rooftop itself has enough structural capacity to support the green roof system.
f) All green roof systems should include a waterproofing layer that will prevent stormwater runoff from damaging the underlying rooftop.
g) The waterproofing layer should be protected from root penetration by an impermeable, physical root barrier. Chemical root barriers or physical root barriers that have been impregnated with pesticides, metals or other chemicals that may leach into post-construction stormwater runoff should not be used.
h) A drainage layer should be placed between the root barrier and the engineered growing media. The drainage layer should consist of synthetic or inorganic materials (e.g., gravel, recycled polyethylene) that are capable of both retaining water and providing efficient drainage when the layer becomes saturated. The required depth of the drainage layer will be governed by the required storage capacity of the green roof system and by the structural capacity of the rooftop itself.
i) An outlet (e.g., scupper and downspout) should be provided to convey stormwater runoff out of the drainage layer and off of the rooftop when the drainage layer becomes saturated.
j) An appropriate engineered growing media, consisting of approximately 80% lightweight inorganic materials, 15% organic matter (e.g., well-aged compost) and 5% sand, should be installed above the drainage layer. The engineered growing media should have a maximum water retention capacity of approximately 30%.
k) To prevent clogging within the drainage layer, the engineered growing media should be separated from the drainage layer by a layer of permeable filter fabric. The filter fabric should be a non-woven geotextile with a permeability that is greater than or equal to the hydraulic conductivity of the overlying engineered growing media.

l) The engineered growing media should be between 4 and 6 inches deep, unless synthetic moisture retention materials (e.g., drainage mat with moisture storage "cups") are placed directly beneath the engineered growing media layer. When synthetic moisture retention materials are used, a 2 inch deep engineered growing media layer may be used.

m) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to help ensure that these larger storm events are able to safely bypass the green roof system. An overflow system, such as a traditional rooftop drainage system with inlets set slightly above the elevation of the surface of the green roof, should be designed to convey the stormwater runoff generated by these larger storm events safely off of the rooftop.

n) A landscaping plan should be prepared for all green roofs. The landscaping plan shall be reviewed and approved by the DSR prior to construction.

o) When developing a landscaping plan, consultation with a botanist, landscape architect or other qualified professional to identify tolerant plants is recommended. Planting recommendations for green roofs include:
   i. Drought- and full sun-tolerant vegetation that requires minimal irrigation after establishment.
   ii. Low maintenance vegetation that is self-sustaining and does not require mowing, trimming or the use of fertilizers, pesticides or herbicides.
   iii. Vegetation that is fire resistant and able to withstand heat, cold and high winds.

p) Since sedum and succulent plants possess many of the characteristics listed above, they are recommended for use on green roof systems installed in Jasper County. Herbs, forbs, grasses and other groundcovers may also be used, but these plants typically have higher watering and maintenance requirements.

q) Methods used to establish vegetative cover on a green roof should achieve at least 75 percent vegetative cover one year after installation.

4.7.3.5 Construction Considerations

To help ensure that green roofs are properly installed on a development site, the following are recommended:

a) To help prevent compaction of the engineered growing media, heavy foot traffic should be kept off of green roof surfaces during and after construction.

b) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted on a green roof.

4.7.4 Permeable Pavements

4.7.4.1 Description

Permeable pavements represent an alternative to traditional impervious paving surfaces. They typically consist of an underlying drainage layer and an overlying permeable surface layer. A permeable pavement system allows stormwater runoff to pass through the surface course (i.e., pavement surface) into an underlying stone reservoir, where it is temporarily stored and allowed to infiltrate into the surrounding soils or conveyed back into the storm drain system

Figure 4-3
Permeable Pavement
Source: David Jirousek

through an underdrain. This allows permeable pavement systems to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads.

4.7.4.2 Discussion

There are a variety of permeable pavement surfaces available in the commercial marketplace, including pervious concrete, porous asphalt, permeable interlocking concrete pavers, concrete grid pavers and plastic grid pavers. Each of these permeable pavement surfaces is briefly described below:

a) Pervious Concrete: Pervious concrete (also known as *porous concrete*) is similar to conventional concrete in structure and form, but consists of a special open-graded surface course, typically 4 to 8 inches thick, that is bound together with portland cement. This open-graded surface course has a void ratio of 15% to 25% (conventional concrete pavement has a void ratio of between 3% and 5%), which gives it a high permeability that is often many times more than that of the underlying native soils, and allows rainwater and stormwater runoff to rapidly pass through it and into the underlying stone reservoir. Although this particular type permeable pavement surface may not require an underlying base layer to support traffic loads, site planning and design teams may wish to provide it to increase the stormwater storage capacity provided by a pervious concrete system.
b) Porous Asphalt: Porous asphalt is similar to pervious concrete, and consists of a special open-graded surface course bound together by asphalt cement. The open-graded surface course in a typical porous asphalt installation is 3 to 7 inches thick and has a void ratio of between 15% and 20%. Porous asphalt is thought to have a limited ability to maintain its structure and permeability during hot summer months and, consequently, is currently *not recommended* for use in Jasper County.
c) Permeable Interlocking Concrete Pavers: Permeable interlocking concrete pavers (PICP) are solid structural units (e.g., blocks, bricks) that are installed in a way that provides regularly spaced openings through which stormwater runoff can rapidly pass through the pavement surface and into the underlying stone reservoir. The regularly spaced openings, which generally make up between 8% and 20% of the total pavement surface, are typically filled with pea gravel (i.e., ASTM D 448 Size No. 8, 3/8" to 1/8"). Typical PICP systems consist of the pavers, a 1.5 to 3 inch thick fine gravel bedding layer and an underlying stone reservoir.
d) Concrete Grid Pavers: Concrete grid pavers (CGP) are precast concrete units that allow rainfall and stormwater runoff to pass through large openings that are filled with gravel, sand or topsoil and turf. CGP are typically 3.5 inches thick and have a void ratio of between 20% and 50%, which means that the material used to fill the spaces between the grids has a large influence on the overall permeability (i.e., void space) of a CGP system. A typical CGP installation consists of the pavers, a 1 to 1.5 inch sand or pea gravel bedding layer and an underlying stone reservoir.
e) Plastic Grid Pavers: Plastic grid pavers (PGP) are similar to CGP. They consist of flexible, interlocking plastic units that allow rainfall and stormwater runoff to pass through large openings that are filled with gravel, sand or topsoil and turf. Since the empty plastic grids have a void ratio of between 90% and 98%, the material used to fill the spaces between the grids has a large influence on the overall permeability (i.e., void space) a PGP system.

When designing a permeable pavement system, not only must the storage capacity of the system be considered, but also the structural capacity of the underlying soils and the underlying stone reservoir. The infiltration rate and structural capacity of the native soils found on a development site directly influence the size of the stone reservoir that is needed to provide structural support for a permeable pavement system and measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads. Permeable pavement systems should be designed to accommodate the stormwater runoff volume generated by the runoff reduction rainfall event. If this cannot be accomplished, due to site characteristics or constraints, permeable pavement systems should be used in combination with other runoff reducing low impact development practices.

4.7.4.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help satisfy Jasper County's stormwater management criteria:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by a non-underdrained permeable pavement system from the runoff reduction volume conveyed through the system. Subtract 50% of the storage volume provided by an underdrained permeable pavement system from the runoff reduction volume conveyed through the system.
b) Water Quality Protection: Subtract 100% of the storage volume provided by a non-underdrained permeable pavement system from the runoff reduction volume conveyed through the system. Subtract 50% of the storage volume provided by an underdrained permeable pavement system from the runoff reduction volume conveyed through the system.

In order to be eligible for these credits, permeable pavement systems must satisfy the planning and design criteria outlined below.

4.7.4.4 Planning and Design Criteria

Permeable pavement systems must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Permeable pavement system should only be used to replace traditional impervious paving surfaces. They should not be used to receive any stormwater runoff generated elsewhere on the development site.
b) Although permeable pavement systems may be installed on development sites with slopes of up to 6%, they should be designed with slopes that are as close to flat as possible to help ensure that stormwater runoff is evenly distributed throughout the stone reservoir.
c) Permeable pavement system can be designed without an underdrain on development sites that have underlying soils with an infiltration rate of 0.25 inches per hour (in/hr) or greater, as determined by NRCS soil survey data and subsequent field testing. Field infiltration tests shall be used to confirm infiltration rates and shall be approved by the DSR prior to use.
d) At least one infiltration test for every 5,000 square feet of permeable pavement that will be sued on the development site shall be conducted. If the infiltration rate of the underlying soils on the development site is not 0.25 inches per hour (in/hr) or greater, an underdrain should be included in the permeable pavement system design.
e) Since clay lenses or any other restrictive layers located below the bottom of a permeable pavement system will reduce soil infiltration rates, infiltration testing should be conducted within any confining layers that are found within 4 feet of the bottom of a proposed permeable pavement system.
f) Permeable pavement systems should be designed to provide enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event.

g) Permeable pavement systems should be designed to completely drain within 48 hours of the end of a rainfall event. Where site characteristics allow, it is preferable to design permeable pavement systems to drain within 24 hours of the end of a rainfall event to help prevent the formation of nuisance ponding conditions.

h) An appropriate permeable pavement surface should be selected for the intended application. The permeable pavement surface should be able to support the maximum projected traffic load.

i) Most permeable pavement surfaces need to be supported by an underlying stone reservoir (also known as a *gravel base* or *aggregate base*). The depth of the stone reservoir typically ranges between 1 and 4 feet, but should be determined by considering both the required stormwater storage capacity and the maximum projected traffic load that will be experienced by the permeable pavement system. On most development sites, the maximum projected traffic load will determine the depth of the underlying stone reservoir.

j) The stone reservoir should be filled with clean, washed stone. The stone used in the stone reservoir should be 1.5 to 2.5 inches in diameter, with a void space of approximately 40%. Unwashed aggregate contaminated with soil or other fines may not be used in the stone reservoir.

k) If no underdrain is required, underlying native soils should be separated from the stone reservoir by a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16"). The choker stone should be placed between the stone reservoir and the underlying native soils.

l) If an underdrain is required, it should be placed beneath the stone reservoir. The underdrain should consist of a 4 to 6 inch perforated PVC (AASHTO M 252) pipe bedded in an 8 inch layer of clean, washed stone. The pipe should have 3/8 inch perforations, spaced 6 inches on center, and should have a minimum slope of 0.5%. The clean, washed stone should be ASTM D448 size No. 57 stone (i.e., 1-1/2 to 1/2 inches in size) and should be separated from the stone reservoir by a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16").

m) The sides of the stone reservoir should be lined with a layer of appropriate permeable filter fabric. The filter fabric should be a non-woven geotextile with a permeability that is greater than or equal to the infiltration rate of the surrounding native soils.

n) The depth from the bottom of a permeable pavement system to the top of the water table should be at least 2 feet to prevent nuisance ponding and ensure proper operation of the permeable pavement system.

o) A concrete header curb at least 12" in width by 15" in depth shall be used to separate permeable pavements and asphalt pavements to prevent washout of asphalt or concrete roadway base course material.

p) To prevent damage to building foundations and contamination of groundwater aquifers permeable pavement systems, should be located at least:
   i. 10 feet from building foundations
   ii. 10 feet from property lines
   iii. 100 feet from private water supply wells
   iv. 1,200 feet from public water supply wells
   v. 100 feet from septic systems
   vi. 100 feet from surface waters
   vii. 400 feet from public water supply surface waters

q) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to help ensure that these larger storm events are able to safely bypass the permeable pavement system. An overflow system should be designed to convey the stormwater runoff generated by these larger storm events safely off of the pavement surface. Methods that can be used to accommodate the stormwater runoff rates and volumes generated by these larger storm events include:

i. Allowing excess stormwater runoff to be safely conveyed off of the permeable pavement surface via sheet flow.
ii. Using storm drain inlets set slightly above the elevation of the permeable pavement surface to collect excess stormwater runoff. This will create some ponding on the surface of the permeable pavement system, but can be used to safely convey excess stormwater runoff off of the permeable pavement surface.
iii. Placing a perforated pipe (e.g., underdrain) near the top of the stone reservoir to provide additional conveyance of stormwater runoff after the stone reservoir has been filled.
iv. Placing an underground detention system beneath or adjacent to the permeable pavement system.

4.7.4.5 Construction Considerations

To help ensure that permeable pavement systems are successfully installed on a development site, the following are recommended:

a) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of permeable pavement areas before, during and immediately after construction. This can typically be accomplished by clearly delineating permeable pavement areas on all development plans and, if necessary, protecting them with temporary construction fencing.
b) Excavation for permeable pavement systems should be limited to the width and depth specified in the development plans. Excavated material should be placed away from the excavation so as not to jeopardize the stability of the side walls.
c) The native soils along the bottom of the permeable pavement system should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of the choker stone, underdrain and stone reservoir.
d) The sides of all excavations should be trimmed of all large roots that will hamper the installation of the permeable filter fabric used to line the sides of the stone reservoir.

4.7.5 Undisturbed Pervious Areas

4.7.5.1 Description

Undisturbed pervious areas, including primary and secondary conservation areas, can be used to receive the post-construction stormwater runoff generated elsewhere on a development site. If stormwater runoff can be evenly distributed over them as overland sheet flow, undisturbed pervious areas can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Therefore, they can be used to receive stormwater runoff on a development site and help satisfy Jasper County's stormwater management regulations.

4.7.5.2 Discussion

The native vegetation found in these undisturbed pervious areas increases evaporation and transpiration rates, slows and filters stormwater runoff and helps improve soil porosity and soil infiltration rates. If concentrated stormwater runoff is allowed to enter an undisturbed pervious area, it can cause soil erosion and can significantly reduce the stormwater management benefits that the undisturbed pervious area provides. Therefore, stormwater runoff needs to be intercepted and distributed evenly, as overland sheet flow, across an undisturbed pervious area that will be used to receive post-construction stormwater runoff. This can be accomplished by limiting the length of the flow path within the contributing drainage area and by using a level spreader at the upstream end of the undisturbed pervious area that will receive post-construction stormwater runoff.

Since the undisturbed pervious areas that are used to receive stormwater runoff on a development site are typically designed to be in-line stormwater management practices, consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to help ensure that they do not cause significant damage within the undisturbed pervious areas.

4.7.5.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Reduce the runoff reduction volume conveyed through an undisturbed pervious area located on A/B soils by 90%. Reduce the runoff reduction volume conveyed through an undisturbed pervious area located on C/D soils by 60%.
b) Water Quality Protection: Reduce the runoff reduction volume conveyed through an undisturbed pervious area located on A/B soils by 90%. Reduce the runoff reduction volume conveyed through an undisturbed pervious area located on C/D soils by 60%.

In order to receive stormwater runoff and be eligible for these credits, undisturbed pervious areas used to receive post-construction stormwater runoff must satisfy the planning and design criteria outlined below.

4.7.5.4 Planning and Design Criteria

Undisturbed pervious areas used to receive stormwater runoff on a development site shall meet all of the following criteria to be eligible for the stormwater management credits described above:

a) The following primary and secondary conservation areas should not be used to receive post-construction stormwater runoff on a development site:
    i. Rivers
    ii. Perennial and Intermittent Streams
    iii. Freshwater Wetlands
    iv. Tidal Rivers and Streams
    v. Tidal Creeks
    vi. Coastal Marshlands
    vii. Tidal Flats
    viii. Scrub-Shrub Wetlands
    ix. Near Coastal Waters
    x. Beaches
    xi. Shellfishing Areas
    xii. Erodible Soils
    xiii. Steep Slopes (i.e., Areas with Slopes Greater Than 15%)
b) Although the primary and secondary conservation areas listed above cannot be used to receive post-construction stormwater runoff on a development site, other undisturbed pervious areas, including aquatic buffers, floodplains, stands of trees and other existing

vegetation, and areas preserved through the use of reduced clearing and grading, may be used to help reduce post-construction stormwater runoff rates, volumes and pollutant loads.

c) The length of the flow path within the contributing drainage area should be 150 feet or less for pervious drainage areas and 75 feet or less for impervious drainage areas.
d) The average slope of the contributing drainage area should be 3% or less, unless terracing or level spreaders are used at 20 foot intervals along the length of the flow path to slow and redistribute stormwater runoff as overland sheet flow.
e) Stormwater runoff shall be conveyed into undisturbed pervious areas as overland sheet flow. A level spreader should be used at the upstream end of the undisturbed pervious area to ensure that stormwater runoff enters it as overland sheet flow.
f) A pea gravel diaphragm makes an effective level spreader at the upstream end of undisturbed pervious areas used to receive stormwater runoff. A pea gravel diaphragm, which is a small trench filled with pea gravel (i.e., ASTM D 448 Size No. 8, 3/8” to 1/8”), intercepts stormwater runoff and distributes it evenly, as overland sheet flow, across an undisturbed pervious area. Other types of level spreaders that can be used to redistribute stormwater runoff at the upstream end of undisturbed pervious areas include concrete sills, curb stops and curbs with sawteeth cut into them.
g) The length of the flow path within the undisturbed pervious area used to receive post-construction stormwater runoff should be 50 feet or more.
h) The average slope of the undisturbed pervious area used to receive post-construction stormwater runoff should be 6% or less. Greater slopes would encourage the formation of concentrated flow, which would cause soil erosion and significantly reduce the stormwater management benefits that undisturbed pervious areas provide.
i) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to help ensure that these larger storm events do not cause significant damage to the undisturbed pervious areas. If necessary, a bypass channel or overflow spillway may be used to manage the stormwater runoff generated by these larger storm events.
j) Undisturbed pervious areas used to receive stormwater runoff should not be disturbed before, during or after construction (except for temporary disturbances associated with incidental utility construction, restoration activities, or removal of invasive vegetation).

4.7.5.4 Construction Considerations

To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of all undisturbed pervious areas used to receive post-construction stormwater runoff before, during and after construction. This can typically be accomplished by clearly delineating receiving undisturbed pervious areas on all development plans and protecting them with temporary fencing prior to the start of land disturbing activities.

4.7.6 Vegetated Filter Strips

4.7.6.1 Description

Vegetated filter strips (also known as filter strips, vegetated filters or grass filters) are uniformly graded, densely vegetated areas of land designed to slow and filter stormwater runoff. They are typically installed in areas that have been disturbed by clearing, grading and other land disturbing activities and are typically vegetated with managed turf. If stormwater runoff can be evenly distributed over them as overland sheet flow, they can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites, particularly when they are located on areas with permeable soils (i.e., hydrologic soil group A and B soils). Therefore, vegetated filter strips can be used to help satisfy Jasper County's stormwater management requirements.

4.7.6.2 Discussion

Vegetated filter strips can be attractively integrated into development sites as landscaping features and are well suited to receive stormwater runoff from local streets and roadways, highways, roof downspouts, small parking lots and disturbed pervious surfaces (e.g., lawns, parks, community open spaces). They are particularly well suited for use in aquatic buffers, in the landscaped areas commonly found between adjoining properties (e.g., setbacks) and incompatible land uses (e.g., residential and commercial land uses) and around the perimeter of parking lots. They can also be used to pretreat stormwater runoff before it enters other low impact development practices, such as undisturbed pervious areas, bioretention areas and infiltration practices, which increases the reductions in stormwater runoff rates, volumes and pollutant loads that these other low impact development practices provide.

If concentrated stormwater runoff is allowed to enter a vegetated filter strip, it can cause soil erosion and can significantly reduce the stormwater management benefits that the filter strip provides. Consequently, stormwater runoff needs to be intercepted and distributed evenly, as overland sheet flow, across a vegetated filter strip. This can be accomplished by limiting the length of the flow path within the contributing drainage area and by using a level spreader at the upstream end of the vegetated filter strip that will receive post-construction stormwater runoff.

There are two different filter strip designs that can be used on a development site. The first is a simple design, while the second is more advanced, and includes a permeable berm at the downstream end of the filter strip. The permeable berm is used to temporarily store stormwater runoff within the filter strip, which increases the residence time that it provides and reduces the required width of the filter strip.

Since the vegetated filter strips that are used to receive stormwater runoff on a development site are typically designed to be in-line stormwater management practices, consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to help ensure that they do not cause significant damage to a vegetated filter strip.

4.7.6.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Reduce the runoff reduction volume conveyed through a vegetated filter strip located on A/B or amended soils by 60%. Reduce the runoff reduction volume conveyed through a vegetated filer strip located on C/D soils by 30%.
b) Water Quality Protection: Reduce the runoff reduction volume conveyed through a vegetated filter strip located on A/B or amended soils by 60%. Reduce the runoff reduction volume conveyed through a vegetated filter strip located on C/D soils by 30%.

In order to receive stormwater runoff and b eligible for these credits, vegetated filter strips must satisfy the planning and design criteria outlined below.

4.7.6.4 Planning and Design Criteria

Vegetated filter strips used to receive stormwater runoff on a development site must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) The length of the flow path within the contributing drainage area should be 150 feet or less for pervious drainage areas and 75 feet or less for impervious drainage areas.
b) The average slope of the contributing drainage area should be 3% or less, unless terracing or level spreaders are used at 20 foot intervals along the length of the flow path to slow and redistribute stormwater runoff as overland sheet flow.
c) In order to use vegetated filter strips as receiving low impact development practices, stormwater runoff needs to be conveyed into them as overland sheet flow. A level spreader should be used at the upstream end of the filter strip to ensure that stormwater runoff enters it as overland sheet flow.
d) A pea gravel diaphragm makes an effective level spreader at the upstream end of vegetated filter strips used to receive post-construction stormwater runoff. A pea gravel diaphragm, which is a small trench filled with pea gravel (i.e., ASTM D 448 Size No. 8, 3/8" to 1/8"), intercepts stormwater runoff and distributes it evenly, as overland sheet flow, across a filter strip. Other types of level spreaders that can be used to redistribute stormwater runoff at the upstream end of vegetated filter strips include concrete sills, curb stops and curbs with sawteeth cut into them.
e) The average slope of the vegetated filter strip should be between 0.5% and 6%. Greater slopes would encourage the formation of shallow, concentrated flow within the filter strip, while lesser slopes would encourage ponding.
f) The length of the flow path within a vegetated filter strip should be no less than 25 feet. The length of the flow path within a vegetated filter strip designed with permeable berm may be shorter, but should be no less than 15 feet long.
g) Permeable berms should be constructed using hydrologic soil group A and B soils (i.e., sands, gravels, sandy loams) that will support plant growth.
h) The maximum ponding depth behind a permeable berm should be 12 inches or less.
i) Appropriately sized outlets should be provided within permeable berms to ensure that vegetated filter strips will drain within 24 hours following the end of a rainfall event.
j) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to help ensure that these larger storm events do not cause significant damage to vegetated filter strips. If necessary, a bypass channel or overflow spillway may be used to manage the stormwater runoff generated by these larger storm events.
k) A landscaping plan shall be prepared for all vegetated filter strips. The landscaping plan shall be reviewed and approved by the DSR prior to construction.
l) Vegetation commonly planted on vegetated filter strips includes turf, shrubs, trees and other herbaceous vegetation. Although managed turf is most commonly used, the use of trees, shrubs and/or other native vegetation is encouraged to help establish mature native plant communities within vegetated filter strips.
m) When developing a landscaping plan, grasses and other vegetation that will be able to tolerate the stormwater runoff rates and volumes that will pass through the vegetated filter strip should be chosen. Vegetation used in vegetated filter strips should also be able to tolerate both wet and dry conditions.
n) Methods used to establish vegetative cover within a vegetated filter strip should achieve at least 75 percent vegetative cover one year after installation.
o) To help prevent soil erosion and sediment loss, landscaping should be provided immediately after the vegetated filter strip has been installed. Temporary irrigation may be needed to quickly establish vegetative cover on a vegetated filter strip.

4.7.6.5 Construction Considerations

To help ensure that vegetated filter strips are successfully installed on a development site, site planning and design teams should consider the following recommendations:

a) Vegetated filter strips should be installed only after their contributing drainage areas have been completely stabilized.
b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used on vegetated filter strips. Appropriate measures should be taken (e.g., silt fence, temporary diversion berm) to pretreat and/or divert post-construction stormwater runoff around a vegetated filter strip until vegetative cover has been established.
c) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of vegetated filter strips during and after construction.
d) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within a vegetated filter strip.

4.7.7 Grass Channels

4.7.7.1 Description


Figure 4-4
Grass Channel
Source: USDA-Natural Resources Conservation Service - Illinois

Where site characteristics permit, grass channels, which are densely vegetated stormwater conveyance features, can be used to receive and convey post-construction stormwater runoff. They are typically installed in areas that have been disturbed by clearing, grading and other land disturbing activities, and are typically vegetated with managed turf. If properly designed, grass channels can provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads. Therefore, they can be used to help meet Jasper County's stormwater management regulations.

4.7.7.2 Discussion

Conventional storm drain systems are designed to quickly and efficiently convey stormwater runoff away from buildings, roadways and other impervious surfaces and into rivers, streams and other aquatic resources. When these conventional systems are used to receive and convey stormwater runoff on development sites, opportunities to reduce post-construction stormwater runoff rates, volumes and pollutant loads are lost. To take better advantage of these opportunities, grass channels can be used in place of conventional storm drain systems (e.g., curb and gutter systems, storm sewers, concrete channels) to receive and convey stormwater runoff.

Grass channels (also known as *vegetated open channels*) are densely vegetated stormwater conveyance features designed to slow and filter stormwater runoff. They differ from the old, unvegetated roadside ditches of the past, which often suffered from erosion and standing water and occasionally worked to undermine the roadway itself. If grass channels are properly designed (e.g., sufficient channel widths, relatively flat slopes, dense vegetative cover), they can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads, particularly when they are located on areas with permeable soils (i.e., hydrologic soil group A and B soils).

Grass channels can be integrated into development sites as landscaping features and are well suited to receive stormwater runoff from local streets and roadways, highways, small parking lots and disturbed pervious surfaces (e.g., lawns, parks, community open spaces). They are typically installed in areas that have been disturbed by clearing, grading and other land disturbing activities and are particularly well suited for use in roadway rights-of-way. Grass channels are typically less expensive to install than conventional storm drain systems and can be used to pretreat stormwater runoff before it enters other low impact development practices, such as undisturbed pervious areas, bioretention areas and infiltration practices, which increases the reductions in stormwater runoff rates, volumes and pollutant loads that these other low impact development practices provide.

Two of the primary concerns associated with grass channels are channel capacity and erosion control. In order to address these two concerns, peak discharge rate generated by the runoff reduction rainfall event should not flow through the grass channel at a velocity greater than 1.0 foot per second (ft/s). Grass channels should provide at least 10 minutes of residence time for the peak discharge rate generated by the runoff reduction rainfall event. Check dams can be placed across grass channels to help slow post-construction stormwater runoff and increase residence times.

4.7.7.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Reduce the runoff reduction volume conveyed through a *grass channel* located on A/B or amended soils by 25%. Reduce the runoff reduction volume conveyed through a *grass channel* located on C/D soils by 12.5%.
b) Water Quality Protection: Reduce the runoff reduction volume conveyed through a *grass channel* located on A/B or amended soils by 25%. Reduce the runoff reduction volume conveyed through a *grass channel* located on C/D soils by 12.5%.

In order to receive stormwater runoff and be eligible for these credits, grass channels must satisfy the planning and design criteria outlined below.

4.7.7.4 Planning and Design Criteria

Grass channels used to receive stormwater runoff on a development site must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Grass channels should be used to receive stormwater runoff from relatively small drainage areas of 5 acres or less. The stormwater runoff rates and volumes from larger contributing drainage areas typically become too large to be properly conveyed within a grass channel.
b) Although grass channels may be installed on development sites with slopes of between 0.5% and 3%, it is recommended that they be designed with slopes of between 1% and 2% to help ensure adequate drainage. Slopes greater than 3% would encourage erosion within the grass channel, while slopes less than 0.5% would encourage ponding.

c) Grass channels should be designed to accommodate the peak discharge rate generated by the runoff reduction rainfall event.
d) To help prevent erosion within grass channels, the peak discharge rate generated by the runoff reduction rainfall event should be designed to flow through a grass channel at a velocity of 1.0 foot per second (ft/s) or less.
e) To provide adequate residence time for stormwater runoff, grass channels should be designed to provide at least 10 minutes of residence time for the peak discharge rate generated by the runoff reduction rainfall event. Residence times may be increased by adjusting channel dimensions, slopes and vegetative covers or by including check dams in the channel design.
f) The bottom of a grass channel should be designed to be between 2 and 8 feet wide. Channel bottoms greater than 8 feet wide encourage channel braiding, while channel bottoms less than 2 feet wide encourage soil erosion. If a channel bottom needs to be more than 8 feet wide to accommodate the peak discharge rate generated by the runoff reduction rainfall event, the use of a compound channel cross-section (e.g. two smaller channels separated by a permeable berm) a smaller pilot channel is recommended.
g) Grass channels should be designed with trapezoidal or parabolic cross-sections, and should be designed with side slopes of 3:1 (H:V) or flatter.
h) The depth from the bottom of a grass channel to the top of the water table should be at least 2 feet to help prevent ponding and ensure proper operation of the grass channel. On development sites with high water tables, wet swales should be used to intercept, convey and treat post-construction stormwater runoff.
i) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to help ensure that they do not cause localized flooding or significant damage to grass channels. Grass channels should be designed to able to safely convey the required design event.
j) A landscaping plan should be prepared for all grass channels. The landscaping plan shall be reviewed and approved by the DSR.
k) Vegetation commonly planted in grass channels includes turf, shrubs, trees and other herbaceous vegetation. Although managed turf is most commonly used, trees, shrubs and/or other native vegetation are encouraged to help establish mature native plant communities in and around grass channels.
l) When developing a landscaping plan, grasses and other vegetation should be chosen that will be able to stabilize soils and tolerate the stormwater runoff rates and volumes that will pass through the grass channel. Vegetation used in grass channels should also be able to tolerate both wet and dry conditions.
m) Methods used to establish vegetative cover within a grass channel should achieve at least 90 percent vegetative cover one year after installation.
n) To help prevent soil erosion and sediment loss, landscaping should be provided immediately after the grass channel has been installed. Temporary irrigation may be needed to quickly establish vegetative cover within a grass channel.

4.7.7.5 Construction Considerations

To help ensure that grass channels are successfully installed on a development site, the following are recommended:

a) Grass channels should be installed only after their contributing drainage areas have been completely stabilized.
b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used on grass channels. Appropriate measures should be taken

(e.g., silt fence, temporary diversion berm) to pretreat and/or divert post-construction stormwater runoff around a grass channel until vegetative cover has been established.

c) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of grass channels during and after construction.
d) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within a grass channel.

4.7.8 Simple Downspout Disconnection

4.7.8.1 Description

Where site characteristics permit, simple downspout disconnections can be used to spread rooftop runoff from individual downspouts across lawns and other pervious areas, where it is slowed, filtered and allowed to infiltrate into the native soils. They are typically used in areas that have been disturbed by clearing, grading and other land disturbing activities and are typically vegetated with managed turf. If properly designed, simple downspout disconnections can provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Therefore, they can be used to help meet Jasper County's stormwater management requirements.

Figure 4-5
Simple Downspout Disconnection
Source: Montgomery County Maryland Department of Environmental Protection

4.7.8.2 Discussion

In order to use simple downspout disconnections to receive post-construction stormwater runoff, downspouts must be designed to discharge to a lawn or other pervious area. The pervious area located below the simple downspout disconnection should slope away from buildings and other impervious surfaces to prevent damage to building foundations and discourage rooftop runoff from reconnecting with the storm drain system

The primary concern associated with a simple downspout disconnection is the length of the flow path in the lawn or other pervious area located below the disconnection point. In order to provide adequate residence time for stormwater runoff, the length of the flow path in the pervious area located below a simple downspout disconnection should be equal to or greater than the length of the flow path of the contributing drainage area. If this cannot be accomplished, due to site characteristics or constraints, other low impact development practices, such as vegetated filter strips, rain gardens, dry wells, and rainwater harvesting should be considered.

4.7.8.3 Stormwater Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on A/B or amended soils by 60%. Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on C/D soils by 30%.
b) Water Quality Protection: Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on A/B or amended soils by 60%. Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on C/D soils by 30%.

In order to receive stormwater runoff and be eligible for these credits, simple downspout disconnections must satisfy the planning and design criteria outlined below.

4.7.8.4 Planning and Design Criteria

Simple downspout disconnections must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Simple downspout disconnections should be used to receive stormwater runoff from small drainage areas of 2,500 square feet or less. The stormwater runoff rates and volumes from larger contributing drainage areas typically become too large to be properly received by simple downspout disconnections.
b) The length of the flow path within the contributing drainage area should be 75 feet or less. In contributing drainage areas with longer flow paths, stormwater runoff tends to become shallow, concentrated flow, which can cause soil erosion and can significantly reduce the stormwater management benefits that simple downspout disconnections can provide. In these situations, grass channels or swales should be used to receive post-construction stormwater runoff.
c) To provide adequate residence time for stormwater runoff, the length of the flow path in the pervious area located below a simple downspout disconnection should be at least 15 feet long and equal to or greater than the length of the flow path in its contributing drainage area. If this cannot be accomplished, due to site characteristics or constraints, other low impact development practices, such as vegetated filter strips, rain gardens, dry wells, and rainwater harvesting should be considered.
d) Although simple downspout disconnections may be used on development sites with slopes of between 0.5% and 6%, it is recommended that they be designed with slopes of between 1% and 5% to help ensure adequate drainage. Slopes greater than 6% would encourage erosion within the pervious areas located below the simple downspout disconnection, while slopes less than 0.5% would encourage ponding.
e) All simple downspout disconnections should be designed to convey stormwater runoff away from buildings to prevent damage to building foundations. This typically involves extending downspouts to a point that is at least 2 feet away from buildings that do not have basements or to a point that is at least 6 feet away from buildings that do have basements.
f) All simple downspout disconnections should be located at least 10 feet away from all impervious surfaces of equal or lower elevation to discourage rooftop runoff from reconnecting with the storm drain system.
g) Vegetation commonly planted in the pervious areas located below simple downspout disconnections includes turf, shrubs, trees and other herbaceous vegetation. Although managed turf is most commonly used, trees, shrubs and/or other native vegetation to help establish mature native plant communities in the pervious areas located below simple downspout disconnections are encouraged.

h) Methods used to establish vegetative cover within the pervious area located below a simple downspout disconnection should achieve at least 75 percent vegetative cover one year after installation.
i) To help prevent soil erosion and sediment loss, landscaping should be provided immediately after the simple downspout disconnection has been completed. Temporary irrigation may be needed to quickly establish vegetative cover within the pervious areas located below simple downspout disconnections.

4.7.8.5 Construction Considerations

To help ensure that simple downspout disconnections are properly installed on a development site, the following are recommended:

a) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used within the pervious areas located below simple downspout disconnections.
b) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of the pervious areas located below simple downspout disconnections during and immediately after construction.
c) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within the pervious area located below a simple downspout disconnection.

4.7.9 Rain Gardens

4.7.9.1 Description

Rain gardens are small, landscaped depressional areas that are filled with amended native soils or an engineered soil mix and are planted with trees, shrubs and other herbaceous vegetation. They are designed to capture and temporarily store stormwater runoff so that it may be subjected to the hydrologic processes of evaporation, transpiration and infiltration. This allows rain gardens to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Consequently, they can be used to help meet Jasper County's stormwater management requirements.

Figure 4-6
Rain Garden
Source: David Jirousek

4.7.9.2 Discussion

The primary concern associated with the design of a rain garden is its storage capacity, which directly influences its ability to reduce stormwater runoff rates, volumes and pollutant loads. Rain gardens that can accommodate the stormwater runoff volume generated by the runoff reduction rainfall event should be designed. If this cannot be accomplished, due to site characteristics or constraints, rain gardens can be used in combination with other runoff reducing low impact development practices, such as dry wells and rainwater harvesting, to provide more substantial reductions in stormwater runoff rates, volumes and pollutant loads.

4.7.9.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by a rain garden from the runoff reduction volume conveyed through the rain garden.
b) Water Quality Protection: Subtract 100% of the storage volume provided by a rain garden from the runoff reduction volume conveyed through the rain garden.

In order to receive stormwater runoff and be eligible for these credits, rain gardens must satisfy the planning and design criteria outlined below.

4.7.9.4 Planning and Design Criteria

Rain gardens must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Rain gardens should be used to receive stormwater runoff from small drainage areas of 2,500 square feet or less. The stormwater runoff rates and volumes from larger contributing drainage areas typically become too large to be properly received by rain gardens.
b) The length of the flow path within the contributing drainage area should be 150 feet or less for pervious drainage areas and 75 feet or less for impervious drainage areas. In contributing drainage areas with longer flow paths, stormwater runoff tends to becomes shallow, concentrated flow, which can cause soil erosion and can significantly reduce the stormwater management benefits that rain gardens can provide. In these situations, bioretention areas should be used to receive post-construction stormwater runoff.
c) Although rain gardens may be installed on development sites with slopes of up to 6%, they should be designed with slopes that are as close to flat as possible to help ensure that stormwater runoff is evenly distributed over the planting bed.
d) Rain gardens should be designed to provide enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event.
e) Rain gardens should be designed to completely drain within 24 hours of the end of a rainfall event. Where site characteristics allow, it is preferable to design rain gardens to drain within 12 hours of the end of a rainfall event to help prevent the formation of nuisance ponding conditions.
f) Rain gardens may be designed with a maximum ponding depth of 12 inches, although a ponding depth of 6 inches is recommended to help prevent the formation of nuisance ponding conditions.
g) Unless a shallow water table is found on the development site, all rain garden planting beds should be at least 24 inches deep. If a shallow water table is found on the development site, the depth of the planting bed may be reduced to 18 inches.
h) The soils used within rain garden planting beds may consist of either amended native soils or an engineered soil mix, but should meet the following specifications:
    i. Texture: Sandy loam or loamy sand.
    ii. Sand Content: Soils should contain 85%-88% clean, washed sand.
    iii. Topsoil Content: Soils should contain 8%-12% topsoil.
    iv. Organic Matter Content: Soils should contain 3%-5% organic matter.
    v. Infiltration Rate: Soils should have an infiltration rate of at least 0.25 inches per hour (in/hr), although an infiltration rate of between 1 and 2 in/hr is preferred.
    vi. Phosphorus Index (P-Index): Soils should have a P-Index of less than 30.

   vii. Exchange Capacity (CEC): Soils should have a CEC that exceeds 10 milliequivalents (meq) per 100 grams of dry weight.
   viii. pH: Soils should have a pH of 6-8.

i) The organic matter used within a rain garden planting bed should be a well-aged compost that meets the specifications outlined for Soil Restoration.
j) All rain gardens should be located at least 10 feet away from buildings to prevent damage to building foundations.
k) All rain gardens should be located at least 10 feet away from all impervious surfaces of equal or lower elevation to discourage rooftop runoff from "reconnecting" with the storm drain system.
l) Rain gardens should be designed with side slopes of 3:1 (H:V) or flatter.
m) The depth from the bottom of a rain garden to the top of the water table should be at least 2 feet to help prevent ponding and ensure proper operation of the rain garden. On development sites with high water tables, small stormwater wetlands (i.e., pocket wetlands) should be used to intercept and treat post-construction stormwater runoff.
n) If used to receive non rooftop runoff, rain gardens should be preceded by a pea gravel diaphragm or equivalent level spreader device (e.g., concrete sills, curb stops, curbs with sawteeth cut into them) to intercept stormwater runoff and distribute it evenly, as overland sheet flow, into the rain garden.
o) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events (e.g., 25-year, 24-hour storm event) to ensure that these larger storm events are able to safely bypass the rain garden. An overflow system, such as a spillway with an invert set slightly above the elevation of maximum ponding depth within the rain garden, should be designed to convey the stormwater runoff generated by these larger storm events safely out of the rain garden.
p) A landscaping plan should be prepared for all rain gardens. The landscaping plan shall be reviewed and approved by the DSR.
q) Vegetation commonly planted in rain gardens includes native trees, shrubs and other herbaceous vegetation. When developing a landscaping plan, vegetation should be chosen that will be able to stabilize soils and tolerate the stormwater runoff rates and volumes that will pass through the rain garden. Vegetation used in rain gardens should also be able to tolerate both wet and dry conditions. Refer to the South Carolina DHEC Stormwater Management BMP Handbook http://www.scdhec.gov/environment/ocrm/bmp_docs.htm Appendix D for vegetation recommendations.
r) A mulch layer, consisting of 2-4 inches of fine shredded hardwood mulch or shredded hardwood chips, should be included on the surface of the rain garden.
s) Methods used to establish vegetative cover within a rain garden should achieve at least 75 percent vegetative cover one year after installation.
t) To help prevent soil erosion and sediment loss, landscaping should be provided immediately after the rain garden has been installed. Temporary irrigation may be needed to quickly establish vegetative cover within a rain garden.

4.7.9.5 Construction Considerations

To help ensure that rain gardens are successfully installed on a development site, the following are recommended:

a) If rain gardens will be used to receive non rooftop runoff, they should only be installed after their contributing drainage areas have been completely stabilized.
b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used within rain gardens. Appropriate measures should be taken

(e.g., silt fence, temporary diversion berm) to pretreat and/or divert post-construction stormwater runoff around a rain garden until vegetative cover has been established.

c) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of rain gardens before, during and after construction. This can typically be accomplished by clearly delineating rain gardens on all development plans and, if necessary, protecting them with temporary construction fencing.
d) The native soils along the bottom of the rain garden should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of the amended native soils or engineered soil mix.
e) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within a rain garden.

4.7.10 Stormwater Planters

4.7.10.1 Description

Stormwater planters are landscape planter boxes that are specially designed to receive post-construction stormwater runoff. They consist of planter boxes that are equipped with waterproof liners, filled with an engineered soil mix and planted with trees, shrubs and other herbaceous vegetation. Stormwater planters are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration before being conveyed back into the storm drain system through an underdrain. This allows them to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites.

4.7.10.2 Discussion

Stormwater planters are essentially small, underdrained bioretention areas that are designed to fit within landscape planter boxes. The primary concern associated with the design of a stormwater planter is its storage capacity, which directly influences its ability to reduce stormwater runoff rates, volumes and pollutant loads. Stormwater planters that can accommodate the stormwater runoff volume generated by the runoff reduction rainfall event should be designed. If this cannot be accomplished, due to site characteristics or constraints, stormwater planters can be used in combination with other runoff reducing low impact development practices, such dry wells and rainwater harvesting, to supplement the stormwater management benefits provided by the planters.

4.7.10.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help satisfy Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 50% of the storage volume provided by a stormwater planter from the runoff reduction volume conveyed through the stormwater planter.
b) Water Quality Protection: Subtract 50% of the storage volume provided by a stormwater planter from the runoff reduction volume conveyed through the stormwater planter.

In order to receive stormwater runoff and be eligible for these credits, stormwater planters must satisfy the planning and design criteria outlined below.

4.7.10.4 Planning and Design Criteria

Stormwater planters must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Stormwater planters should be used to receive stormwater runoff from small drainage areas of 2,500 square feet or less. The stormwater runoff rates and volumes from larger contributing drainage areas typically become too large to be properly received by stormwater planters.
b) The length of the flow path within the contributing drainage area should be 150 feet or less for pervious drainage areas and 75 feet or less for impervious drainage areas. In contributing drainage areas with longer flow paths, stormwater runoff tends to becomes shallow, concentrated flow, which can cause soil erosion and can significantly reduce the stormwater management benefits that stormwater planters can provide. In these situations, bioretention areas should be used to receive post-construction stormwater runoff.
c) Stormwater planters should be designed to provide enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event.
d) Stormwater planters should be designed to completely drain within 24 hours of the end of a rainfall event. Where site characteristics allow, it is preferable to design stormwater planters to drain within 12 hours of the end of a rainfall event to help prevent the formation of nuisance ponding conditions.
e) Stormwater planters may be designed with a maximum ponding depth of 12 inches, although a ponding depth of 6 inches is recommended to help prevent the formation of nuisance ponding conditions.
f) A minimum of 2 inches of freeboard should be provided between the elevation of the maximum ponding depth and the top of the planter box.
g) Unless a shallow water table is found on the development site, all stormwater planter planting beds should be at least 24 inches deep. If a shallow water table is found on the development site, the depth of the planting bed may be reduced to 18 inches.
h) The soils used within stormwater planter planting beds should be an engineered soil mix that meets the following specifications:
    i. Texture: Sandy loam or loamy sand.
    ii. Sand Content: Soils should contain 85%-88% clean, washed sand.
    iii. Topsoil Content: Soils should contain 8%-12% topsoil.
    iv. Organic Matter Content: Soils should contain 3%-5% organic matter.
    v. Infiltration Rate: Soils should have an infiltration rate of at least 0.25 inches per hour (in/hr), although an infiltration rate of between 1 and 2 in/hr is preferred.
    vi. Phosphorus Index (P-Index): Soils should have a P-Index of less than 30.
    vii. Exchange Capacity (CEC): Soils should have a CEC that exceeds 10 milliequivalents (meq) per 100 grams of dry weight.
    viii. pH: Soils should have a pH of 6-8.
i) The organic matter used within a stormwater planter planting bed should be a well-aged compost that meets the specifications outlined for Soil Restoration.
j) A minimum width, measured from inside wall to inside wall, of 18 inches is recommended for all stormwater planters.
k) All stormwater planters should be equipped with a waterproof liner to prevent damage to building foundations and other adjacent impervious surfaces.
l) Although stormwater planters may be used on development sites with slopes of up to 6%, they should be designed with slopes that are as close to flat as possible to help ensure that stormwater runoff is evenly distributed over the planting bed.

m) Stormwater planters should be constructed of stone, concrete, brick or other durable material. Chemically treated wood that can leach toxic chemicals and contaminate stormwater runoff should not be used to construct a stormwater planter.
n) Stormwater planters should be equipped with an underdrain consisting of a 4 inch perforated PVC (AASHTO M 252) pipe bedded in a 6 inch layer of clean, washed stone. The pipe should have 3/8 inch perforations, spaced 6 inches on center, and should have a minimum slope of 0.5%. The clean, washed stone should be ASTM D448 size No. 57 stone (i.e., 1-1/2 to 1/2 inches in size) and should be separated from the planting bed by a layer of permeable filter fabric or a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16"). If permeable filter fabric is used, the filter fabric should be a non-woven geotextile with a permeability that is greater than or equal to the hydraulic conductivity of the overlying planting bed.
o) Unless a shallow water table is found on the development site, the distance from the bottom of a stormwater planter to the top of the water table should be at least 2 feet. If a shallow water table is found on the development site, the distance from the bottom of a stormwater planter to the top of the water table may be reduced to 12 inches.
p) If used to receive non rooftop runoff, stormwater planters should be preceded by a pea gravel diaphragm or equivalent level spreader device (e.g., concrete sills, curb stops, curbs with sawteeth cut into them) to intercept stormwater runoff and distribute it evenly, as overland sheet flow, across the stormwater planter.
q) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events to help ensure that these larger storm events are able to safely bypass the stormwater planter. An overflow system, such as an overdrain with an invert set slightly above the elevation of maximum ponding depth, should be designed to convey the stormwater runoff generated by these larger storm events safely out of the stormwater planter.
r) A landscaping plan should be prepared for all stormwater planters. The landscaping plan shall be reviewed and approved by the DSR.
s) Vegetation commonly planted in stormwater planters includes native trees, shrubs and other herbaceous vegetation. When developing a landscaping plan, vegetation that will be able to stabilize soils and tolerate the stormwater runoff rates and volumes that will pass through the stormwater planter should be chosen.
t) A mulch layer, consisting of 2-4 inches of fine shredded hardwood mulch or shredded hardwood chips, should be included on the surface of the stormwater planter.
u) Methods used to establish vegetative cover within a stormwater planter should achieve at least 75 percent vegetative cover one year after installation.
v) To help prevent soil erosion and sediment loss, landscaping should be provided immediately after the stormwater planter has been installed. Temporary irrigation may be needed to quickly establish vegetative cover within a stormwater planter.

4.7.10.5 Construction Considerations

To help ensure that stormwater planters are successfully installed on a development site, the following are recommended:

a) If stormwater planters will be used to receive non rooftop runoff, they should only be installed after their contributing drainage areas have been completely stabilized.
b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used within the stormwater planter. Appropriate measures should be taken (e.g., temporary diversion) to divert post-construction stormwater runoff around a stormwater planter until vegetative cover has been established.

c) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of stormwater planters during and after construction.
d) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within a stormwater planter.

4.7.11 Dry Wells

4.7.11.1 Description

Dry wells (also known as seepage pits and french drains) are low impact development practices that are located below the surface of development sites. They consist of shallow excavations, typically filled with stone, that are designed to intercept and temporarily store post-construction stormwater runoff until it infiltrates into the underlying and surrounding soils. If properly designed, they can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Therefore, dry wells can be used to help meet Jasper County's stormwater management requirements.

4.7.11.2 Discussion

As infiltration-based low impact development practices, dry wells are limited to use in areas where the soils are permeable enough and the water table is low enough to provide for the infiltration of stormwater runoff. They should only be considered for use on development sites where fine sediment (e.g., clay, silt) loads will be relatively low, as high sediment loads will cause them to clog and fail. In addition, dry wells should be carefully sited to avoid the potential contamination of water supply aquifers.

The primary concern associated with the design of a dry well is its storage capacity, which directly influences its ability to reduce stormwater runoff rates, volumes and pollutant loads. Dry wells that can accommodate the stormwater runoff volume generated by the runoff reduction rainfall event should be designed. If this cannot be accomplished, due to site characteristics or constraints, dry wells can be used in combination with other runoff reducing low impact development practices, such as rain gardens and rainwater harvesting, to supplement the stormwater management benefits provided by the dry wells.

4.7.11.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by a dry well from the runoff reduction volume conveyed through the dry well.
b) Water Quality Protection: Subtract 100% of the storage volume provided by a dry well from the runoff reduction volume conveyed through the dry well.

4.7.11.4 Planning and Design Criteria

Dry wells must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Dry wells should be used to receive stormwater runoff from small drainage areas of 2,500 square feet or less. The stormwater runoff rates and volumes from larger contributing drainage areas typically become too large to be properly received by a dry well.
b) The length of the flow path within the contributing drainage area should be 150 feet or less for pervious drainage areas and 75 feet or less for impervious drainage areas. In contributing drainage areas with longer flow paths, stormwater runoff tends to becomes shallow, concentrated flow, which can significantly reduce the stormwater management benefits that dry wells can provide. In these situations, bioretention areas and infiltration practices should be used to receive post-construction stormwater runoff.
c) Although dry wells may be installed on development sites with slopes of up to 6%, they should be designed with slopes that are as close to flat as possible to help ensure that stormwater runoff is evenly distributed throughout the stone reservoir.
d) Dry wells should be located in a lawn or other disturbed pervious area and should be designed so that the top of the dry well is located as close to the surface as possible. Dry wells should not be located beneath a driveway, parking lot or other impervious surface.
e) Dry wells should be used on development sites that have underlying soils with an infiltration rate of 0.50 inches per hour (in/hr) or greater, as determined by NRCS soil survey data and subsequent field testing. Field infiltration test protocol, shall be approved by the DSR prior to use.
f) At least one infiltration test for each dry well that will be used on the development site shall be conducted.
g) Since clay lenses or any other restrictive layers located below the bottom of a dry well will reduce soil infiltration rates, infiltration testing should be conducted within any confining layers that are found within 4 feet of the bottom of a proposed dry well.
h) Dry wells should be designed to provide enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event.
i) Dry wells should be designed to completely drain with 24 hours of the end of a rainfall event. Where site characteristics allow, it is preferable to design dry wells to drain within 12 hours of the end of a rainfall event to help prevent the formation of nuisance ponding conditions.
j) Broader, shallower dry wells perform more effectively by distributing stormwater runoff over a larger surface area. However, a minimum depth of 18 inches is recommended for all dry well designs to prevent them from consuming a large amount of surface area on development sites. Whenever practical, the depth of dry wells should be kept to 36 inches or less.
k) Dry wells should be filled with clean, washed stone. The stone used in the dry well should be 1.5 to 2.5 inches in diameter, with a void space of approximately 40%. Unwashed aggregate contaminated with soil or other fines may not be used in the dry well.
l) Underlying native soils should be separated from the dry well stone by a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16"). The choker stone should be placed between the dry well stone and the underlying native soils.
m) The top and sides of the dry well should be lined with a layer of appropriate permeable filter fabric. The filter fabric should be a non-woven geotextile with a permeability that is greater than or equal to the infiltration rate of the surrounding native soils. The top layer of the filter fabric should be located 6 inches from the top of the excavation, with the remaining space filled with appropriate landscaping. This top layer serves as a sediment barrier and, consequently, will need to be replaced over time. The top layer of filter fabric shall be readily separated from the filter fabric used to line the sides of the dry well.
n) The depth from the bottom of a dry well to the top of the water table should be at least 2 feet to prevent nuisance ponding and ensure proper operation of the dry well.

o) To prevent damage to building foundations and contamination of groundwater aquifers, dry wells should be located at least:
   i. 10 feet from building foundations
   ii. 10 feet from property lines
   iii. 100 feet from private water supply wells
   iv. 1,200 feet from public water supply wells
   v. 100 feet from septic systems
   vi. 100 feet from surface waters
   vii. 400 feet from public water supply surface waters

p) An observation well should be installed in every dry well. An observation well consists of a 4 to 6 inch perforated PVC (AASHTO M 252) pipe that extends to the bottom of the dry well. The observation well can be used to observe the rate of drawdown within the dry well following a storm event. It should be installed along the centerline of the dry well, flush with the elevation of the surface of the dry well. A visible floating marker should be provided within the observation well and the top of the well should be capped and locked to prevent tampering and vandalism.

q) If used to receive rooftop runoff, dry wells should be preceded by a leaf screen installed in the gutter or downspout. This will prevent leaves and other large debris from clogging the dry well.

r) If used to receive non rooftop runoff, dry wells should be preceded by a pea gravel diaphragm or equivalent level spreader device (e.g., concrete sills, curb stops, curbs with sawteeth cut into them) and a vegetated filter strip.

s) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events to help ensure that these larger storm events are able to safely bypass the dry well. An overflow, such as a vegetated filter strip or grass channel, should be designed to convey the stormwater runoff generated by these larger storm events safely out of the dry well.

t) The landscaped area above the surface of a dry well may be covered with pea gravel (i.e., ASTM D 448 size No. 8, 3/8” to 1/8”). This pea gravel layer provides sediment removal and additional pretreatment upstream of the dry well and can be easily removed and replaced when it becomes clogged.

u) Alternatively, a dry well may be covered with an engineered soil mix, such as that prescribed for Rain Gardens, and planted with managed turf or other herbaceous vegetation. This may be an attractive option when dry wells are placed in disturbed pervious areas (e.g., lawns, parks, community open spaces).

4.7.11.5 Construction Considerations

To help ensure that dry wells are successfully installed on a development site, the following are recommended:

a) If dry wells will be used to receive non rooftop runoff, the dry wells should only be installed after receiving contributing drainage areas that have been completely stabilized. To help prevent dry well failure, stormwater runoff may be diverted around the dry well until the contributing drainage area has been stabilized.

b) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of dry wells before, during and immediately after construction. This can typically be accomplished by clearly delineating dry wells on all development plans and, if necessary, protecting them with temporary construction fencing.

c) Excavation for dry wells should be limited to the width and depth specified in the development plans. Excavated material should be placed away from the excavation so as not to jeopardize the stability of the side walls.

d) The native soils along the bottom of the dry well should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of the choker stone and dry well stone.
e) The sides of all excavations should be trimmed of all large roots that will hamper the installation of the permeable filter fabric used to line the sides and top of the dry well.

4.7.12 Rainwater Harvesting

4.7.12.1 Description

Rainwater harvesting is the ancient stormwater management practice of intercepting, diverting and storing rainfall for later use. In a typical rainwater harvesting system, rainfall is collected from a gutter and downspout system, screened and washed, and conveyed into an above- or below-ground storage tank or cistern. Once captured in the storage tank or cistern, it may be used for non-potable indoor or outdoor uses. If properly designed, rainwater harvesting systems can significantly reduce post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Rainwater harvesting also helps reduce the demand on public water supplies, which, in turn, helps protect aquatic resources, such as groundwater aquifers, from drawdown and seawater intrusion.

4.7.12.2 Discussion

There are two basic types of rainwater harvesting systems: (1) systems that are used to supply water for non-potable outdoor uses, such as landscape irrigation, car and building washing and fire fighting; and (2) systems that are used to supply water for non-potable indoor uses, such as laundry and toilet flushing. Rainwater harvesting systems used to supply water for non-potable indoor uses are more complex and require separate plumbing, pressure tanks, pumps and backflow preventers.

Whether it is used to supply water for non-potable indoor or outdoor uses, a well-designed rainwater harvesting system typically consists of five major components, including the collection and conveyance system (e.g., gutter and downspout system), pretreatment devices (e.g., leaf screens, first flush diverters, roof washers), the storage tank or cistern, the overflow pipe (which allows excess stormwater runoff to bypass the storage tank or cistern) and the distribution system (which may or may not require a pump, depending on site characteristics). When designing a rainwater harvesting system, each of these components, as well as the size of the contributing drainage area, local rainfall patterns and the projected water demand, should be considered to determine how large the cistern or storage tank must be to provide enough water for the desired non-potable indoor or outdoor use.

4.7.12.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 75% of the storage volume provided by a rainwater harvesting system from the runoff reduction volume captured by the system.
b) Water Quality Protection: Subtract 75% of the storage volume provided by a rainwater harvesting system from the runoff reduction volume captured by the system.

4.7.12.4 Planning and Design Criteria

Rainwater harvesting systems must meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Rainwater harvesting systems may be installed on nearly any development site. However, placing storage tanks or cisterns at higher elevations may reduce or eliminate pumping requirements.
b) The quality of harvested rainwater will vary according to the material from which the rooftop is constructed. Water harvested from certain types of rooftops, such as asphalt shingle, tar and gravel and treated wood shingle roofs, should only be used for non-potable outdoor uses, as these materials may leach toxic compounds into stormwater runoff.
c) Rainwater harvesting systems should be designed to provide at least enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event. The required size of a rainwater harvesting system is governed by several factors, including the size of the contributing drainage area, local rainfall patterns and the projected demand for the harvested rainwater. The projected water demand should be calculated and then water balance calculations should be conducted, based on the size of the contributing drainage area and local precipitation data, to size a rainwater harvesting system.
d) Since it provides storage for the harvested rainwater, the storage tank (also known as a *cistern*) is the most important and typically the most expensive component of a rainwater harvesting system. Storage tanks can be constructed from a variety of materials, including wood, plastic, fiberglass or galvanized metal. An appropriate cistern for the intended application should be chosen and should be ensured that it has been sealed with a water safe, non-toxic substance.
e) Rain barrels (i.e., small storage tanks capable of storing less than 100 gallons of stormwater runoff) rarely provide enough storage capacity to accommodate the stormwater runoff volume generated by the target runoff reduction rainfall event. Consequently, they should not be used as part of a rainwater harvesting system, except on small drainage areas of 2,500 square feet or less in size.
f) All storage tanks should be opaque or otherwise protected from direct sunlight to inhibit algae growth. They should also be screened to discourage mosquito breeding and reproduction, but should be accessible for cleaning, inspection and maintenance.
g) Rooftop drainage systems (e.g., gutter and downspout systems) should be designed as they would be for a building designed without a rainwater harvesting system. Drainage system components leading to the cistern should have a minimum slope of 2% to ensure that harvested rainwater is actually conveyed into the storage tank.
h) Pretreatment is needed to remove debris, dust, leaves and other material that accumulates on rooftops, as it may cause clogging within a rainwater harvesting system. Pretreatment devices that may be used include leaf screens, roof washers and first-flush diverters, each of which are described briefly below:
    i. Leaf Screens*:* Leaf screens are mesh screens installed either in the gutter or downspout that are used to remove leaves and other large debris from rooftop runoff. Leaf screens must be regularly cleaned to be effective. If not regularly maintained, they can become clogged and prevent rainwater from flowing into the storage tank.
    ii. First Flush Diverters*:* First flush diverters direct the initial pulse of stormwater runoff away from the storage tank and into an adjacent pervious area. While leaf screens effectively remove larger debris such as leaves and twigs from harvested rainwater, first flush diverters can be used to remove smaller contaminants such as dust, pollen and bird and rodent feces.

   iii. Roof Washers: Roof washers are placed just ahead of storage tanks and are used to filter small debris from the harvested rainwater. Roof washers consist of a small tank, usually between 25 and 50 gallons in size, with leaf strainers and filters with openings as small as 30 microns. The filter functions to remove very small particulate matter from harvested rainwater. All roof washers must be cleaned on a regular basis. Without regular maintenance, they may not only become clogged and prevent rainwater from entering the storage tank, but may become breeding grounds for bacteria and other pathogens.

i) An overflow pipe should be provided to allow stormwater runoff to bypass the storage tank or cistern when it reaches its storage capacity. The overflow pipe should have a conveyance capacity that is equal to or greater than that of the inflow pipe and should direct excess stormwater runoff to another low impact development practice, such as a vegetated filter strip, grass channel or rain garden.
j) All overflow pipes should be directed away from adjacent buildings to prevent damage to building foundations.
k) Distribution systems may be gravity fed or may include a pump to provide the energy necessary to convey harvested rainwater from the storage tank to its final destination. Rainwater harvesting systems used to provide water for non-potable outdoor uses typically use gravity to feed watering hoses through a tap and spigot arrangement.

4.7.12.5 Construction Considerations

To help ensure that rainwater harvesting systems are successfully installed on a development site, site planning and design teams should consider the following recommendations:

a) Rainwater harvesting systems may be installed on development and redevelopment sites after building rooftops and rooftop drainage systems (e.g., gutter and downspout systems) have been constructed.

4.7.13 Bioretention Areas

4.7.13.1 Description

Bioretention areas (also known as bioretention filters and biofilters), which may also be classified as a stormwater management practice, are shallow depressional areas that are filled with an engineered soil mix and are planted with trees, shrubs and other herbaceous vegetation. They are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration, before being conveyed back into the storm drain system through an underdrain or allowed to infiltrate into the surrounding soils. This allows them to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites.

4.7.13.2 Discussion

Bioretention areas are one of the most effective low impact development practices that can be used in Jasper County to reduce post-construction stormwater runoff rates, volumes and pollutant loads. Bioretention areas differ from rain gardens, in that they are designed to receive stormwater runoff from larger drainage areas and may be equipped with an underdrain.

4.7.13.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by a non-underdrained bioretention area from the runoff reduction volume conveyed through the bioretention area. Subtract 50% of the storage volume provided by an underdrained bioretention area from the runoff reduction volume conveyed through the bioretention area.
b) Water Quality Protection: Subtract 100% of the storage volume provided by a non-underdrained bioretention area from the runoff reduction volume conveyed through the bioretention area. Subtract 50% of the storage volume provided by an underdrained bioretention area from the runoff reduction volume conveyed through the bioretention area.

In order to receive stormwater runoff and be eligible for these credits, bioretention areas must satisfy the planning and design criteria outlined below.

4.7.13.4 Planning and Design Criteria

Information regarding the planning and design of bioretention areas is provided in section pertaining to stormwater management practices (Section 5.5.3.4, page 5-16).

4.7.13.5 Construction Considerations

Information regarding the construction considerations of bioretention areas is provided in the section pertaining to stormwater management practices (Section 5.5.3.5, page 5-18).

4.7.14 Infiltration Practices

4.7.14.1 Description

Infiltration practices, which may also be classified as a stormwater management practice, are shallow excavations, typically filled with stone or an engineered soil mix, that are designed to intercept and temporarily store post-construction stormwater runoff until it infiltrates into the underlying and surrounding soils. If properly designed, they can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Consequently, infiltration practices can be used to meet Jasper County's stormwater management requirements.

4.7.14.2 Discussion

Although infiltration practices can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads, they have historically experienced high rates of failure due to clogging caused by poor design, poor construction and neglected maintenance. If infiltration practices are to be used on a development site, great care should be taken to ensure that they are adequately designed, carefully installed and properly maintained over time. They should only be applied on development sites that have permeable soils (i.e., hydrologic soil group A and B soils) and that have a water table and confining layers (e.g., bedrock, clay lenses) that are located at least 2 feet below the bottom of the trench or basin. Additionally, infiltration practices should always be designed with adequate pretreatment (e.g,. vegetated filter strip, sediment forebay) to prevent sediment from reaching them and causing them to clog and fail.

There are two major variations of infiltration practices, namely infiltration trenches and infiltration basins. A brief description of each of these design variants is provided below:

a) Infiltration Trenches: Infiltration trenches are excavated trenches filled with stone. Stormwater runoff is captured and temporarily stored in the stone reservoir, where it is allowed to infiltrate into the surrounding and underlying native soils. Infiltration trenches can be used to receive stormwater runoff from contributing drainage areas of up to 2 acres in size and should only be used on development sites where sediment loads can be kept relatively low.
b) Infiltration Basins: Infiltration basins are shallow, landscaped excavations filled with an engineered soil mix. They are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration, before being allowed to infiltrate into the surrounding soils. They are essentially non-underdrained bioretention areas, and should also only be used on development sites where sediment loads can be kept relatively low.

4.7.14.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by an infiltration practice from the runoff reduction volume conveyed through the infiltration practice.
b) Water Quality Protection: Subtract 100% of the storage volume provided by an infiltration practice from the runoff reduction volume conveyed through the infiltration practice.

In order to receive stormwater runoff and be eligible for these credits, infiltration practices must satisfy the planning and design criteria outlined below.

4.7.14.4 Planning and Design Criteria

Information regarding the planning and design of infiltration practices is provided in the section pertaining to stormwater management practices (Section 5.5.5.4, page 5-23).

4.7.14.5 Construction Considerations

Information regarding the construction considerations of infiltration practices is provided in the section pertaining to stormwater management practices (Section 5.5.5.5, page 5-26).

4.7.15 Dry Swales

4.7.15.1 Description

Dry swales (also known as bioswales), which may also be classified as a stormwater management practice, are vegetated open channels that are filled with an engineered soil mix and are planted with trees, shrubs and other herbaceous vegetation. They are essentially linear bioretention areas, in that they are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration, before being conveyed back into the storm drain system through an underdrain or allowed to infiltrate into the surrounding soils.

4.7.15.2 Discussion

Dry swales, which may also be classified as a stormwater management practice, are vegetated open channels that are filled with an engineered soil mix and are planted with trees, shrubs and other herbaceous vegetation. They are essentially linear bioretention areas, in that they are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration, before being conveyed back into the storm drain system through an underdrain or allowed to infiltrate into the surrounding soils. This allows them to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Consequently, they can be used to meet Jasper County's stormwater management requirements.

4.7.15.3 Stormwater Management Credits

This low impact development practice has been assigned quantifiable stormwater management credits that can meet Jasper County's stormwater management requirements:

- Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by a non-underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*. Subtract 50% of the storage volume provided by an underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*.
- Water Quality Protection: Subtract 100% of the storage volume provided by a non-underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*. Subtract 50% of the storage volume provided by an underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*.

In order to receive stormwater runoff and be eligible for these credits, dry swales must satisfy the planning and design criteria outlined below.

4.7.15.4 Planning and Design Criteria

Information regarding the planning and design of dry swales is provided in the section pertaining to stormwater management practices (Section 5.5.6.4, page 5-27).

Table 4.1: How Green Infrastructure Practices Can Be Used to Help Satisfy the Stormwater Management Criteria				
Green Infrastructure Practice	**Stormwater Runoff Reduction**	**Water Quality Protection**	**Manual Section**	**Page Number**
Better Site Planning Techniques				
Protect Primary Conservation Areas	**"Credit":** Subtract any *primary and secondary conservations areas* from the total site area when calculating the runoff reduction volume.	**"Credit":** Subtract any *primary and secondary conservations areas* from the total site area when calculating the runoff reduction volume.	4.5.1	4-6
Protect Secondary Conservation Areas			4.5.2	4-8
Better Site Design Techniques				
Reduce Clearing and Grading Limits	**"Credit":** Subtract 50% of any *undisturbed pervious areas* from the total site area when calculating the runoff reduction volume.	**"Credit":** Subtract 50% of any *undisturbed pervious areas* from the total site area when calculating the runoff reduction volume.	4.6.1	4-9
Reduce Roadway Lengths and Widths	**"Credit":** "Self-crediting," in that minimizing the creation of new impervious cover results in a lower volumetric runoff and, consequently, a lower runoff reduction volume.	**"Credit":** "Self-crediting," in that minimizing the creation of new impervious cover results in a lower volumetric runoff and, consequently, a lower runoff reduction volume.	4.6.2	4-10
Use Fewer or Alternative Cul-de-Sacs			4.6.3	4-11
Reduce Parking Lot Footprints			4.6.4	4-12
Create Landscaping Areas in Parking Lots			4.6.5	4-14
Reduce Driveway Lengths and Widths			4.6.6	4-15
Reduce Sidewalk Lengths and Widths			4.6.7	4-15
Reduce Building Footprints			4.6.8	4-16
Reduce Setbacks and Frontages			4.6.9	4-17
Low Impact Development Practices				
Alternatives to Disturbed Pervious Surfaces				
Soil Restoration	**"Credit":** Subtract 50% of any *restored pervious areas* from the total site area and re-calculate the runoff reduction volume.	**"Credit":** Subtract 50% of any *restored pervious areas* from the total site area and re-calculate the runoff reduction volume.	4.7.1	4-18
Site Reforestation/Revegetation	**"Credit":** Subtract 50% of any *reforested/revegetated areas* from the total site area and re-calculate the runoff reduction volume.	**"Credit":** Subtract 50% of any *reforested/revegetated areas* from the total site area and re-calculate the runoff reduction volume.	4.7.2	4-20

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 4.1: How Green Infrastructure Practices Can Be Used to Help Satisfy the Stormwater Management Criteria

Green Infrastructure Practice	Stormwater Runoff Reduction	Water Quality Protection	Manual Section	Page Number
Soil Restoration with Site Reforestation/Revegetation	**"Credit":** Subtract 100% of any *restored and reforested/revegetated areas* from the total site area and re-calculate the runoff reduction volume.	**"Credit":** Subtract 100% of any *restored and reforested/revegetated areas* from the total site area and re-calculate the runoff reduction volume.	4.7.2	4-20
Alternatives to Impervious Surfaces				
Green Roofs	**"Credit":** Reduce the runoff reduction volume conveyed through a *green roof* by 60%.	**"Credit":** Reduce the runoff reduction volume conveyed through a *green roof* by 60%.	4.7.3	4-22
Permeable Pavement No Underdrain	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained *permeable pavement system* from the runoff reduction volume conveyed through the *system.*	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained *permeable pavement system* from the runoff reduction volume conveyed through the *system.*	4.7.4	4-25
Permeable Pavement Underdrain	**"Credit":** Subtract 50% of the storage volume provided by a underdrained *permeable pavement system* from the runoff reduction volume conveyed through the *system.*	**"Credit":** Subtract 50% of the storage volume provided by a underdrained *permeable pavement system* from the runoff reduction volume conveyed through the *system.*	4.7.4	4-25
"Receiving" Low Impact Development Practices				
Undisturbed Pervious Areas, A/B Soils	**"Credit":** Reduce the runoff reduction volume conveyed through an *undisturbed pervious area* located on A/B soils by 90%	**"Credit":** Reduce the runoff reduction volume conveyed through an *undisturbed pervious area* located on A/B soils by 90%	4.7.5	4-29
Undisturbed Pervious Areas, C/D Soils	**"Credit":** Reduce the runoff reduction volume conveyed through an *undisturbed pervious area* located on C/D soils by 60%.	**"Credit":** Reduce the runoff reduction volume conveyed through an *undisturbed pervious area* located on C/D soils by 60%.	4.7.5	4-29

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 4.1: How Green Infrastructure Practices Can Be Used to Help Satisfy the Stormwater Management Criteria

Green Infrastructure Practice	Stormwater Runoff Reduction	Water Quality Protection	Manual Section	Page Number
Vegetated Filter Strips, A/B or Amended Soils	**"Credit":** Reduce the runoff reduction volume conveyed through a *vegetated filter strip* located on A/B or amended soils by 60%	**"Credit":** Reduce the runoff reduction volume conveyed through a *vegetated filter strip* located on A/B or amended soils by 60%	4.7.6	4-31
Vegetated Filter Strips, C/D Soils	**"Credit":** Reduce the runoff reduction volume conveyed through a *vegetated filter strip* located on C/D soils by 30%	**"Credit":** Reduce the runoff reduction volume conveyed through a *vegetated filter strip* located on C/D soils by 30%	4.7.6	4-31
Grass Channels, A/B or Amended Soils	**"Credit":** Reduce the runoff reduction volume conveyed through a *grass channel* located on A/B or amended soils by 25%.	**"Credit":** Reduce the runoff reduction volume conveyed through a *grass channel* located on A/B or amended soils by 25%.	4.7.7	4-34
Grass Channels, C/D Soils	**"Credit":** Reduce the runoff reduction volume conveyed through a *grass channel* located on C/D soils by 12.5%.	**"Credit":** Reduce the runoff reduction volume conveyed through a *grass channel* located on C/D soils by 12.5%.	4.7.7	4-34
Simple Downspout Disconnection, A/B or Amended Soils	**"Credit":** Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on A/B or amended soils by 60%.	**"Credit":** Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on A/B or amended soils by 60%.	4.7.8	4-37
Simple Downspout Disconnection, C/D Soils	**"Credit":** Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on C/D soils by 30%.	**"Credit":** Reduce the runoff reduction volume conveyed through a *simple downspout disconnection* located on C/D soils by 30%.	4.7.8	4-37
Rain Gardens	**"Credit":** Subtract 100% of the storage volume provided by a *rain garden* from the runoff reduction volume conveyed through the *rain garden.*	**"Credit":** Subtract 100% of the storage volume provided by a *rain garden* from the runoff reduction volume conveyed through the *rain garden.*	4.7.9	4-39

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 4.1: How Green Infrastructure Practices Can Be Used to Help Satisfy the Stormwater Management Criteria

Green Infrastructure Practice	Stormwater Runoff Reduction	Water Quality Protection	Manual Section	Page Number
Stormwater Planters	**"Credit":** Subtract 50% of the storage volume provided by a *stormwater planter* from the runoff reduction volume conveyed through the *stormwater planter.*	**"Credit":** Subtract 50% of the storage volume provided by a *stormwater planter* from the runoff reduction volume conveyed through the *stormwater planter.*	4.7.10	4-42
Dry Wells	**"Credit":** Subtract 100% of the storage volume provided by a *dry well* from the runoff reduction volume conveyed through the *dry well.*	**"Credit":** Subtract 100% of the storage volume provided by a *dry well* from the runoff reduction volume conveyed through the *dry well.*	4.7.11	4-45
Rainwater Harvesting	**"Credit":** Subtract 75% of the storage volume provided by a *rainwater harvesting system* from the runoff reduction volume conveyed by the *system.*	**"Credit":** Subtract 75% of the storage volume provided by a *rainwater harvesting system* from the runoff reduction volume conveyed by the *system.*	4.7.12	4-48
Bioretention Areas, No Underdrain	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained *bioretention area* from the runoff reduction volume conveyed through the *bioretention area.*	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained *bioretention area* from the runoff reduction volume conveyed through the *bioretention area.*	4.7.13	4-50
Bioretention Areas, Underdrain	**"Credit":** Subtract 50% of the storage volume provided by a underdrained *bioretention area* from the runoff reduction volume conveyed through the *bioretention area.*	**"Credit":** Subtract 50% of the storage volume provided by a underdrained *bioretention area* from the runoff reduction volume conveyed through the *bioretention area.*	4.7.13	4-50
Infiltration Practices	**"Credit":** Subtract 100% of the storage volume provided by an *infiltration practice* from the runoff reduction volume conveyed through the *infiltration practice.*	**"Credit":** Subtract 100% of the storage volume provided by an *infiltration practice* from the runoff reduction volume conveyed through the *infiltration practice.*	4.7.14	4-51

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 4.1: How Green Infrastructure Practices Can Be Used to Help Satisfy the Stormwater Management Criteria

Green Infrastructure Practice	Stormwater Runoff Reduction	Water Quality Protection	Manual Section	Page Number
Dry Swales, No Underdrain	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*.	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*.	4.7.15	4-52
Dry Swales, Underdrain	**"Credit":** Subtract 100% of the storage volume provided by an underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*.	**"Credit":** Subtract 100% of the storage volume provided by an underdrained *dry swale* from the runoff reduction volume conveyed through the *dry swale*.	4.7.15	4-52

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 4.2: Factors to Consider When Evaluating the Overall Feasibility of Green Infrastructure Practices

Green Infrastructure Practice	Drainage Area	Area Required	Slope	Minimum Head	Minimum Depth to Water Table	Soils	Manual Section	Page Number
Better Site Planning Techniques								
Protect Primary Conservation Areas	N/A	10,000 SF minimum to receive stormwater management "credits"	No restrictions	N/A	N/A	No restrictions	4.5.1	4-6
Protect Secondary Conservation Areas	N/A	10,000 SF minimum to receive stormwater management "credits"	Protect slopes >15%	N/A	N/A	Protect erodible soils	4.5.2	4-8
Better Site Design Techniques								
Reduce Clearing and Grading Limits	N/A	No restrictions	No restrictions	N/A	N/A	No restrictions	4.6.1	4-9
Reduce Roadway Lengths and Widths	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.2	4-10
Use Fewer or Alternative Cul-de-Sacs	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.3	4-11
Reduce Parking Lot Footprints	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.4	4-12
Create Landscaping Areas in Parking Lots	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.5	4-14
Reduce Driveway Lengths and Widths	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.6	4-15
Reduce Sidewalk Lengths and Widths	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.7	4-15
Reduce Building Footprints	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.8	4-16
Reduce Setbacks and Frontages	N/A	N/A	No restrictions	N/A	N/A	No restrictions	4.6.9	4-17
Low Impact Development Practices								
Alternatives to Disturbed Pervious Surfaces								
Soil Restoration	N/A	No restrictions	10% maximum	N/A	1.5 FT	Restore hydrologic soil group C/D or disturbed soils	4.7.1	4-18

*Refer to Section 4-4 (page 4-X) for a description of the feasibility factors.

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual

Table 4.2: Factors to Consider When Evaluating the Overall Feasibility of Green Infrastructure Practices

Green Infrastructure Practice	Drainage Area	Area Required	Slope	Minimum Head	Minimum Depth to Water Table	Soils	Manual Section	Page Number
Site Reforestation / Revegetation	N/A	10,000 SF minimum to receive stormwater management "credits"	25% maximum	N/A	No restrictions	No restrictions	4.7.2	4-20
Alternatives to Impervious Surfaces								
Green Roofs	N/A	No restrictions	25% maximum, although 10% or less is recommended	6 to 12 inches	N/A	Use appropriate engineered growing media	4.7.3	4-22
Permeable Pavement	N/A	No restrictions	6% maximum	2 to 4 feet	2 feet	Should drain within 48 hours of end of rainfall event	4.7.4	4-25
"Receiving" Low Impact Development Practices								
Undisturbed Pervious Areas	Length of flow path in contributing drainage area maximum 75 to 150 feet long	Length of flow path in undisturbed pervious area minimum 50 feet long	Maximum 3% in contributing drainage area: 0.5% to 6% in undisturbed pervious area	N/A	No restrictions	No restrictions	4.7.5	4-29
Vegetated Filter Strips	Length of flow path in contributing drainage area maximum 75 to 150 feet long	Length of flow path in vegetated filter strip minimum 15 to 25 feet long	Maximum 3% in contributing drainage area: 0.5% to 6% in vegetated filter strip	N/A	No restrictions	No restrictions	4.7.6	4-31
Grass Channels	5 acres	Bottom of grass channel 2 to 8 feet wide; side slopes of 3:1 or flatter	0.5% to 3%, although 1% to 2% is recommended	N/A	2 feet	No restrictions	4.7.7	4-34
Simple Downspout Disconnection	2,500 square feet; length of flow path in contributing drainage area maximum 75 feet long	Length of flow path at least 15 feet long and equal to or greater than that of contributing drainage area	0.5% to 6%, although 1% to 5% is recommended	N/A	No restrictions	No restrictions	4.7.8	4-37

*Refer to Section 4-4 (page 4-X) for a description of the feasibility factors.

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual

Table 4.2: Factors to Consider When Evaluating the Overall Feasibility of Green Infrastructure Practices

Green Infrastructure Practice	Drainage Area	Area Required	Slope	Minimum Head	Minimum Depth to Water Table	Soils	Manual Section	Page Number
Rain Gardens	2,500 square feet; length of flow path in contributing drainage area maximum 75 to 150 feet long	10-20% of contributing drainage area	6% maximum	30 to 36 inches	2 feet	Should drain within 24 hours of end of rainfall event	4.7.9	4-39
Stormwater Planters	2,500 square feet; length of flow path in contributing drainage area maximum 75 to 150 feet long	5% of contributing drainage area	6% maximum	30 to 36 inches	2 feet	Should drain within 24 hours of end of rainfall event	4.7.10	4-42
Dry Wells	2,500 square feet; length of flow path in contributing drainage area maximum 75 to 150 feet long	5-10% of contributing drainage area	6% maximum	2 feet	2 feet	Should drain within 24 hours of end of rainfall event	4.7.11	4-42
Rainwater Harvesting	No restrictions	Varies according to the dimensions of the rain tank or cistern used to store the harvested rainwater	No restrictions	N/A	N/A	N/A	4.7.12	4-48
Bioretention Areas	5 acres	5-10% of contributing drainage area	6% maximum	42 to 48 inches	2 feet	Should drain within 48 hours of end of rainfall event	4.7.13	4-50
Infiltration Practices	2 to 5 acres	5% of contributing drainage area	6% maximum	42 to 48 inches	2 feet	Should drain within 48 hours of end of rainfall event	4.7.14	4-51
Dry Swales	5 acres	5-10% of contributing drainage area	0.5% to 4%, although 1% to 2% is recommended	36 to 48 inches	2 feet	Should drain within 48 hours of end of rainfall event	4.7.15	4-52

*Refer to Section 4-4 (page 4-X) for a description of the feasibility factors.

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual

Table 4.3: Factors to Consider When Evaluating the Applicability of Green Infrastructure on a Development Site

Green Infrastructure Practice	Rural Use	Suburban Use	Urban Use	Construction Cost	Maintenance	Manual Section	Page Number
Better Site Planning Techniques							
Protect Primary Conservation Areas	✓	✓	✱	Low	Low	4.5.1	4-6
Protect Secondary Conservation Areas	✓	✓	✱	Low	Low	4.5.2	4-8
Better Site Design Techniques							
Reduce Clearing and Grading Limits	✓	✓	✓	Low	Low	4.6.1	4-9
Reduce Roadway Lengths and Widths	✓	✓	✱	None	None	4.6.2	4-10
Use Fewer or Alternative Cul-de-Sacs	✓	✓	✱	None	None	4.6.3	4-11
Reduce Parking Lot Footprints	✱	✓	✓	None	None	4.6.4	4-12
Create Landscaping Areas in Parking Lots	✱	✓	✓	None	None	4.6.5	4-14
Reduce Driveway Lengths and Widths	✓	✓	✱	None	None	4.6.6	4-15
Reduce Sidewalk Lengths and Widths	✱	✓	✓	None	None	4.6.7	4-15
Reduce Building Footprints	✱	✓	✓	None	None	4.6.8	4-16
Reduce Setbacks and Frontages	✓	✓	✱	None	None	4.6.9	4-17

Notes:

✓ = Suitable for use on development sites located in these areas

✱ = Under certain situations, can be used on development sites located in these areas.

N/A = Not applicable.

*Refer to Section 4-4 (page 4-X) for a description of the applicable factors.

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual

Table 4.3: Factors to Consider When Evaluating the Applicability of Green Infrastructure on a Development Site

Green Infrastructure Practice	Rural Use	Suburban Use	Urban Use	Construction Cost	Maintenance	Manual Section	Page Number
Low Impact Development Practices **Alternatives to Disturbed Pervious Surfaces**							
Soil Restoration	✓	✓	✓	Medium	Low	4.7.1	4-18
Site Reforestation / Revegetation	✓	✓	✱	Medium	Low	4.7.2	4-20
Alternatives to Impervious Surfaces							
Green Roofs	✱	✓	✓	High	Low	4.7.3	4-22
Permeable Pavement	✱	✓	✓	High	High	4.7.4	4-25
"Receiving" Low Impact Development Practices							
Undisturbed Pervious Areas	✓	✓	N/A	Low	Low	4.7.5	4-29
Vegetated Filter Strips	✓	✓	✱	Low	Low	4.7.6	4-31
Grass Channels	✓	✓	N/A	Low	Medium	4.7.7	4-34
Simple Downspout Disconnection	✓	✓	✱	Low	Low	4.7.8	4-37
Rain Gardens	✓	✓	✱	Low	Medium	4.7.9	4-39
Stormwater Planters		✓	✓	High	Medium	4.7.10	4-42
Dry Wells	✓	✓	✓	Medium	Medium	4.7.11	4-42
Rainwater Harvesting	✓	✓	✓	Medium	High	4.7.12	4-48
Bioretention Areas	✓	✓	✓	Medium	Medium	4.7.13	4-50
Infiltration Practices	✓	✓	✓	Medium	High	4.7.14	4-51
Dry Swales	✓	✓	✱	Medium	Medium	4.7.15	4-52

Notes:

✓ = Suitable for use on development sites located in these areas

✱ = Under certain situations, can be used on development sites located in these areas.

N/A = Not applicable.

*Refer to Section 4-4 (page 4-X) for a description of the applicable factors.

*Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual

5.0 Stormwater Management Practices

5.1 Overview

Stormwater management practices (also known as structural stormwater controls, structural stormwater best management practices or structural stormwater BMPs) are engineered facilities designed to intercept and manage post-construction stormwater runoff rates, volumes and pollutant loads. Together with green infrastructure practices, which can be used to help prevent increases in post-construction stormwater runoff rates, volumes and pollutant loads, stormwater management practices can be used to help control and minimize the negative impacts of land development and nonpoint source pollution. Stormwater management practices can be used whenever green infrastructure practices cannot be used to completely satisfy Jasper County's stormwater management requirements.

This Section provides additional information about using stormwater management practices to help meet Jasper County's stormwater management requirements.

5.2 Recommended Stormwater Management Practices

The stormwater management practices *recommended* for use in Jasper County have been divided into two groups: (1) general application practices (also known as *general application controls*); and (2) limited application practices (also known as *limited application controls* or *detention controls*). Each of these groups is briefly described below.

5.2.1 General Application Practices

General application practices can be used to treat stormwater runoff and manage the post-construction stormwater runoff rates and volumes generated by larger, less frequent rainfall events. Several of these practices, namely bioretention areas, infiltration practices and dry swales, can also be used to reduce post-construction stormwater runoff volumes and are also classified as runoff reducing low impact development practices.

Since they can be used to both treat and manage post-construction stormwater runoff, it is recommended that general application practices be used whenever green infrastructure practices cannot be used to completely satisfy the stormwater runoff reduction and stormwater quality protection requirements. The general application practices recommended for use in Jasper County include:

5.2.1.1 Stormwater Ponds

Stormwater ponds are stormwater detention basins that have a permanent pool of water. Post-construction stormwater runoff is conveyed into the pool, where it is both detained and treated over an extended period of time. The types of stormwater ponds that are recommended for use in Jasper County include:

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

5.2.1.2 Stormwater Wetlands

Stormwater wetlands are constructed wetland systems built for stormwater management purposes. Stormwater wetlands typically consist of a combination of open water, shallow marsh and semi-wet areas, and can be used to both detain and treat post-construction stormwater runoff. The types of stormwater wetlands that are recommended for use in Jasper County include:

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

5.2.1.3 Bioretention Areas

Bioretention areas, which may also be classified as a low impact development practice, are shallow depressional areas that use an engineered soil mix and vegetation to intercept and treat post-construction stormwater runoff. After passing through a bioretention area, stormwater runoff may be returned to the stormwater conveyance system through an underdrain, or may be allowed to fully or partially infiltrate into the surrounding soils.

5.2.1.4 Filtration Practices

Filtration practices are multi-chamber structures designed to treat post-construction stormwater runoff using the physical processes of screening and filtration. Sand is typically used as the filter media. After passing through a filtration practice, stormwater runoff is typically returned to the conveyance system through an underdrain. The filtration practices that are recommended for use in Jasper County include:

- Surface Sand Filter
- Perimeter Sand Filter

5.2.1.5 Infiltration Practices

Infiltration practices, which may also be classified as a runoff reducing low impact development practice, are shallow excavations, typically filled with stone or an engineered soil mix, that are designed to intercept and temporarily store post-construction stormwater runoff until it infiltrates into the surrounding soils. The infiltration practices that are recommended for use in Jasper County include:

- Infiltration Trench
- Infiltration Basin

5.2.1.6 Swales

Swales are vegetated open channels that are designed to manage post-construction stormwater runoff within wet or dry cells formed by check dams or other control structures (e.g., culverts). The two types of swales that are recommended for use in Jasper County include:

- Dry Swale
- Wet Swale

Because of their ability to reduce annual stormwater runoff volumes and pollutant loads, dry swales may also be classified as a low impact development practice.

5.2.2 Limited Application Practices

There are two groups of limited application stormwater management practices that can be used in Jasper County, each of which is briefly described below:

5.2.2.1 Water Quantity Management Practices

Water quantity management practices can only be used to manage the post-construction stormwater runoff rates and volumes generated by larger, less frequent rainfall events. They provide little, if any, stormwater runoff reduction or stormwater treatment. Consequently, it is recommended that they be used only on a limited basis, and only when green infrastructure practices and general application stormwater management practices cannot be used to completely satisfy Jasper County's water quality management requirements. The water quantity management practices that may be used in Jasper County include:

- Dry Detention Basins
- Dry Extended Detention Basins
- Multi-Purpose Detention Areas
- Underground Detention Systems

5.2.2.2 Water Quality Management Practices

Water quality management practices can only be used to treat post-construction stormwater runoff. They typically have high or special maintenance requirements, provide little, if any, stormwater runoff reduction, and cannot be used to manage the post-construction stormwater runoff rates and volumes generated by larger, less frequent rainfall events. Consequently, they can only be on a limited basis, and only when green infrastructure practices and general stormwater management application practices cannot be used to completely satisfy Jasper County's stormwater runoff reduction and stormwater quality protection requirements. The water quality management practices that may be used in Jasper County include:

- Organic Filters
- Underground Filters
- Submerged Gravel Wetlands
- Gravity (Oil-Grit) Separators
- Alum Treatment Systems
- Proprietary Systems

5.3 Other Stormwater Management Practices

5.3.1 Not Recommended Stormwater Management Practices

Proprietary catch basin inserts and media filter systems are not allowed for new development and redevelopment in Jasper County. These proprietary devices tend to clog very easily and typically carry a very high long-term maintenance burden. Although they are not allowed for use on new development and redevelopment sites, these proprietary devices may be used in retrofit applications where surface space is at a premium.

5.3.2 New and Innovative Stormwater Management Practices

The use of new and innovative stormwater management practices is encouraged in Jasper County, provided that their ability to satisfy stormwater management design criteria has been sufficiently documented. At its discretion, the DSR may allow for the use of a stormwater management practice that is not discussed in this manual. However, the DSR will not approve practices not described in this manual without reliable information about performance, design, and maintenance requirements.

5.4 Stormwater Management Practices Selection

In general, the following information should be considered when deciding what stormwater management practices can be used on a development site:

- Ability to Help Satisfy the Stormwater Management Criteria
- Overall Feasibility
- Site Applicability

In addition, the following site characteristics and constraints, which are commonly encountered in Jasper County should be considered and will influence the use of stormwater management practices on a development site:

- Poorly drained soils, such as hydrologic soil group C and D soils
- Well drained soils, such as hydrologic soil group A and B soils
- Flat terrain
- Shallow water table
- Tidally-influenced drainage

5.4.1 Evaluate Overall Feasibility

The overall feasibility of each stormwater management practice should be assessed. Additional information about the following feasibility categories is included in Table 5.2 (pages 5-42 to 5-44):

a) Drainage Area: This column describes how large of a contributing drainage area each stormwater management practice can realistically handle. It indicates the maximum size of the contributing drainage area that each stormwater management practice should be designed to receive stormwater runoff from.
b) Area Required: This column indicates how much space the stormwater management practice typically consumes on a development site.
c) Slope: This column describes the influence that site slope can have on the performance of the stormwater management practice. It indicates the maximum or minimum slope on which the stormwater management practice can be installed.
d) Minimum Head: This column provides an estimate of the minimum amount of elevation difference needed within the stormwater management practice, from the inflow to the outflow, to allow for gravity operation.
e) Minimum Depth to Water Table: This column indicates the minimum distance that should be provided between the bottom of the stormwater management practice and the top of the water table.
f) Soils: This column describes the influence that the underlying soils (i.e., hydrologic soil groups) can have on the performance of the stormwater management practice.

5.4.2 Evaluate Site Applicability

The applicability of the stormwater management practices on a particular development site should be evaluated. Additional information about the following applicable categories is included in Table 5.3 (page 5-47 to 5-48).

a) Rural Use: This column indicates whether or not the stormwater management practice is suitable for use in rural areas and on low-density development sites.
b) Suburban Use: This column indicates whether or not the stormwater management practice is suitable for use in suburban areas and on medium-density development sites.
c) Urban Use: This column identifies the stormwater management practices that are suitable for use in urban and ultra-urban areas where space is at a premium.
d) Construction Cost: This column assess the relative construction cost of each of the stormwater management practices.
e) Maintenance: This column assesses the relative maintenance burden associated with each stormwater management practice. It is important to note that all stormwater management practices require some kind of routine inspection and maintenance.

5.5 General Application Stormwater Management Practices

This section contains information about the general application of stormwater management practices that are recommended for use in Jasper County. Each stormwater management practice is described, and the applicability and design is discussed, and information about how they can be used to help satisfy Jasper County's stormwater management requirements is presented. The stormwater management practices profiled in this section include:

- Stormwater Ponds
- Stormwater Wetlands
- Bioretention Areas
- Filtration Practices
- Infiltration Practices
- Swales

5.5.1 Stormwater Ponds

5.5.1.1 Description

Stormwater ponds (also known as retention ponds, wet ponds, or wet extended detention ponds) are stormwater detention basins that are designed to have a permanent pool of water (i.e., dead storage) throughout the year. Post-construction stormwater runoff is conveyed into the pool, where it is detained and treated over an extended period of time, primarily through gravitational settling and biological uptake, until it is displaced by stormwater runoff from the next rain event. The permanent pool also helps protect deposited sediments from resuspension. Above the permanent pool, temporary storage (i.e., live storage) can be provided above the permanent pool for stormwater quantity control. This allows stormwater ponds to both treat stormwater runoff and manage the stormwater runoff rates and volumes generated by larger, less frequent rainfall events on development sites.

5.5.1.2 Discussion

Stormwater ponds treat post-construction stormwater runoff through a combination of physical, chemical and biological processes. The primary pollutant removal mechanism at work is gravitational settling, which works to remove particulate matter, organic matter, metals and bacteria as stormwater runoff is conveyed through the permanent pool. Another primary pollutant removal mechanism at work in stormwater ponds is biological uptake of nutrients by algae and wetland vegetation. Volatilization and other chemical processes also work to break down and eliminate a number of other stormwater pollutants (e.g., hydrocarbons) in stormwater ponds.

Figure 5-1
Stormwater Pond
Source: North Carolina State University-Biological & Agricultural Engineering

Stormwater ponds are among the most common stormwater management practices used in Jasper County and the rest of the United States. They are typically created by excavating a depressional area to create “dead storage” below the water surface elevation of the receiving storm drain system, stream or other aquatic resource. A well-designed pond can be attractively integrated into a development site as a landscaping feature and, if appropriately designed, sited and landscaped, can provide some wildlife habitat. However, caution should be used when siting a stormwater pond. Ponds should be designed to not negatively impact any primary conservation areas or other natural resources. Other potential drawbacks associated with stormwater ponds should also be considered, including their potential to become a source of mosquitoes and harmful algal blooms.

There are several variations of stormwater ponds that can be used to manage post-construction stormwater runoff on development sites, the most common of which include wet ponds, wet extended detention ponds and micropool extended detention ponds. In addition, multiple stormwater ponds can be placed in series or parallel to increase storage capacity or address specific site characteristics or constraints (e.g., flat terrain). A brief description of each of these design variants is provided below:

a) Wet Ponds: Wet ponds are stormwater detention basins that are designed to have a permanent pool that provides enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event. Stormwater runoff is conveyed into the pool, where it is detained and treated over an extended period of time, primarily through gravitational settling and biological uptake, until it is displaced by stormwater runoff from the next rain event. Additional temporary storage (i.e., live storage) can be provided above the permanent pool for stormwater quantity control.
b) Wet Extended Detention (ED) Ponds: Wet extended detention ponds are wet ponds that are designed to have a permanent pool that provides enough storage for approximately 50% of the stormwater runoff volume generated by the runoff reduction rainfall event. The remainder of the stormwater runoff volume generated by the runoff reduction rainfall event is managed in an extended detention zone provided immediately above the permanent pool. During wet weather, stormwater runoff is detained in the extended detention zone and released over a 24-hour period.
c) Micropool Extended Detention (ED) Ponds: Micropool extended detention ponds are a variation of the standard wet extended detention pond that have only a small permanent pool (i.e., micropool). The “micropool” provides enough storage for approximately 10% of the stormwater runoff volume generated by the target runoff reduction rainfall event. The remainder of the stormwater runoff volume generated by the target runoff reduction rainfall event is managed in an extended detention zone

provided immediately above the "micropool" and released over an extended 24-hour period.

d) Multiple Pond Systems: Multiple pond systems consist of a series of two or more wet ponds, wet extended detention ponds or micropool extended detention ponds. The additional cells can increase the storage capacity provided on a development or redevelopment site.

5.5.1.3 Stormwater Management Credits

Stormwater ponds have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: None. Although stormwater ponds provide moderate to high removal of many of the pollutants of concern typically contained in post-construction stormwater runoff, recent research shows that they provide little, if any, reduction of post-construction stormwater runoff volumes. Although stand-alone stormwater ponds cannot be used to help satisfy the stormwater runoff reduction criteria, stormwater ponds may be used as "cisterns" in large-scale rainwater harvesting systems, which help reduce post-construction stormwater runoff volumes on a development site.

b) Water Quality Protection: Assume that a stormwater pond provides an 80% reduction in TSS loads, a 30% reduction in TN loads and a 70% reduction in bacterial loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, stormwater ponds must satisfy the planning and design criteria outlined below.

5.5.1.4 Planning and Design Criteria

a) General Design

   i. Stormwater ponds should have a minimum contributing drainage area of 25 acres or more for wet pond or wet ED pond to maintain a permanent pool. For a micropool ED pond, the minimum drainage area is 10 acres. A smaller drainage area can be considered when water availability can be confirmed (such as from a groundwater source or areas with a high water table). Ensure that an appropriate anti-clogging device is provided for the pond outlet.
   ii. A stormwater pond should be sited such that the topography allows for maximum runoff storage at minimum excavation or construction costs. Pond siting should also take into account the location and use of other site features such as buffers and undisturbed natural areas and should attempt to aesthetically "fit" the facility into the landscape.
   iii. Stormwater ponds should not be located on steep (>15%) or unstable slopes.
   iv. Stormwater ponds cannot be located within a stream or any other navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and possibly other applicable State and local permits.
   v. Minimum setback requirements for stormwater pond facilities:
      - From a property line - 10 feet
      - From a private well - 100 feet
      - From a septic system tank/leach field - 50 feet
   vi. All utilities should be located outside of the pond/basin site.
   vii. A well-designed stormwater pond consists of:
      - Permanent pool of water,
      - Overlying zone in which runoff control volumes are stored, and

    - Shallow littoral zone (aquatic bench) along the edge of the permanent pool that acts as a biological filter.

viii. In addition, all stormwater pond designs need to include a sediment forebay at the inflow to the basin to allow heavier sediments to drop out of suspension before the runoff enters the permanent pool.

ix. Additional pond design features include an emergency spillway, maintenance access, safety bench, pond buffer, and appropriate native landscaping.

b) Physical Specifications / Geometry

In general, pond designs are unique for each site and application. However, there are a number of geometric ratios and limiting depths for pond design that must be observed for adequate pollutant removal, ease of maintenance, and improved safety.

i. Proper geometric design is essential to prevent hydraulic short-circuiting (unequal distribution of inflow), which results in the failure of the pond to achieve adequate levels of pollutant removal. The minimum length-to-width ratio for the permanent pool shape is 1.5:1, and should ideally be greater than 3:1 to avoid short-circuiting. In addition, ponds should be wedge-shaped when possible so that flow enters the pond and gradually spreads out, improving the sedimentation process. Baffles, pond shaping or islands can be added within the permanent pool to increase the flow path.

ii. Maximum depth of the permanent pool should generally not exceed 8 feet to avoid stratification and anoxic conditions. Minimum depth for the pond bottom should be 3 to 4 feet. Deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects.

iii. Side slopes to the pond should not usually exceed 3: 1 (h:v) without safety precautions or if mowing is anticipated and should terminate on a safety bench.

iv. The perimeter of all deep pool areas (4 feet or greater in depth) should be surrounded by two benches: safety and aquatic. For larger ponds, a safety bench extends approximately 15 feet outward from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench should be 6%. An aquatic bench extends inward from the normal pool edge (15 feet on average) and has a maximum depth of 18 inches below the normal pool water surface elevation.

v. The contours and shape of the permanent pool should be irregular to provide a more natural landscaping effect.

c) Pretreatment / Inlets

i. Each pond should have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal in a larger permanent pool. The forebay should consist of a separate cell, formed by an acceptable barrier. A forebay is to be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond.

ii. A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.

iii. Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the pond can be partially or totally submerged. Exit velocities from the forebay must be nonerosive.

d) Outlet Structures

i. Flow control from a stormwater pond is typically accomplished with the use of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the pond with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment. The riser should be located within the embankment for maintenance access, safety and aesthetics.

- ii. A number of outlets at varying depths in the riser provide flow control. The number of orifices can vary and is usually a function of the pond design. Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, v-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.
- iii. Higher flows pass through openings or slots protected by trash racks further up on the riser.
- iv. After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars may be installed on the outlet barrel to reduce the potential for pipe failure.
- v. Riprap, plunge pools or pads, or other energy dissipators are to be placed at the outlet of the barrel to prevent scouring and erosion.

e) Emergency Spillway

- i. An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
- ii. A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the 100-year flood event to the lowest point of the dam embankment, not counting the emergency spillway.

f) Safety Features

- i. Fencing of ponds is not generally desirable. A preferred method is to manage the contours of the pond through the inclusion of a safety bench (see above) to eliminate dropoffs and reduce the potential for accidental drowning. In addition, the safety bench may be landscaped to deter access to the pool.
- ii. The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent access. Warning signs should be posted near the pond to prohibit swimming and fishing in the facility.

g) Landscaping

- i. Aquatic vegetation can play an important role in pollutant removal in a stormwater pond. In addition, vegetation can enhance the appearance of the pond, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a pond design, along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED ponds), and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation.
- ii. Woody vegetation may not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- iii. A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas that are required by other regulations or that are part of the overall

stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided.

iv. Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.
v. The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.
vi. A fountain or solar-powered aerator may be used for oxygenation of water in the permanent pool.
vii. Compatible multi-objective use of stormwater pond locations is strongly encouraged.

5.5.1.5 Construction Considerations

To help ensure that stormwater ponds are successfully installed on a development site, the following are recommended:

a) Because stormwater ponds are typically installed early in the construction phase, they may accumulate a significant amount of sediment during construction. Any accumulated sediment should be removed from stormwater ponds near the end of the construction phase.
b) To help prevent excessive sediment accumulation, stormwater runoff may be diverted around the stormwater pond until the contributing drainage area has become stabilized.
c) Sediment markers should be installed in forebays and permanent pools to help determine when sediment removal is needed.

5.5.2 Stormwater Wetlands

5.5.2.1 Description

Figure 5-2
Stormwater Wetland
Source: F. X. Browne, Inc.

Stormwater wetlands (also known as constructed wetlands) are constructed wetland systems built for stormwater management purposes. They typically consist of a combination of open water, shallow marsh and semi-wet areas that are located just above the permanent water surface. As stormwater runoff flows through a wetland, it is treated, primarily through gravitational settling and biological uptake. Temporary storage (i.e., live storage) can be provided above the permanent water surface for stormwater quantity control. This allows wetlands to both treat stormwater runoff and manage the stormwater runoff rates and volumes generated by larger rainfall events.

5.5.2.2 Discussion

Stormwater wetlands treat post-construction stormwater runoff through a combination of physical, chemical and biological processes. The primary pollutant removal mechanisms at work in stormwater wetlands are biological uptake, physical screening and gravitational settling. Other pollutant removal mechanisms at work in stormwater wetlands include volatilization and other biological and chemical processes.

Stormwater wetlands are among the most effective stormwater management practices that can be used Jasper County and the rest of the United States. They are typically created by excavating a depressional area to create “dead storage” below the water surface elevation of the receiving storm drain system, stream or other aquatic resource. A well-designed stormwater wetland can be attractively integrated into a development site as a landscaping feature and, if appropriately designed, sited and landscaped, can provide valuable wildlife habitat. Stormwater wetlands differ from natural wetland systems in that they are engineered facilities designed specifically for the purpose of managing post-construction stormwater runoff. They typically have less biodiversity than natural wetlands in terms of both plant and animal life but, like natural wetlands, require continuous base flow or a high water table to maintain a permanent water surface and support the growth of aquatic vegetation.

There are several variations of stormwater wetlands that can be used to manage post-construction stormwater runoff on development sites, including shallow wetlands, shallow extended detention wetlands and pocket wetlands. In addition, stormwater wetlands can be used in combination with stormwater ponds to increase storage capacity or address specific site characteristics or constraints (e.g., flat terrain). A brief description of each of these design variants is provided below:

a) Shallow Wetlands: In a shallow wetland, most of the storage volume provided by the wetland is contained in some relatively shallow high marsh and low marsh areas. The only deep water areas found within a shallow wetland are the forebay, which is located at the entrance to the wetland, and the micropool, which is located at the outlet. One disadvantage to the shallow wetland design is that, since most of the storage volume is provided in the relatively shallow high marsh and low marsh areas, a large amount of land may be needed to provide enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event.

b) Shallow Extended Detention (ED) Wetlands: A shallow extended detention wetland is essentially the same as a shallow wetland, except that approximately 50% of the stormwater runoff volume generated by the runoff reduction rainfall event is managed in an extended detention zone provided immediately above the permanent water surface. During wet weather, stormwater runoff is detained in the extended detention zone and released over a 24-hour period. Although this design variant requires less land than the shallow wetland design variant, it can be difficult to establish vegetation within the extended detention zone due to the fluctuating water surface elevations found within.

c) Pond/Wetland Systems: A pond/wetland system has two separate cells, one of which is a wet pond and the other of which is a shallow wetland. The wet pond cell is used to trap sediment and reduce stormwater runoff velocities upstream of the shallow wetland cell. Less land is typically required for pond/wetland systems than for shallow wetlands or shallow extended detention wetlands.

d) Pocket Wetlands: Pocket wetlands can be used to intercept and manage stormwater runoff from relatively small drainage areas of up to about 10 acres in size. In order to ensure that they have a permanent water surface throughout the year, they are typically designed to interact with the groundwater table.

5.5.2.3 Stormwater Management Credits

Stormwater wetlands have been assigned quantifiable stormwater management credits that can be used to meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: None. Although stormwater wetlands provide moderate to high removal of many of the pollutants of concern typically contained in post-construction stormwater runoff, recent research shows that they provide little, if any, reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that a stormwater wetland provides an 80% reduction in TSS loads, a 30% reduction in TN loads and an 80% reduction in bacteria loads.

5.5.2.4 Planning and Design Criteria

a) Location and Siting
    i. Stormwater wetlands should normally have a minimum contributing drainage area of 25 acres or more. For a pocket wetland, the minimum drainage area is 5 acres.
    ii. A continuous base flow or high water table is required to support wetland vegetation.
    iii. Wetland siting should also take into account the location and use of other site features such as natural depressions, buffers, and undisturbed natural areas, and should attempt to aesthetically "fit" the facility into the landscape.
    iv. Stormwater wetlands cannot be located within navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and other state and local permits.
    v. If possible, a wetland should be designed as an off-line system to bypass higher flows rather than passing them through the wetland system.
    vi. Minimum setback requirements for stormwater facilities (when not specified by local ordinance or criteria):
        - From a property line – 10 feet
        - From a private well – 100 feet
        - From a septic system tank / leach field – 50 feet
    vii. All utilities should be located outside of the wetland site.

b) General Design
    i. A well-designed stormwater wetland consists of:
        - Shallow marsh areas of varying depths with wetland vegetation,
        - Permanent micropool, and
        - Overlying zone in which runoff control volumes are stored.
    ii. In addition, all wetland designs must include a sediment forebay at the inflow to the facility to allow heavier sediments to drop out of suspension before the runoff enters the wetland marsh.
    iii. Additional pond design features include an emergency spillway, maintenance access, safety bench, wetland buffer, and appropriate wetland vegetation and native landscaping.

c) Physical Specifications / Geometry
    i. The stormwater wetland should be designed with the recommended proportion of depth zones. Each of the four wetland design variants has depth zone allocations which are given as a percentage of the stormwater wetland surface area. The four basic depth zones are:

    - Deepwater Zone: From 1.5 to 6 feet deep. Includes the outlet micropool and deepwater channels through the wetland facility. This zone supports little emergent wetland vegetation, but my support submerged or floating vegetation.
    - Low Marsh Zone: From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growth of several emergent wetland plant species.
    - High Marsh Zone: From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.
    - Semi-wet Zone: Those areas above the permanent pool that are inundated during larger storm events. This zone supports a number of species that can survive flooding.
  - ii. A minimum dry weather flow path of 2:1 (length and width) is required from inflow to outlet across the stormwater wetland and should ideally be greater than 3:1. This path may be achieved by constructing internal dikes or berms, using marsh plantings, and by using multiple cells. Finger dikes are commonly used in surface flow systems to create serpentine configurations and prevent short-circuiting. Microtopography (contours along the bottom of a wetland or marsh that provide a variety of conditions for different species needs and increases the surface area to volume ratio) is encouraged to enhance wetland diversity.
  - iii. A 4- to 6-foot deep micropool must be included in the design at the outlet to prevent the outlet from clogging and resuspension of sediments, and to mitigate thermal effects.
  - iv. Maximum depth of any permanent pool areas should generally not exceed 6 feet.
  - v. The perimeter of all deep pool areas (4 feet or greater in depth) should be surrounded by safety and aquatic benches similar to those for stormwater ponds.
  - vi. The contours of the wetland should be irregular to provide a more natural landscaping effect.

- d) Pretreatment / Inlets
  - i. Sediment regulation is critical to sustain stormwater wetlands. A wetland facility should have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay should consist of a separate cell, formed by an acceptable barrier. A forebay is to be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the wetland facility.
  - ii. A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
  - iii. Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the pond can be partially or totally submerged. Exit velocities from the forebay must be nonerosive.

- e) Outlet Structures
  - i. Flow control from a stormwater wetland is typically accomplished with the use of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the micropool with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment. The riser should be located within the embankment for maintenance access, safety and aesthetics.

ii. A number of outlets at varying depths in the riser provide flow control. The number of orifices can vary and is usually a function of the pond design.

For shallow and pocket wetlands, the riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period. Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet pond, it simply displaces that same volume through the channel protection orifice. Thus an off-line shallow or pocket wetland providing *only* water quality treatment can use a simple overflow weir as the outlet structure.

Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

iii. Higher flows pass through openings or slots protected by trash racks further up on the riser.

iv. After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars may be installed on the outlet barrel to reduce the potential for pipe failure.

v. Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the outlet of the barrel to prevent scouring and erosion.

f) Emergency Spillway
   i. An emergency spillway is to be included in the stormwater wetland design to safely pass flows that exceed the design storm flows. The spillway prevents the wetland's water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
   ii. A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the 100-year flood event to the lowest point of the wetland embankment, not counting the emergency spillway.

g) Safety Features
   i. Fencing of wetlands is not generally desirable. A preferred method is to manage the contours of deep pool areas through the inclusion of a safety bench to eliminate drop-offs and reduce the potential for accidental drowning.
   ii. The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.

h) Landscaping
   i. A landscaping plan should be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of landscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material.
   ii. Landscaping zones include low marsh, high marsh, and semi-wet zones. The low marsh zone ranges from 6 to 18 inches below the normal pool. This zone is suitable for the growth of several emergent plant species. The high marsh zone ranges from 6 inches below the pool up to the normal pool. This zone will support greater density and diversity of emergent wetland plant species. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone. The semi-wet zone

refers to those areas above the permanent pool that are inundated on an irregular basis and can be expected to support wetland plants.

iii. The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.
iv. Woody vegetation may not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
v. A wetland buffer shall extend 25 feet outward from the maximum water surface elevation, with an additional 15-foot setback to structures. The wetland buffer should be contiguous with other buffer areas that are required by other regulations or that are part of the overall stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided.
vi. Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs and native ground covers.
vii. The soils of a wetland buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and back fill these with uncompacted topsoil.

5.5.2.5 Construction Considerations

To help ensure that stormwater wetlands are successfully installed on a development site, the following are recommended:

a) While the earthwork for a stormwater wetland can be completed early in the construction phase, stormwater wetlands should not be landscaped until the end of the construction phase, when the contributing drainage area has been stabilized.
b) Because stormwater wetlands are typically installed early in the construction phase, they may accumulate a significant amount of sediment during construction. Any accumulated sediment should be removed from stormwater wetlands near the end of the construction phase.
c) To help prevent excessive sediment accumulation, stormwater runoff may be diverted around the stormwater wetland until the contributing drainage area has become stabilized.
d) Sediment markers should be installed in forebays and permanent pools to help determine when sediment removal is needed.

5.5.3 Bioretention Areas

5.5.3.1 Description

Bioretention areas (also known as bioretention filters and biofilters), which may also be classified as a low impact development practice, are shallow depressional areas that are filled with an engineered soil mix and are planted with trees, shrubs and other herbaceous vegetation. Bioretention areas are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration, before being conveyed back into the storm drain system through an underdrain or allowed to infiltrate into the surrounding soils. This allows them to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites.

5.5.3.2 Discussion

Bioretention areas are one of the most effective stormwater management practices that can be used in Jasper County to reduce post-construction stormwater runoff rates, volumes and pollutant loads. They also provide a number of other benefits, including improved aesthetics, wildlife habitat, urban heat island mitigation and improved air quality. Bioretention areas differ from rain gardens, in that they are designed to receive stormwater runoff from larger drainage areas and may be equipped with an underdrain.

5.5.3.3 Stormwater Management Credits

Bioretention areas have been assigned quantifiable stormwater management credits that can be used to meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by a non-underdrained bioretention area from the runoff reduction volume conveyed through the bioretention area. Subtract 50% of the storage volume provided by an underdrained bioretention area from the runoff reduction volume conveyed through the bioretention area.
b) Water Quality Protection: Assume that a bioretention area provides an 80% reduction in TSS loads, a 60% reduction in TN loads and an 80% reduction in bacteria loads.

5.5.3.4 Planning and Design Criteria

Bioretention areas shall meet all of the following criteria to be eligible for the stormwater management credits described above:

a) Although bioretention areas can be used to manage post-construction stormwater runoff from contributing drainage areas as large as 5 acres in size, contributing drainage areas of between 2,500 square feet and 2 acres are preferred. Multiple bioretention areas can be used to manage stormwater runoff from larger contributing drainage areas.
b) Although bioretention areas may be used on development sites with slopes of up to 6%, they should be designed with slopes that are as close to flat as possible to help ensure that stormwater runoff is evenly distributed over the planting bed.
c) Bioretention areas can be designed without an underdrain on development sites that have underlying soils with an infiltration rate of 0.25 inches per hour (in/hr) or greater, as determined by NRCS soil survey data and subsequent field testing. Field infiltration test shall be approved by the DSR prior to use.
d) Although the number of infiltration tests needed on a development site will ultimately be determined by the local development review authority, at least one infiltration test is recommended for each bioretention area that will be used on the development site. If the infiltration rate of the underlying soils on the development site is not 0.25 inches per hour (in/hr) or greater, an underdrain should be included in the bioretention area design.
e) Since clay lenses or any other restrictive layers located below the bottom of a bioretention area will reduce soil infiltration rates, infiltration testing should be conducted within any confining layers that are found within 4 feet of the bottom of a proposed bioretention area.

f) Bioretention areas should be designed to provide enough storage for the stormwater runoff volume generated by the target runoff reduction rainfall event (e.g., 85th percentile rainfall event).

g) Bioretention areas should be designed to completely drain within 48 hours of the end of a rainfall event. Where site characteristics allow, it is preferable to design bioretention areas to drain within 24 hours of the end of a rainfall event to help prevent the formation of nuisance ponding conditions.

h) Unless a shallow water table is found on the development site, all bioretention area planting beds should be at least 36 inches deep. If a shallow water table is found on the development site, the depth of the planting bed may be reduced to 18 inches.

i) The soils used within bioretention area planting beds should be an engineered soil mix that meets the following specifications:
    i. Texture: Sandy loam or loamy sand.
    ii. Sand Content: Soils should contain 85%-88% clean, washed sand.
    iii. Topsoil Content: Soils should contain 8%-12% topsoil.
    iv. Organic Matter Content: Soils should contain 3%-5% organic matter.
    v. Infiltration Rate: Soils should have an infiltration rate of at least 0.25 inches per hour (in/hr), although an infiltration rate of between 1 and 2 in/hr is preferred.
    vi. Phosphorus Index (P-Index): Soils should have a P-Index of less than 30.
    vii. Exchange Capacity (CEC): Soils should have a CEC that exceeds 10 milliequivalents (meq) per 100 grams of dry weight.
    viii. pH: Soils should have a pH of 6-8.

j) The organic matter used within a bioretention area planting bed should be a well-aged compost that meets the specifications outlined in the section pertaining to soil restoration (Section 4.7.1, page 4-17).

k) Bioretention areas should be preceded by a pea gravel (i.e., ASTM D 448 Size No. 8, 3/8" to 1/8") diaphragm or equivalent level spreader device (e.g., concrete sills, curb stops, curbs with "sawteeth" cut into them) and appropriate pretreatment device, such as a vegetated filter strip or sediment forebay.

l) If no underdrain is required, underlying native soils should be separated from the planting bed by a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16"). The choker stone should be placed between the planting bed and the underlying native soils.

m) If an underdrain is required, it should be placed beneath the planting bed. The underdrain should consist of a 4 to 6 inch perforated PVC (AASHTO M 252) pipe bedded in an 8 inch layer of clean, washed stone. The pipe should have 3/8 inch perforations, spaced 6 inches on center, and should have a minimum slope of 0.5%. The clean, washed stone should be ASTM D448 size No. 57 stone (i.e., 1-1/2 to 1/2 inches in size) and should be separated from the planting bed by a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16").

n) Bioretention areas should be designed with side slopes of 3:1 (H:V) or flatter.

o) The depth from the bottom of a bioretention area to the top of the water table should be at least 2 feet to help prevent ponding and ensure proper operation of the bioretention area. On development sites with high water tables, small stormwater wetlands (i.e., pocket wetlands) should be used to intercept and treat post-construction stormwater runoff.

p) To prevent damage to building foundations and contamination of groundwater aquifers, bioretention areas, should be located at least:
    i. 10 feet from building foundations
    ii. 10 feet from property lines
    iii. 100 feet from private water supply wells
    iv. 1,200 feet from public water supply wells

  - v. 100 feet from septic systems
  - vi. 100 feet from surface waters
  - vii. 400 feet from public water supply surface waters
- q) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events to help ensure that these larger storm events are able to safely bypass the bioretention area. An overflow system should be designed to convey the stormwater runoff generated by these larger storm events safely out of the bioretention area. Methods that can be used to accommodate the stormwater runoff rates and volumes generated by these larger storm events include:
  - i. Using yard drains or storm drain inlets set at the maximum ponding depth to collect excess stormwater runoff.
  - ii. Placing a vertical gravel curtain drain at the downstream end of the bioretention area) to provide additional conveyance of stormwater runoff into the underdrain after the planting bed has been filled.
  - iii. Placing a perforated pipe (e.g., underdrain) near the top of the planting bed to provide additional conveyance of stormwater runoff after the planting bed has been filled.
- r) A landscaping plan should be prepared for all bioretention areas. The landscaping plan should be reviewed and approved by the local development review authority prior to construction.
- s) Vegetation commonly planted in bioretention areas includes native trees, shrubs and other herbaceous vegetation. When developing a landscaping plan, vegetation that will be able to stabilize soils and tolerate the stormwater runoff rates and volumes that will pass through the bioretention area should be chosen. Vegetation used in bioretention areas should also be able to tolerate both wet and dry conditions.
- t) A mulch layer, consisting of 2-4 inches of fine shredded hardwood mulch or shredded hardwood chips, should be included on the surface of the bioretention area.
- u) Methods used to establish vegetative cover within a bioretention area should achieve at least 75 percent vegetative cover one year after installation.
- v) To help prevent soil erosion and sediment loss, landscaping should be provided immediately after the bioretention area has been installed. Temporary irrigation may be needed to quickly establish vegetative cover within a bioretention area.

5.5.3.5 Construction Considerations

To help ensure that bioretention areas are successfully installed on a development site, site planning and design teams should consider the following recommendations:

- a) To prevent practice failure due to sediment accumulation and pore clogging, bioretention areas should only be installed after their contributing drainage areas have been completely stabilized. To help prevent practice failure, stormwater runoff may be diverted around the bioretention area until the contributing drainage area has become stabilized.
- b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used within the bioretention area. Appropriate measures should be taken (e.g., temporary diversion) to divert post-construction stormwater runoff around a bioretention area until vegetative cover has been established.
- c) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of bioretention areas before, during and after construction. This can typically be accomplished by clearly delineating bioretention areas on all development plans and, if necessary, protecting them with temporary construction fencing.

d) The native soils along the bottom of the bioretention area should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of the underdrain and/or engineered soil mix.
e) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within a bioretention area.

5.5.4 Filtration Practices

5.5.4.1 Description

Most filtration practices are two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which works to remove trash, debris and larger sediment particles. The second chamber is a filtration chamber, which removes additional stormwater pollutants by conveying stormwater runoff through a filter media. After passing through the filter media (e.g., sand), stormwater runoff is typically returned to the conveyance system through an underdrain. Because they have very few site constraints beyond head requirements (i.e., vertical distance between inlet and outlet), filtration practices can often be used on development sites where other stormwater management practices, such as stormwater ponds and infiltration practices, cannot.

5.5.4.2 Discussion

Filtration practices treat stormwater runoff primarily through a combination of the physical processes of gravitational settling, physical screening, filtration, absorption and adsorption. The filtration process effectively removes suspended solids, particulate matter, heavy metals and fecal coliform bacteria and other pathogens from stormwater runoff. Surface filters that are designed with vegetative cover provide additional opportunities for biological uptake of nutrients by the vegetation and for biological decomposition of other stormwater pollutants, such as hydrocarbons.

There are several variations of filtration practices that can be used to manage post-construction stormwater runoff on development sites, the most common of which include surface sand filters and perimeter sand filters. A brief description of each of these design variants is provided below:

Figure 5-3
Perimeter Sand Filter in Parking Lot
Source: Clean Water Education Partnership

a) Surface Sand Filters: Surface sand filters are ground-level, open air practices that consist of a pretreatment forebay and a filter bed chamber. Surface sand filters can treat stormwater runoff from contributing drainage areas as large as 10 acres in size and are typically designed as off-line stormwater management practices. Surface sand filters can be designed as excavations, with earthen side slopes, or as structural concrete or block structures.
b) Perimeter Sand Filters: Perimeter sand filters are enclosed stormwater management practices that are typically located just below grade in a trench along the perimeter of parking lot, driveway or other impervious surface. Perimeter sand filters consist of a

pretreatment forebay and a filter bed chamber. Stormwater runoff is conveyed into a perimeter sand filter through grate inlets located directly above the system.

Other design variants, including the underground sand filter and the organic filter, are intended primarily for use on ultra-urban development sites, where space is limited.

5.5.4.3 Stormwater Management Credits

Filtration practices have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: None. Although filtration practices provide moderate to high removal of many of the pollutants of concern typically contained in post-construction stormwater runoff, recent research shows that they provide little, if any, reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that a filtration practice provides an 80% reduction in TSS loads, a 30% reduction in TN loads and a 40% reduction in bacteria loads.

In order to manage post-construction stormwater runoff and be eligible for these "credits," filtration practices must satisfy the planning and design criteria outlined below.

5.5.4.4 Planning and Design Criteria

a) Location and Siting
   i. Surface sand filters should have a contributing drainage area of 10 acres or less. The maximum drainage area for a perimeter sand filter is 2 acres.
   ii. Sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with less than 50% imperviousness or high clay/silt sediment loads must not use a sand filter without adequate pretreatment due to potential clogging and failure of the filter bed. Any disturbed areas within the sand filter facility drainage area should be identified and stabilized. Filtration controls should only be constructed after the construction site is stabilized.
   iii. Surface sand filters are generally used in an off-line configuration where the water quality volume is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the water quality volume are diverted to other controls or downstream using a diversion structure or flow splitter.
   iv. Perimeter sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.
   v. Sand filter systems are designed for intermittent flow and must be allowed to drain and reaerate between rainfall events. They should not be used on sites with a continuous flow.

b) Surface Sand Filter. A surface sand filter facility consists of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (a.k.a sedimentation chamber) while the second chamber houses the sand filter bed. Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system.

c) Perimeter Sand Filter. A perimeter sand filter facility is a vault structure located just below grade level. Runoff enters the device through inlet grates along the top of the structure into the sedimentation chamber. Runoff is discharged from the sedimentation chamber through a weir into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system.

d) Pretreatment / Inlets
  i. Pretreatment of runoff in a sand filter system is provided by the sedimentation chamber.
  ii. Inlets to surface sand filters are to be provided with energy dissipaters. Exit velocities from the sedimentation chamber must be nonerosive.

e) Outlet Structures. Outlet pipe is to be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways).

f) Emergency Spillway. An emergency or bypass spillway must be included in the surface sand filter to safely pass flows that exceed the design storm flows. The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway should be located so that downstream buildings and structures will not be impacted by spillway discharges.

g) Maintenance Access. Adequate access must be provided for all sand filter systems for inspection and maintenance, including the appropriate equipment and vehicles. Access grates to the filter bed need to be included in a perimeter sand filter design. Facility designs must enable maintenance personnel to easily replace upper layers of the filter media.

h) Safety Features. Surface sand filter facilities can be fenced to prevent access. Inlet and access grates to perimeter sand filters may be locked.

i) Landscaping. Surface filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

5.5.4.5 Construction Considerations

To help ensure that filtration practices are successfully installed on a development site, the following are recommended:

a) To prevent practice failure due to sediment accumulation and pore clogging, filtration practices should only be installed after their contributing drainage areas have been completely stabilized. To help prevent practice failure, stormwater runoff may be diverted around the filtration practice until the contributing drainage area has become stabilized.
b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used within any landscaped filtration practices (e.g., surface sand filters). Appropriate measures should be taken (e.g., temporary diversion) to divert post-construction stormwater runoff around a landscaped filtration practice until vegetative cover has been established.
c) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of filtration practices during and after construction.
d) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within a landscaped filtration practice.

5.5.5 Infiltration Practices

5.5.5.1 Description

Infiltration practices, which may also be classified as a runoff reducing low impact development practice, are shallow excavations, typically filled with stone or an engineered soil mix, that are designed to intercept and temporarily store post-construction stormwater runoff until it infiltrates into the underlying and surrounding soils. If properly designed, they can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites. Therefore, infiltration practices can be used to help meet Jasper County's stormwater management requirements.

5.5.5.2 Discussion

Although infiltration practices can provide significant reductions in post-construction stormwater runoff rates, volumes and pollutant loads, they have historically experienced high rates of failure due to clogging caused by poor design, poor construction and neglected maintenance. If infiltration practices are to be used on a development site, great care should be taken to ensure that they are adequately designed, carefully installed and properly maintained over time. They should only be applied on development sites that have permeable soils (i.e., hydrologic soil group A and B soils) and that have a water table and confining layers (e.g., clay lenses) that are located at least 2 feet below the bottom of the trench or basin. Additionally, infiltration practices should always be designed with adequate pretreatment (e.g., vegetated filter strip, sediment forebay) to prevent sediment from reaching them and causing them to clog and fail.

There are two major variations of infiltration practices, namely infiltration trenches and infiltration basins. A brief description of each of these design variants is provided below:

a) Infiltration Trenches: Infiltration trenches are excavated trenches filled with stone. Stormwater runoff is captured and temporarily stored in the stone reservoir, where it is allowed to infiltrate into the surrounding and underlying native soils. Infiltration trenches can be used to manage post-construction stormwater runoff from contributing drainage areas of up to 2 acres in size and should only be used on development sites where sediment loads can be kept relatively low.

b) Infiltration Basins: Infiltration basins are shallow, landscaped excavations filled with an engineered soil mix. They are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration, before being allowed to infiltrate into the surrounding soils. They are essentially non-underdrained bioretention areas, and should also only be used on development sites where sediment loads can be kept relatively low.

Figure 5-4
Infiltration Trench
Source: Bellingham, WA

5.5.5.3 Stormwater Management Credits

Infiltration practices have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by an infiltration practice from the runoff reduction volume conveyed through the infiltration practice.
b) Water Quality Protection: Assume that an infiltration practice provides an 80% reduction in TSS loads, an 60% reduction in TN loads and an 80% reduction in bacteria loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, infiltration practices must satisfy the planning and design criteria outlined below.

5.5.5.4 Planning and Design Criteria

Infiltration practices must meet all of the following criteria to be eligible for the stormwater management "credits" described above:

a) Infiltration trenches should be used to manage post-construction stormwater runoff from relatively small drainage areas of 2 acres or less. The stormwater runoff rates and volumes from larger contributing drainage areas typically become too large to be properly managed within an infiltration trench.
b) Although infiltration basins can be used to manage post-construction stormwater runoff from contributing drainage areas as large as 5 acres in size, contributing drainage areas of between 2,500 square feet and 2 acres are preferred. Multiple infiltration basins can be used to manage stormwater runoff from larger contributing drainage areas.
c) Although infiltration practices may be used on development sites with slopes of up to 6%, they should be designed with slopes that are as close to flat as possible to help ensure that stormwater runoff is evenly distributed over the stone reservoir or planting bed.
d) Infiltration practices should be used on development sites that have underlying soils with an infiltration rate of 0.25 inches per hour (in/hr) or greater, as determined by NRCS soil survey data and subsequent field testing. Field infiltration shall be used and shall be approved by the Adminstrator.
e) At least one infiltration test is required for each infiltration practice that will be used on the development site.
f) Since clay lenses or any other restrictive layers located below the bottom of an infiltration practice will reduce soil infiltration rates, infiltration testing should be conducted within any confining layers that are found within 4 feet of the bottom of a proposed infiltration practice.
g) Infiltration practices should be designed to provide enough storage for the stormwater runoff volume generated by the runoff reduction rainfall event
h) Infiltration practices should be designed to completely drain within 48 hours of the end of a rainfall event. Where site characteristics allow, it is preferable to design infiltration practices to drain within 24 hours of the end of a rainfall event to help prevent the formation of nuisance ponding conditions.
i) Infiltration trenches should be located in a lawn or other pervious area and should be designed so that the top of the dry well is located as close to the surface as possible. Infiltration trenches should not be located beneath a driveway, parking lot or other impervious surface.
j) Broader, shallower infiltration trenches perform more effectively by distributing stormwater runoff over a larger surface area. However, a minimum depth of 36 inches is

recommended for all infiltration trench designs to prevent them from consuming a large amount of surface area on development sites. Whenever practical, the depth of infiltration trenches should be kept to 60 inches or less.

k) Unless a shallow water table is found on the development site, all infiltration trenches should be designed to be at least 36 inches deep. If a shallow water table is found on the development site, the depth of the stone reservoir may be reduced to 18 inches.

l) Infiltration trenches should be filled with clean, washed stone. The stone used in the infiltration trench should be 1.5 to 2.5 inches in diameter, with a void space of approximately 40%. Unwashed aggregate contaminated with soil or other fines may not be used in the trench.

m) Underlying native soils should be separated from the stone reservoir by a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16"). The choker stone should be placed between the stone reservoir and the underlying native soils.

n) The top and sides of the infiltration trench should be lined with a layer of appropriate permeable filter fabric. The filter fabric should be a non-woven geotextile with a permeability that is greater than or equal to the infiltration rate of the surrounding native soils. The top layer of the filter fabric should be located 6 inches from the top of the excavation, with the remaining space filled with pea gravel (i.e., ASTM D 448 Size No. 8, 3/8" to 1/8") or other appropriate landscaping. This top layer serves as a sediment barrier and, consequently, will need to be replaced over time. The top layer of filter fabric shall be designed such that it can be readily separated from the filter fabric used to line the sides of the infiltration trench.

o) The soils used within infiltration basin planting beds should be an engineered soil mix that meets the following specifications:
    i. Texture: Sandy loam or loamy sand.
    ii. Sand Content: Soils should contain 85%-88% clean, washed sand.
    iii. Topsoil Content: Soils should contain 8%-12% topsoil.
    iv. Organic Matter Content: Soils should contain 3%-5% organic matter.
    v. Infiltration Rate: Soils should have an infiltration rate of at least 0.25 inches per hour (in/hr), although an infiltration rate of between 1 and 2 in/hr is preferred.
    vi. Phosphorus Index (P-Index): Soils should have a P-Index of less than 30.
    vii. Exchange Capacity (CEC): Soils should have a CEC that exceeds 10 milliequivalents (meq) per 100 grams of dry weight.
    viii. pH: Soils should have a pH of 6-8.

p) The organic matter used within an infiltration basin planting bed should be a well-aged compost that meets the specifications outlined in the section pertaining to soil restoration.

q) Underlying native soils should be separated from the planting bed by a thin, 2 to 4 inch layer of choker stone (i.e., ASTM D 448 size No. 8, 3/8" to 1/8" or ASTM D 448 size No. 89, 3/8" to 1/16"). The choker stone should be placed between the planting bed and the underlying native soils.

r) Infiltration practices should be preceded by a pea gravel (i.e., ASTM D 448 Size No. 8, 3/8" to 1/8") diaphragm or equivalent level spreader device (e.g., concrete sills, curb stops, curbs with "sawteeth" cut into them) and appropriate pretreatment device, such as a vegetated filter strip or sediment forebay.

s) The depth from the bottom of an infiltration practice to the top of the water table should be at least 2 feet to help prevent ponding and ensure proper operation of the infiltration practice. On development sites with high water tables, small stormwater wetlands (i.e., pocket wetlands) should be used to intercept and treat post-construction stormwater runoff.

t) To help prevent damage to building foundations and contamination of groundwater aquifers, infiltration practices should be located at least:

  i. 10 feet from building foundations
  ii. 10 feet from property lines
  iii. 100 feet from private water supply wells
  iv. 1,200 feet from public water supply wells
  v. 100 feet from septic systems
  vi. 100 feet from surface waters
  vii. 400 feet from public water supply surface waters

u) An observation well should be installed in every infiltration practice. An observation well consists of a 4 to 6 inch perforated PVC (AASHTO M 252) pipe that extends to the bottom of the infiltration practice. The observation well can be used to observe the rate of drawdown within the infiltration practice following a storm event. It should be installed along the centerline of the infiltration practice, flush with the elevation of the surface of the infiltration practice. A visible floating marker should be provided within the observation well and the top of the well should be capped and locked to prevent tampering and vandalism.

v) Consideration should be given to the stormwater runoff rates and volumes generated by larger storm events to help ensure that these larger storm events are able to safely bypass the infiltration practice. An overflow system should be designed to convey the stormwater runoff generated by these larger storm events safely out of the infiltration practice. Methods that can be used to accommodate the stormwater runoff rates and volumes generated by these larger storm events include:
  i. Using storm drain inlets set slightly above the elevation of the surface of an infiltration trench to collect excess stormwater runoff. This will create some ponding on the surface of the infiltration trench, but can be used to safely convey excess stormwater runoff off of the surface of the trench.
  ii. Using yard drains or storm drain inlets set at the maximum ponding depth of an infiltration basin to collect excess stormwater runoff.
  iii. Using a spillway with an invert set slightly above the elevation of maximum ponding depth to convey the stormwater runoff generated by larger storm events safely out of an infiltration basin.
  iv. Placing a perforated pipe (e.g., underdrain) near the top of the stone reservoir or planting bed to provide additional conveyance of stormwater runoff after the infiltration trench or basin has been filled.

w) The landscaped area above the surface of an infiltration trench may be covered with pea gravel (i.e., ASTM D 448 size No. 8, 3/8” to 1/8”). This pea gravel layer provides sediment removal and additional pretreatment upstream of the infiltration trench and can be easily removed and replaced when it becomes clogged.

x) Alternatively, an infiltration trench may be covered with an engineered soil mix, such as that prescribed for use in infiltration basins, and planted with managed turf or other herbaceous vegetation. This may be an attractive option when infiltration trenches are placed in disturbed pervious areas (e.g., lawns, parks, community open spaces).

y) A landscaping plan should be prepared for all infiltration basins. The landscaping plan should be reviewed and approved by the local development review authority prior to construction.

z) Vegetation commonly planted in infiltration basins includes native trees, shrubs and other herbaceous vegetation. When developing a landscaping plan, vegetation that will be able to stabilize soils and tolerate the stormwater runoff rates and volumes that will pass through the infiltration basin should be chosen. Vegetation used in infiltration basins should also be able to tolerate both wet and dry conditions.

aa) A mulch layer, consisting of 2-4 inches of fine shredded hardwood mulch or shredded hardwood chips, should be included on the surface of an infiltration basin.

bb) Methods used to establish vegetative cover within an infiltration basin should achieve at least 75 percent vegetative cover one year after installation.

cc) To help prevent soil erosion and sediment loss, landscaping should be provided immediately after an infiltration basin has been installed. Temporary irrigation may be needed to quickly establish vegetative cover within an infiltration basin.

5.5.5.5 Construction Considerations

To help ensure that infiltration practices are successfully installed on a development site, the following are recommended:

a) To prevent practice failure due to sediment accumulation and pore clogging, infiltration practices should only be installed after their contributing drainage areas have been completely stabilized. To help prevent infiltration practice failure, stormwater runoff may be diverted around the infiltration practice until the contributing drainage area has become stabilized.

b) Simple erosion and sediment control measures, such as temporary seeding and erosion control mats, should be used within any landscaped infiltration practices. Appropriate measures should be taken (e.g., temporary diversion) to divert post-construction stormwater runoff around a landscaped infiltration practice until vegetative cover has been established.

c) To help prevent soil compaction, heavy vehicular and foot traffic should be kept out of infiltration practices before, during and after construction. This can typically be accomplished by clearly delineating infiltration practices on all development plans and, if necessary, protecting them with temporary construction fencing.

d) Excavation for infiltration practices should be limited to the width and depth specified in the development plans. Excavated material should be placed away from the excavation so as not to jeopardize the stability of the side walls.

e) The sides of all excavations should be trimmed of all large roots that will hamper the installation of the permeable filter fabric used to line the sides and top of an infiltration trench.

f) The native soils along the bottom of an infiltration practice should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of the choker stone and stone reservoir or engineered soil mix.

g) Construction contracts should contain a replacement warranty that covers at least three growing seasons to help ensure adequate growth and survival of the vegetation planted within a landscaped infiltration practice.

5.5.6 Swales

5.5.6.1 Description

Swales (also known as enhanced swales, vegetated open channels or water quality swales) are vegetated open channels that are designed to manage post-construction stormwater runoff within wet or dry cells formed by check dams or other control structures (e.g., culverts). They are designed with relatively mild slopes to force stormwater runoff to flow through them slowly and at relatively shallow depths, which encourages sediment and other stormwater pollutants to settle out. Check dams and/or berms installed perpendicular to the flow path further promote settling and also encourage stormwater runoff to infiltrate into the underlying native soils. Swales differ from grass channels, in that they are designed with specific features that enhance their ability to manage stormwater runoff rates, volumes and pollutant loads on development sites.

5.5.6.2 Discussion

There are several variations of swales that can be used to manage post-construction stormwater runoff on development sites, the most common of which include dry swales and wet swales. A brief description of each of these design variants is provided below:

a) Dry Swales: Dry swales (also known as bioswales), which may also be classified as a low impact development practice, are vegetated open channels that are filled with an engineered soil mix and are planted with trees, shrubs and other herbaceous vegetation. They are essentially linear bioretention areas, in that they are designed to capture and temporarily store stormwater runoff in the engineered soil mix, where it is subjected to the hydrologic processes of evaporation and transpiration, before being conveyed back into the storm drain system through an underdrain or allowed to infiltrate into the surrounding soils. This allows them to provide measurable reductions in post-construction stormwater runoff rates, volumes and pollutant loads on development sites.
b) Wet Swales: Wet swales (also known as wetland channels or linear stormwater wetlands) are vegetated channels designed to retain water and maintain hydrologic conditions that support the growth of wetland vegetation. A high water table or poorly drained soils are necessary to maintain a permanent water surface within a wet swale. The wet swale essentially acts as a linear wetland treatment system, where the stormwater runoff volume generated by the runoff reduction rainfall event is intercepted and treated over time.

5.5.6.3 Stormwater Management Credits

Swales have been assigned quantifiable stormwater management credits that can be used to meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: Subtract 100% of the storage volume provided by a non-underdrained dry swale from the runoff reduction volume conveyed through the dry swale. Subtract 50% of the storage volume provided by an underdrained dry swale from the runoff reduction volume conveyed through the dry swale. Although wet swales provide moderate to high removal of many of the pollutants of concern typically contained in post-construction stormwater runoff, recent research shows that they provide little, if any, reduction of post-construction stormwater runoff volumes.

b) Water Quality Protection: Assume that a dry swale provides an 80% reduction in TSS loads, a 50% reduction in TN loads and a 60% reduction in bacteria loads. Assume that a wet swale provides an 80% reduction in TSS loads, a 25% reduction in TN loads and a 40% reduction in bacteria loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, swales must satisfy the planning and design criteria outlined below.

5.5.6.4 Planning and Design Criteria

a) Location and Siting
    i. A dry or wet swale should be sited such that the topography allows for the design of a channel with sufficiently mild slope (unless small drop structures are used) and cross-sectional area to maintain non-erosive velocities.
    ii. Enhanced swale systems should have a contributing drainage area of 5 acres or less.

   iii. Swale siting should also take into account the location and use of other site features, such as buffers and undisturbed natural areas, and should attempt to aesthetically "fit" the facility into the landscape.
   iv. A wet swale can be used where the water table is at or near the soil surface.

b) General Design
   i. Both types of enhanced swales are designed to treat the runoff reduction volume, and to safely pass larger storm flows. Flow enters the channel through a pretreatment forebay. Runoff can also enter along the sides of the channel as sheet flow through the use of a pea gravel flow spreader trench along the top of the bank.
   ii. Dry Swale: A dry swale system consists of an open conveyance channel with a filter bed of permeable soils that overlays an underdrain system. Flow passes into and is detained in the main portion of the channel where it is filtered through the soil bed. Runoff is collected and conveyed by a perforated pipe and gravel underdrain system to the outlet.
   iii. Wet Swale: A wet swale or wetland channel consists of an open conveyance channel which has been excavated to the water table or to poorly drained soils. Check dams are used to create multiple wetland "cells," which act as miniature shallow marshes.

c) Physical Specifications I Geometry
   i. Channel slopes between 1% and 2% are recommended unless topography necessitates a steeper slope, in which case 6-to 12-inch drop structures can be placed to limit the energy slope to within the recommended 1% to 2% range. Energy dissipation will be required below the drops. Spacing between the drops should not be closer than 50 feet.
   ii. Dry and wet swales should have a bottom width of 2 to 8 feet to ensure adequate filtration. Wider channels can be designed, but should contain berms, walls, or a multi-level cross section to prevent channel braiding or uncontrolled sub-channel formation.
   iii. Dry and wet swales are parabolic or trapezoidal in cross-section and are typically designed with moderate side slopes no greater than 2:1 for ease of maintenance and side inflow by sheet flow (4:1 or flatter recommended).
   iv. Dry and wet swales should maintain a maximum ponding depth of 18 inches at the end point of the channel. A 12-inch average depth should be maintained.
   v. The peak velocity for the 2-year storm must be nonerosive for the soil and vegetative cover provided.
   vi. If the system is in-line, channels should be sized to convey runoff from larger storm events.

d) Dry Swale
   i. Dry swale channels are sized to store and infiltrate the entire runoff reduction volume with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. The maximum ponding time is 48 hours, though a 24-hour ponding time is more desirable.
   ii. The bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a 6-inch gravel layer. The soil media should have an infiltration rate of at least 1 foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric is placed between the gravel layer and the overlying soil
   iii. The channel and underdrain excavation should be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a

way that causes soil compaction and scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

e) Wet Swale
   i. Wet swale channels are sized to retain the entire runoff reduction volume with less than 18 inches of ponding at the maximum depth point.
   ii. Check dams can be used to achieve multiple wetland cells. V-notch weirs in the check dams can be utilized to direct low flow volumes.

f) Pretreatment / Inlets
   i. Inlets to enhanced swales must be provided with energy dissipators such as riprap.
   ii. Pretreatment of runoff in both a dry and wet swale system is typically provided by a sediment forebay located at the inlet.
   iii. Enhanced swale systems that receive direct concentrated runoff may have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control.
   iv. A pea gravel diaphragm and gentle side slopes should be provided along the top of channels to provide pretreatment for lateral sheet flows.

g) Outlet Structures
   i. *Dry Swale:* The underdrain system should discharge to the storm drainage infrastructure or a stable outfall.
   ii. *Wet Swale:* Outlet protection must be used at any discharge point from a wet swale to prevent scour and downstream erosion.

h) Emergency Spillway. Enhanced swales must be adequately designed to safely pass flows that exceed the design storm flows.

i) Maintenance Access. Adequate access should be provided for all dry and wet swale systems for inspection and maintenance.

j) Safety Features. Ponding depths should be limited to a maximum of 18 inches.

k) Landscaping. Landscape design should specify proper grass species and wetland plants based on specific site soils and hydric conditions present along the channel.

5.6 Limited Application Stormwater Management Practices

5.6.1 Dry Detention / Dry Extended Detention Basins

5.6.1.1 Description

Dry detention and dry extended detention basins are surface storage basins or facilities designed to provide water quantity control through detention and/or extended detention of stormwater runoff.

5.6.1.2 Discussion

Dry detention and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events.

Dry detention basins are intended to provide peak flow reduction and can be designed to control the extreme flood storm events. Both dry detention and dry ED basins provide limited pollutant removal benefits and are not intended for water quality treatment. Detention-only facilities must be used in a treatment train approach with other structural controls that provide treatment of the runoff reduction volume. Compatible multi-objective use of dry detention facilities is strongly encouraged.

5.6.1.3 Stormwater Management Credits

Dry detention and dry extended detention have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements:

a) Stormwater Runoff Reduction: None. Dry detention and dry ED basins are generally implemented for peak runoff rate attenuation and provide little, if any, reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that a dry detention basin provides no water quality credits. Assume that a dry extended detention basin provides a 40% reduction in TSS loads, a 10% reduction in TN loads and a 20% reduction in bacterial loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, dry detention and dry ED basins must satisfy the planning and design criteria outlined below.

5.6.1.4 Planning and Design Criteria

a) Dry detention and dry ED basins are to be located downstream of other structural stormwater controls providing treatment of the runoff reduction volume.
b) The maximum contributing drainage area to be served by a single dry detention or dry ED basin is 75 acres.
c) Dry detention basins are sized to temporarily store the volume of runoff required to reduce the post-development peak flow.
d) Dry ED basins are sized to provide extended detention over 24 hours and can also provide additional storage volume for normal detention.
e) Routing calculations must be used to demonstrate that the storage volume is adequate.
f) Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 2:1 (horizontal to vertical) although 3:1 is preferred. Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above.
g) The maximum depth of the basin should not exceed 10 feet.
h) Areas above the normal high water elevations of the detention facility should be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The bottom area of storage facilities should be graded toward the outlet to prevent standing water conditions. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.
i) Adequate maintenance access must be provided for all dry detention and dry ED basins.

j) Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. A sediment forebay should be provided.
k) For a dry detention basin, the outlet structure is sized for the design flow and can consist of a weir, orifice. outlet pipe, combination outlet, or other acceptable control structure. Small outlets that will be subject to clogging or are difficult to maintain are not acceptable.
l) For a dry ED basin, a low flow orifice capable of releasing the storage volume over 24 hours must be provided. The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack
m) Seepage control or anti-seep collars should be provided for all outlet pipes.
n) Riprap, plunge pools or pads, or other energy dissipators are to be placed at the end of the outlet to prevent scouring and erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance.
o) An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage.
p) A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the 100-year flood event, to the lowest point of the dam embankment not counting the emergency spillway.

5.6.2 Multi-Purpose Detention Areas

5.6.2.1 Description

Multi-purpose detention areas are facilities designed primarily for another purpose, such as parking lots and rooftops that can provide water quantity control through detention of stormwater runoff.

5.6.2.2 Discussion

Multi-purpose detention areas are site areas primarily used for one or more specific activities that are also designed to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. Example of multi-purpose detention areas include:

- Parking Lots
- Rooftops
- Sports Fields
- Recessed Plazas

Multi-purpose detention areas are normally dry between rain events, and by their very nature must be useable for their primary function the majority of the time. As such, multi-purpose detention areas should not be used for extended detention.

5.6.2.3 Stormwater Management Credits

Multi-purpose detention areas, due to their nature, have <u>not</u> been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: None.

b) Water Quality Protection: None.

Multi-purpose detention areas are not intended for stormwater runoff reduction or water quality treatment and must be used in a treatment train approach with other structural controls that can provide these benefits. In order to manage post-construction stormwater runoff multi-purpose detention areas must satisfy the planning and design criteria outlined below.

5.6.2.4 Planning and Design Criteria

a) General
  i. Multi-purpose detention areas can be located upstream or downstream of other structural stormwater controls providing treatment of the runoff reduction volume.
  ii. Multi-purpose detention areas are sized to temporarily store a portion or all of the volume of runoff required to reduce the post-development peak flow to the pre-development rate. Routing calculations must be used to demonstrate that the storage volume is adequate.
  iii. All multi-purpose detention facilities must be designed to minimize potential safety risks, potential property damage, and inconvenience to the facility's primary purposes. Emergency overflows are to be provided for storm events larger than the design storm. The overflow must not create a significant adverse impact to downstream properties or the conveyance system.

b) Parking Lot Storage
  i. Parking lot detention can be implemented in areas where portions of large, paved lots can be temporarily used for runoff storage without significantly interfering with normal vehicle and pedestrian traffic. Parking lot detention can be created in two ways: by using ponding areas along sections of raised curbing, or through depressed areas of pavement at drop inlet locations.
  ii. The maximum depth of detention ponding in a parking lot, except at a flow control structure, should be 6 inches for a 10-year storm, and 9 inches for a 100-year storm. The maximum depth of ponding at a flow control structure is 12 inches for a 100-year storm.
  iii. The storage area (portion of the parking lot subject to ponding) must have a minimum slope of 0.5% towards the outlet to ensure complete drainage following a storm. A slope of 1% or greater is recommended.
  iv. Fire lanes used for emergency equipment must be free of ponding water for runoff events up to the extreme storm (100-year) event.
  v. Flows are typically backed up in the parking lot using a raised inlet.

c) Rooftop Storage
  i. Rooftops can be used for detention storage as long as the roof support structure is designed to address the weight of ponded water and is sufficiently waterproofed to achieve a minimum service life.
  ii. The minimum pitch of the roof area subject to ponding is 0.25 inches per foot.
  iii. The rooftop storage system must include another mechanism for draining the ponding area in the event that the primary outlet is clogged.

d) Sports Fields. Athletic facilities such as football and soccer fields and tracks can be used to provide stormwater detention. This is accomplished by constructing berms around the facilities, which in essence creates very large detention basins. Outflow can be controlled through the use of an overflow weir or other appropriate control structure. Proper grading must be performed to ensure complete drainage of the facility.

e) Public Plazas. In high-density areas, recessed public common areas such as plazas and pavilions can be utilized for stormwater detention. These areas can be designed to flood no more than once or twice annually, and provide important open recreation space during the rest of the year.

5.6.3 Underground Detention Systems

5.6.3.1 Description

Underground detention is detention storage located in underground tanks or chambers or vaults designed to provide water quantity control through detention and/or extended detention of stormwater runoff.

5.6.3.2 Discussion

Underground stormwater storage facilities are typically constructed with reinforced concrete. Detention tanks are underground storage facilities typically constructed with large diameter metal or plastic pipe, or with proprietary systems made from plastics. All serve as an alternative to surface dry detention for stormwater quantity control, particularly for space-limited areas where there is not adequate land for a dry detention basin or multi-purpose detention area.

Underground detention systems can provide extended detention of peak runoff rates. Basic storage design and routing methods are the same as for detention basins except that the bypass for high flows is typically included.

Figure 5-4
Underground Detention System
Source: Stormtech

Prefabricated concrete vaults are available for commercial vendors. In addition, several manufacturers have developed proprietary packaged detention systems.

5.6.3.3 Stormwater Management Credits

Underground detention systems, due to their nature, have <u>not</u> been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: None.
b) Water Quality Protection: None.

Underground detention systems are not intended for stormwater runoff reduction or water quality treatment and must be used in a treatment train approach with other structural controls that provide treatment of the runoff reduction volume. This will prevent the underground vault or tank from becoming clogged with trash or sediment and significantly reduces the maintenance requirements for an underground detention system.

5.6.3.4 Planning and Design Criteria

a) Underground detention systems are to be located downstream of other structural stormwater controls providing treatment of the runoff reduction volume. See Section 3.1 for more information on the use of multiple structural controls in a treatment train.
b) The maximum contributing drainage area to be served by a single underground detention vault or tank is 25 acres.
c) Underground detention systems are sized to provide extended detention of the runoff reduction volume over 24 hours and temporarily store runoff to reduce the post-development peak flow of the pre-development rates. Routing calculations must be used to demonstrate that the storage volume is adequate.
d) Detention Vaults: Minimum 3,000 psi structural reinforced concrete may be used for underground detention vaults. All construction joints must be provided with water stops. Cast-in-place wall sections must be designed as retaining walls. The maximum depth from finished grade to the vault invert should be 20 feet.
e) Detention Tanks: The minimum pipe diameter for underground detention tanks is 36 inches.
f) Underground detention vaults and tanks must meet structural requirements for overburden support and traffic loading if appropriate.
g) Adequate maintenance access must be provided for all underground detention systems. Access must be provided over the inlet pipe and outflow structure. Access openings can consist of a standard frame, grate and solid cover, or a removable panel. Vaults with widths of 10 feet or less should have removable lids.
h) A separate sediment sump or vault chamber should be provided at the inlet for underground detention systems that are in a treatment train with water quality treatment structural controls.
i) A low flow orifice capable of releasing the channel protection volume over 24 hours must be provided. The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack.
Additional outlet based upon hydrologic routing calculations can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure.

j) Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion.
k) A high flow bypass is to be included in the underground detention system design to safely pass the extreme flood flow.

5.6.4 Organic Filters

5.6.4.1 Description

Organic filters are a design variant of the surface sand filter using organic materials in the filter media.

5.6.4.2 Discussion

The organic filter is a design variant of the surface sand filter, which uses organic materials such as leaf compost or a peat/sand mixture as the filter media. The organic material enhances pollutant removal by providing adsorption of contaminants such as soluble metals, hydrocarbons, and other organic chemicals.

As with the surface sand filter, an organic filter consists of a pretreatment chamber, and one or more filter cells. Each filter bed contains a layer of leaf compost or the peat/sand mixture, followed by filter fabric and a gravel/perforated pipe underdrain system. The filter bed and subsoils can be separated by an impermeable polyliner or concrete structure to prevent movement into groundwater.

Organic filters are typically used in high-density applications, or for areas requiring an enhanced pollutant removal ability. Maintenance is typically higher than the surface sand filter facility due to the potential for clogging. In addition, organic filter systems have a higher head requirement than sand filters.

5.6.4.3 Stormwater Management Credits

Organic filters have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: None. Organic filters provide little, if any, reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that an organic filter provides an 80% reduction in TSS loads, a 40% reduction in TN loads and a 40% reduction in bacterial loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, organic filters must satisfy the planning and design criteria outlined below.

5.6.4.4 Planning and Design Criteria

a) Organic filters are typically used on relatively small sites (up to 10 acres), to minimize potential clogging.
   The minimum head requirement (elevation difference needed at a site from the inflow to the outflow) for an organic filter is 5 to 8 feet.
b) Organic filters can utilize a variety of organic materials as the filtering media. Two typical media bed configurations are the peat/sand filter and compost filter. The peat filter includes an 18-inch 50/50 peat/sand mix over a 6-inch sand layer and can be optionally covered by 3 inches of topsoil and vegetation. The compost filter has an 18-inch compost layer. Both variants utilize a gravel underdrain system.
c) The type of peat used in a peat/sand filter is critically important. Fibric peat in which undecomposed fibrous organic material is readily identifiable is the preferred type. Hemic peat containing more decomposed material may also be used. Sapric peat made up of largely decomposed matter should not be used in an organic filter.
d) Typically, organic filters are designed as "off-line" systems, meaning that the runoff reduction volume is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the runoff reduction volume are diverted to other controls or downstream using a diversion structure or flow splitter.

5.6.5 Underground Sand Filters

5.6.5.1 Description

Underground sand filters are a design variant of the sand filter located in an underground vault.

5.6.5.2 Discussion

The underground sand filter is a design variant of the sand filter located in an underground vault designed for high-density land use or ultra-urban applications where there is not enough space for a surface sand filter or other structural stormwater controls.

The underground sand filter is a three-chamber system. The initial chamber is a sedimentation (pretreatment) chamber that temporarily stores runoff and utilizes a wet pool to capture sediment. The sedimentation chamber is connected to the sand filter chamber by a submerged wall that protects the filter bed from oil and trash. The filter bed is 18 to 24 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging. The sand filter chamber also includes an underdrain system with inspection and clean out wells. Perforated drain pipes under the sand filter bed extend into a third chamber that collects filtered runoff. Flows beyond the filter capacity are diverted through an overflow weir.

Due to its location below the surface, underground sand filters have a high maintenance burden and should only be used where adequate inspection and maintenance can be ensured.

5.6.5.3 Stormwater Management Credits

Underground sand filters have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: None. Underground sand filters provide little, if any, reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that an underground sand filter provides an 80% reduction in TSS loads, a 30% reduction in TN loads and a 40% reduction in bacterial loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, underground sand filters must satisfy the planning and design criteria outlined below.

5.6.5.4 Planning and Design Criteria

a) Underground sand filters are typically used on highly impervious sites of 1 acre or less. The maximum drainage area that should be treated by an underground sand filter is 5 acres.
b) Underground sand filters are typically constructed in-line, but can be constructed off-line. For off-line construction, the overflow between the second and third chambers is not included.
c) The underground vault should be tested for water tightness prior to placement of filter layers.
d) Adequate maintenance access must be provided to the sedimentation and filter bed chambers.

5.6.6 Submerged Gravel Wetlands

5.6.6.1 Description

Submerged gravel wetlands are one or more cells filled with crushed rock designed to support wetland plants. Stormwater flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

5.6.6.2 Discussion

The submerged gravel wetland system consists of one or more treatment cells that are filled with crushed rock or gravel and is designed to allow stormwater to flow subsurface through the root zone of the constructed wetland. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. In addition, algae and microbes thrive on the surface area of the rocks. In particular, the anaerobic conditions on the bottom of the filter can foster the denitrification process. Although widely used for wastewater treatment in recent years, only a handful of submerged gravel wetland systems have been designed to treat stormwater. Mimicking the pollutant removal ability of nature, this structural control relies on the pollutant-stripping ability of plants and soils to remove pollutants from runoff.

5.6.6.3 Stormwater Management Credits

Submerged gravel wetlands have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: None. Submerged gravel wetlands provide little, if any, reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that a submerged gravel wetland provides an 80% reduction in TSS loads, a 20% reduction in TN loads and a 40% reduction in bacterial loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, submerged gravel wetlands must satisfy the planning and design criteria outlined below.

5.6.6.4 Planning and Design Criteria

a) Submerged gravel wetlands should be designed as off-line systems designed to handle only the runoff reduction volume.
b) Submerged gravel wetland systems need sufficient drainage area to maintain vegetation.
c) The local slope should be relatively flat (<2%). While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).
d) All submerged gravel wetland designs should include a sediment forebay or other equivalent pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
e) Submerged gravel wetland systems can be allowed to intersect the groundwater table.
f) See the section pertaining to stormwater wetland (Section 5.5.2, page 5-10) for additional planning and design guidance.

5.6.7 Gravity (Oil-Grit) Separators

5.6.7.1 Description

A gravity separator (also known as an oil-grit separators) is a hydrodynamic separation device designed to remove settleable solids, oil and grease, debris and floatables from stormwater runoff through gravitational settling and trapping of pollutants.

5.6.7.2 Discussion

Gravity separators (also known as oil-grit separators) are hydrodynamic separation devices that are designed to remove grit and heavy sediments, oil and grease, debris and floatable matter from stormwater runoff through gravitational settling and trapping. Gravity separator units contain a permanent pool of water and typically consist of an inlet chamber, separation/storage chamber, a bypass chamber, and an access port for maintenance purposes. Runoff enters the inlet chamber where heavy sediments and solids drop out. The flow moves into the main gravity separation chamber, where further settling of suspended solids takes place. Oil and grease are skimmed and stored in a waste oil storage compartment for future removal. After moving into the outlet chamber, the clarified runoff is then discharged.

The performance of these systems is based primarily on the relatively low solubility of petroleum products in water and the difference between the specific gravity of water and the specific gravities of petroleum compounds. Gravity separators are not designed to separate other products such as solvents, detergents, or dissolved pollutants. The typical gravity separator unit may be enhanced with a pretreatment swirl concentrator chamber, oil draw-off devices that continuously remove the accumulated light liquids, and flow control valves regulating the flow rate into the unit.

Gravity separators are best used in commercial, industrial and transportation land uses and are intended primarily as a pretreatment measure for high-density or ultra-urban sites, or for use in hydrocarbon hotspots, such as gas stations and areas with high vehicular traffic. However, gravity separators cannot be used for the removal of dissolved or emulsified oils and pollutants such as coolants, soluble lubricants, glycols and alcohols.

Since resuspension of accumulated sediments is possible during heavy storm events, gravity separator units are typically installed off-line. Gravity separators are available as prefabricated proprietary systems from a number of different commercial vendors.

5.6.7.3 Stormwater Management Credits

Gravity separators have been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: None. Gravity separators provide little, if any, reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that a gravity separator provides a 40% reduction in TSS loads, a 10% reduction in TN loads and a 20% reduction in bacterial loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, gravity separators must satisfy the planning and design criteria outlined below.

5.6.7.4 Planning and Design Criteria

a) The use of gravity (oil-grit) separators should be limited to the following applications:
    i. Pretreatment for other structural stormwater controls
    ii. High-density, ultra urban or other space-limited development sites
    iii. Hotspot areas where the control of grit, floatables, and/or oil and grease are required

b) Gravity separators are typically used for areas less than 5 acres. It is recommended that the contributing area to any individual gravity separator be limited to 1 acre or less of impervious cover.
c) Gravity separator systems can be installed in almost any soil or terrain. Since these devices are underground, appearance is not an issue and public safety risks are low.
d) Gravity separators are rate-based devices. This contrasts with most other stormwater structural controls, which are sized based on capturing and treating a specific volume.
e) Gravity separator units are typically designed to bypass runoff flows in excess of the design flow rate. Some designs have built-in high flow bypass mechanisms. Other designs require a diversion structure or flow splitter ahead of the device in the drainage system. An adequate outfall must be provided.
f) The separation chamber should provide for three separate storage volumes:
    i. A volume for separated oil storage at the top of the chamber
    ii. A volume for settleable solids accumulation at the bottom of the chamber
    iii. A volume required to give adequate flow-through detention time for separation of oil and sediment from the stormwater flow
g) The total wet storage of the gravity separator unit should be at least 400 cubic feet per contributing impervious acre.
h) The minimum depth of the permanent pools should be 4 feet.
i) Horizontal velocity through the separation chamber should be 1 to 3 ft/min or less. No velocities in the device should exceed the entrance velocity.
j) A trash rack should be included in the design to capture floating debris, preferably near the inlet chamber to prevent debris from becoming saturated with oil.
k) Ideally, a gravity separator design will provide an oil draw-off mechanism to a separate chamber or storage area.
l) Adequate maintenance access to each chamber must be provided for inspection and cleanout of a gravity separator unit.
m) Gravity separator units should be watertight to prevent possible groundwater contamination.
n) The design criteria and specifications of a proprietary gravity separator unit should be obtained from the manufacturer.

5.6.8 Alum Treatment Systems

5.6.8.1 Description

The process of alum (aluminum sulfate) treatment provides treatment of stormwater runoff from a piped stormwater drainage system entering a wet pond by injecting liquid alum into storm sewer lines on a flow-weighted basis during rain events.

5.6.8.2 Discussion

When added to runoff, liquid alum forms nontoxic precipitates of aluminum hydroxide [Al(OH)3] and aluminum phosphate [$AlPO_4$], which combine with phosphorus, suspended solids and heavy metals, causing them to be deposited into the sediments of the receiving waters in a stable, inactive state.

The alum precipitate formed during coagulation of stormwater can be allowed to settle in receiving water or collected in small settling basins. Alum precipitates are stable in sediments and will not redissolve due to changes in redox potential or pH under conditions normally found in surface water bodies. Laboratory or field testing may be necessary to verify feasibility and to establish design, maintenance, and operational parameters, such as the optimum coagulant dose required to achieve the desired water quality goals, chemical pumping rates and pump sizes.

5.6.8.3 Stormwater Management Credits

Alum treatment has been assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements.

a) Stormwater Runoff Reduction: None. Alum treatment, by its very nature, does not provide for the reduction of post-construction stormwater runoff volumes.
b) Water Quality Protection: Assume that alum treatment provides a 90% reduction in TSS loads, a 60% reduction in TN loads and a 90% reduction in bacterial loads.

In order to manage post-construction stormwater runoff and be eligible for these credits, alum treatment must satisfy the planning and design criteria outlined below.

5.6.8.4 Planning and Design Criteria

Alum treatment systems are complex, and design details are beyond the scope of this manual. However, further information can be obtained from Internet resources and by contacting local municipalities and engineers who have designed and implemented successful systems. The following are general guidelines for alum treatment systems:

a) Injection points should be 100 feet upstream of discharge points.
b) Alum concentration is typically 10 µg/l.
c) Alum treatments systems may need to control pH.
d) For new pond design, the required size is approximately 1% of the drainage basin size, as opposed to 10 to 15% of the drainage basin area for a standard detention pond.
e) No volume requirement is required when discharging to existing lakes.

5.6.9 Proprietary Structural Controls

5.6.9.1 Description

Proprietary structural controls are manufactured structural control systems available from commercial vendors designed to treat stormwater runoff and/or provide water quantity control.

5.6.9.2 Discussion

There are many types of commercially-available proprietary stormwater structural controls available for both water quality treatment and quantity control. These systems include:

- Hydrodynamic systems such as gravity and vortex separators
- Filtration systems
- Catch basin media inserts
- Chemical treatment systems
- Package treatment plants
- Prefabricated detention structures

Many proprietary systems are useful on small sites and space-limited areas where there is not enough land or room for other structural control alternatives. Proprietary systems can often be used in pretreatment applications in a treatment train. However, proprietary systems are often more costly than other alternatives and may have high maintenance requirements. Perhaps the largest difficulty in using a proprietary system is the lack of adequate independent performance data, particularly for use in Jasper County. Below are general guidelines that should be followed before considering the use of a proprietary commercial system.

5.6.9.3 Stormwater Management Credits

Proprietary stormwater controls may be assigned quantifiable stormwater management credits that can be used to help meet Jasper County's stormwater management requirements. Stormwater credits will be based on independently conducted or reviewed performance monitoring data.

a) Stormwater Runoff Reduction: To be determined (TBD).
b) Water Quality Protection: TBD

In order to manage post-construction stormwater runoff and be eligible for credits, proprietary stormwater controls must satisfy the planning and design criteria outlined below. Information about how specific proprietary devices and systems can be used to help satisfy the stormwater management criteria must be provided by the manufacturer and should be verified using independently-reviewed performance monitoring data and calculations. Information about the performance of proprietary stormwater controls should be provide to the DSR at the earliest design stage possible.

5.6.9.4 Planning and Design Criteria

In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the storm water management goals for which it is being intended. This means that the system must provide:

a) General
    i. Independent third-party scientific verification of the ability of the proprietary system to meet water quality treatment objectives and/or to provide water quantity control.
    ii. Proven record of longevity in the field.
    iii. Proven ability to function in Jasper County (e.g., climate, rainfall patterns, soil types, etc.).

b) Performance Verification. For propriety systems to meet the third-party scientific verification required above for water quality goals, the following monitoring criteria should be met for supporting studies:
    i. At least 15 storm events must be sampled.
    ii. The study must be independent or independently verified (i.e., may not be conducted by the vendor or designer without third-party verification).
    iii. The study must be conducted in the field, as opposed to laboratory testing.
    iv. Field monitoring must be conducted using standard protocols which require proportional sampling both upstream and downstream of the device.
    v. Concentrations reported in the study must be flow-weighted.
    vi. The propriety system or device must have been in place for at least one year at the time of monitoring.
    vii. Although local data is preferred, data from other regions can be accepted as long as the design accounts for the local conditions.

Table 5.1: How Stormwater Management Practices Can Be Used to Help Satisfy the Stormwater Management Criteria

Stormwater Management Practice	Stormwater Runoff Reduction	Water Quality Protection	Manual Section	Page Number
General Application Practices				
Stormwater Ponds	**"Credit":** None.	**"Credit":** Assume that a stormwater pond provides an 80% reduction in TSS load, a 30% reduction in TN load, and a 70% reduction in bacteria load.	5.5.1	5-5
Stormwater Wetlands	**"Credit":** None.	**"Credit":** Assume that a stormwater wetland provides an 80% reduction in TSS load, a 30% reduction in TN load, and an 80% reduction in bacteria load.	5.5.2	5-10
Bioretention Areas, No underdrain	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained bioretention area from the runoff reduction volume conveyed through the bioretention area.	**"Credit":** Assume that a bioretention area provides an 80% reduction in TSS load, a 60% reduction in TN load, and an 80% reduction in bacteria load.	5.5.3	5-15
Bioretention Areas, Underdrain	**"Credit":** Subtract 50% of the storage volume provided by an underdrained bioretentino area from the runoff reduction volume conveyed through the bioretention area.	**"Credit":** Assume that a bioretention area provides an 80% reduction in TSS load, a 60% reduction in TN load, and an 80% reduction in bacteria load.	5.5.3	5-15
Filtration Practices	**"Credit":** None.	**"Credit":** Assume that a filtration practice provides an 80% reduction in TSS load, a 30% reduction in TN load, and a 40% reduction in bacteria load.	5.5.4	5-19
Infiltration Practices	**"Credit":** Subtract 100% of the storage volume provided by an infiltration practice from the runoff reduction volume conveyed through the infiltration practice.	**"Credit":** Assume that an infiltration practice provides an 80% reduction in TSS load, a 60% reduction in TN load, and an 80% reduction in bacteria load.	5.5.5	5-22

* Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 5.1: How Stormwater Management Practices Can Be Used to Help Satisfy the Stormwater Management Criteria

Stormwater Management Practice	Stormwater Runoff Reduction	Water Quality Protection	Manual Section	Page Number
Dry Swales, No Underdrain	**"Credit":** Subtract 100% of the storage volume provided by a non-underdrained dry swale from the runoff reduction volume conveyed through the dry swale.	**"Credit":** Assume that a dry swale provides an 80% reduction in TSS load, a 50% reduction in TN load, and a 60% reduction in bacteria load.	5.5.6	5-26
Dry Swales, Underdrain	**"Credit":** Subtract 50% of the storage volume provided by an underdrained dry swale from the runoff reduction volume (RRv) converyed through the dry swale.	**"Credit":** Assume that a dry swale provides an 80% reduction in TSS load, a 50% reduction in TN load, and a 60% reduction in bacteria load.	5.5.6	5-26
Wet Swales	**"Credit":** None.	**"Credit":** Assume that a wet swale provides an 80% reduction in TSS load, a 25% reduction in TN load, and a 40% reduction in bacteria load.	5.5.6	5-26
Limited Application Practices **Water Quantity Management Practices**				
Dry Detention Basins	**"Credit":** None.	**"Credit":** None.	5.6.1	5-29
Dry Extended Detention Basins	**"Credit":** None.	**"Credit":** Assume that a dry extended detention basin provides a 40% reduction in TSS load, a 10% reduction in TN load, and a 20% reduction in bacteria load.	5.6.1	5-29
Multi-Purpose Detenion Areas	**"Credit":** None.	**"Credit":** None.	5.6.2	5-31
Underground Detention Systems	**"Credit":** None.	**"Credit":** None.	5.6.3	5-33
Water Quality Management Practices				
Organic Filters	**"Credit":** None.	**"Credit":** Assume that an organic filter provides an 80% reduction in TSS load, a 40% reduction in TN load, and a 40% reduction in bacteria load.	5.6.4	5-34

* Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 5.1: How Stormwater Management Practices Can Be Used to Help Satisfy the Stormwater Management Criteria

Stormwater Management Practice	Stormwater Runoff Reduction	Water Quality Protection	Manual Section	Page Number
Underground Filters	**"Credit":** None.	**"Credit":** Assume that an underground filter provides an 80% reduction in TSS load, a 30% reduction in TN load, and a 40% reduction in bacteria load.	5.6.5	5-35
Submerged Gravel Wetlands	**"Credit":** None.	**"Credit":** Assume that an submerged gravel wetland provides an 80% reduction in TSS load, a 20% reduction in TN load, and a 40% reduction in bacteria load.	5.6.6	5-36
Gravity (Oil-Grit) Separators	**"Credit":** None.	**"Credit":** Assume that a gravity (oil-grit) separator provides an 40% reduction in TSS load, a 10% reduction in TN load, and a 20% reduction in bacteria load.	5.6.7	5-37
Alum Treatment Systems	**"Credit":** None.	**"Credit":** Assume that an alum treatment system provides an 90% reduction in TSS load, a 60% reduction in TN load, and a 90% reduction in bacteria load.	5.6.8	5-39
Proprietary Systems	**"Credit":** TBD	**"Credit":** TBD	5.6.9	5-40

* Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 5.2: Factors to Consider When Evaluating the Overall Feasibility of Stormwater Management Practices

Stormwater Management Practice	Drainage Area	Area Required	Slope	Minimum Head	Minimum Depth to Water Table	Soils	Manual Section	Page Number
General Application Practices								
Stormwater Ponds	No restrictions, although a contributing drainage area of between 10 to 25 acres or a shallow water table is typically needed to maintain a permanent pool	2-3% of contributing drainage area	15% max	6 to 8 feet	No restrictions	No restrictions	5.5.1	5-5
Stormwater Wetlands	No restrictions, although a contributing drainage area of between 5 to 25 acres or a shallow water table is typically needed to maintain a permanent water surface	3-5% of contributing drainage area	15% max	2 to 5 feet	No restrictions	No restrictions	5.5.2	5-10
Bioretention Areas	5 acres	5-10% of contributing drainage area	6% max	42 to 48 inches	2 feet	Should drain within 48 hours of end of rainfall event	5.5.3	5-15
Filtration Practices	2 to 10 acres	3-5% of contributing drainage area	6% max	2 to 5 feet	2 feet	Should drain within 36 hours of end of rainfall event	5.5.4	5-19
Infiltration Practices	2 to 5 acres	5% of contributing drainage area	6% max	42 to 48 inches	2 feet	Should drain within 48 hours of end of rainfall event	5.5.5	5-22
Dry Swales	5 acres	5-10% of contirbuting drainage area	0.5% to 4%, although 1% to 2% is recommended	36 to 48 inches	2 feet	Should drain within 48 hours of end of rainfall event	5.5.6	5-26
Wet Swales	5 acres	10-20% of contributing drainage area	0.5% to 4%, although 1% to 2% is recommended	1 to 2 feet	No restrictions	No restrictions	5.5.6	5-26

* Refer to Section 5.4.1 (Page 5-4) for a description of each feasibility factor.

* Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 5.2: Factors to Consider When Evaluating the Overall Feasibility of Stormwater Management Practices

Stormwater Management Practice	Drainage Area	Area Required	Slope	Minimum Head	Minimum Depth to Water Table	Soils	Manual Section	Page Number
Limited Application Practices **Water Quantity Management Practices**								
Dry Detention Basins	No restrictions	1-3% of contributing drainage area	15% max	4 to 8 feet	2 feet	No restrictions	5.6.1	5-29
Dry Extended Detention Basins	No restrictions	1-3% of contributing drainage area	15% max	4 to 8 feet	2 feet	No restrictions	5.6.1	5-29
Multi-Purpose Detention Areas	No restrictions	1-3% of contributing drainage area	15% max	4 to 8 feet	2 feet	No restrictions	5.6.2	5-31
Underground Detention Systems	No restrictions	N/A	15% max	4 to 8 feet	2 feet	No restrictions	5.6.3	5-33
Water Quality Management Practices								
Organic Filters	10 acres	3-5% of contributing drainage area	6% max	2 to 5 feet	2 feet	Should drain within 36 hours of end of rainfall event	5.6.4	5-34
Underground Filters	10 acres	N/A	6% max	2 to 5 feet	2 feet	Should drain within 36 hours of end of rainfall event	5.6.5	5-35
Submerged Gravel Wetlands	5 acres	3-5% of contributing drainage area	0.5% to 4%, although 1% to 2% is recommended	2 to 5 feet	No restrictions	No restrictions	5.6.6	5-36
Gravity (Oil-Grit) Separators	5 acres	N/A	6% max	4 feet	2 feet	No restrictions	5.6.7	5-37
Alum Treatment Systems	No restrictions, although a contributin drainage area of between 10 to 25 acres or a shallow water table is typically needed to construct a stormwater pond	N/A	N/A	6 to 8 feet typically needed to construct a stormwater pond	N/A	N/A	5.6.8	5-39
Proprietary Systems	TBD	TBD	TBD	TBD	TBD	TBD	5.6.9	5-40

* Refer to Section 5.4.1 (Page 5-4) for a description of each feasibility factor.

* Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 5.3: Factors to Consider When Evaluating the Applicability of Stormwater Management Practices on a Development Site

Stormwater Management Practice	Rural Use	Suburban Use	Urban Use	Construction Cost	Maintenance	Manual Section	Page Number
General Application Process							
Stormwater Ponds	✓	✓	N/A	Low	Low	5.5.1	5-5
Stormwater Wetlands	✓	✓	N/A	Low	Medium	5.5.2	5-10
Bioretention Areas	✓	✓	✓	Medium	Medium	5.5.3	5-15
Filtration Practices	✱	✓	✓	High	High	5.5.4	5-19
Infiltration Practices	✓	✓	✓	Medium	High	5.5.5	5-22
Dry Swales	✓	✓	✱	Medium	Medium	5.5.6	5-26
Wet Swales	✓	✓	✱	Medium	Medium	5.5.6	5-26
Limited Application Practices							
Water Quantity Practices							
Dry Detention Basins	✓	✓	N/A	Low	Low	5.6.1	5-29
Dry Extended Detention Basins	✓	✓	N/A	Low	Low	5.6.1	5-29
Multi-Purpose Detention Areas	✱	✓	✓	Low	Low	5.6.2	5-31
Underground Detention Systems	N/A	N/A	✓	High	Medium	5.6.3	5-33
Water Quality Practices							
Organic Filters	✱	✱	✓	High	High	5.6.4	5-34
Underground Filters			✓	High	High	5.6.5	5-35

Notes:

✓ = Suitable for use on development sites located in these areas

✱ = Under certain situations, can be used on development sites located in these areas.

N/A = Not Applicable.

* Refer to Section 5.4.2 (Page 5-5) for a description of each evaluation factor.

* Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

Table 5.3: Factors to Consider When Evaluating the Applicability of Stormwater Management Practices on a Development Site

Stormwater Management Practice	Rural Use	Suburban Use	Urban Use	Construction Cost	Maintenance	Manual Section	Page Number
Submerged Gravel Wetlands	✱	✱	✓	High	High	5.6.6	5-36
Gravity (Oil-Grit) Separators	✱	✱	✓	High	High	5.6.7	5-37
Alum Treatment Systems	✓	✓	N/A	High	High	5.6.8	5-39
Proprietary Systems	✱	✱	✓	TBD	TBD	5.6.9	5-40

Notes:

✓ = Suitable for use on development sites located in these areas

✱ = Under certain situations, can be used on development sites located in these areas.

N/A = Not Applicable.

* Refer to Section 5.4.2 (Page 5-5) for a description of each evaluation factor.

* Modified from the Coastal Stormwater Supplement to the Georgia Stormwater Management Manual.

6.0 Stormwater Management Plan Development

6.1 General

To assist in the assessment of a site's stormwater management system, a stormwater management concept plan for the proposed development project shall be developed and preliminary concept plans shall be discussed at pre-application conferences. The stormwater management concept plan should illustrate the layout of the proposed development project and should show, in general, how post-construction stormwater runoff will be managed on the development site.

The creation of a stormwater management concept plan allows the designer to make decisions about the layout of the proposed development project. During the creation of the stormwater management concept plan, most of the site layout, including the layout of lots, buildings, roadways, parking areas, sidewalks and green infrastructure and stormwater management practices, can be completed.

An iterative, eight-step process can be used to create and assess a stormwater management concept plan:

- Step 1: Use Better Site Planning Techniques
- Step 2: Use Better Site Design Techniques
- Step 3: Calculate Stormwater Runoff Control Volume
- Step 4: Apply Low Impact Development Practices
- Step 5: Check To See If Stormwater Management Criteria Have Been Met
- Step 6: Apply Stormwater Management Practices
- Step 7: Check To See If Stormwater Management Criteria Have Been Met
- Step 8: Finalize Stormwater Management Plan

Each step in this iterative, eight-step process for creating and assessing a stormwater management concept plan is described in more detail below.

6.2 Approach

6.2.1 Step 1: Use Better Site Planning Techniques

The first and, perhaps, most important step in the process of developing a stormwater management concept plan is to use better site planning techniques during the layout of the proposed development project. The better site planning techniques recommended for use in Jasper County are discussed in Section 4.0.

The use of these better site planning techniques not only helps protect important primary and secondary conservation areas from the direct impacts of the land development process, but also helps preserve pre-development site hydrology and reduce post-construction stormwater runoff rates, volumes and pollutant loads.

Protecting primary and secondary conservation areas can be thought of as a self-crediting stormwater management technique (i.e., protecting them implicitly reduces post-construction stormwater runoff rates, volumes and pollutant loads); however, it is important not to overlook the stormwater management and other environmental benefits that these better site planning techniques provide. Better site planning techniques have been assigned quantifiable stormwater management credits that can be used when calculating the stormwater runoff volumes associated with the post-construction stormwater management criteria. Table 4.1 (page 4-52 through 4-56) summarizes these credits.

6.2.2 Step 2: Use Better Site Design Techniques

The next step in the process of developing a stormwater management concept plan is to use better site design techniques during the design of the proposed development project. The better site design techniques recommended for use in Jasper County are discussed in Section 4.0.

The use of these better site design techniques not only helps minimize land disturbance and the creation of new impervious and disturbed pervious cover, but also helps preserve pre-development site hydrology and reduce post-construction stormwater runoff rates, volumes and pollutant loads.

The use of better site design techniques can be thought of as a self-crediting stormwater management technique (i.e., using them implicitly reduces post-construction stormwater runoff rates, volumes and pollutant loads). Table 4.2 (page 4-57 through 4-59) summarizes these credits.

6.2.3 Step 3: Calculate the Stormwater Runoff Reduction Volume

By using a variety of better site planning and design techniques during the creation of a stormwater management concept plan, it is possible to significantly reduce post-construction stormwater runoff rates, volumes and pollutant loads on a development site. This helps reduce the size and cost of the low impact development and stormwater management practices that are needed to address Jasper County's stormwater management requirements.

The amount of stormwater runoff reduction needed to satisfy the stormwater runoff reduction criteria, known as the runoff reduction volume (RR_v), can be calculated by multiplying the depth of rainfall generated by the target runoff reduction rainfall event (85th percentile storm event) by the site area and a volumetric runoff coefficient (R_v):

$$RR_v = (P)\ (R_v)\ (A) \div (12) \qquad (6\text{-}1)$$

Where:

RR_v = runoff reduction volume (acre-feet)
P = target runoff reduction rainfall (inches)
R_v = volumetric runoff coefficient
A = site area (acres)
12 = unit conversion factor (in./ft.)

A site's volumetric runoff coefficient, R_v. is directly related to the amount of impervious cover found on the site:

$$R_v = 0.05 + 0.009(I) \qquad (6\text{-}2)$$

Where:

I = site imperviousness (%)

Calculating the stormwater runoff volume associated with the stormwater runoff reduction criteria is provided below:

- Measuring Impervious Area: The amount of impervious cover found on a development site can be measured directly from a set of development plans.
- Multiple Drainage Areas: When a development site contains or is divided into multiple drainage areas, it is recommended that RR_v be calculated and addressed separately within each drainage area.
- Off-Site Drainage Areas: Stormwater runoff from off-site drainage area may be diverted and conveyed around a development site and excluded from the RR_v calculations.

6.2.4 Step 4: Apply Low Impact Development Practices

The next step in the process of developing a stormwater management concept plan is to distribute low impact development practices across the development site. The low impact development practices recommended for use in Jasper County are discussed in Section 4.7.

After an initial layout of the proposed development project has been completed using better site planning and design techniques and the runoff reduction volumes has been calculated, the designer should be able to begin distributing low impact development practices across the development site. Many of these practices can be placed in the disturbed and undisturbed pervious areas that were protected earlier in the process through the use of better site planning and design techniques.

At this point in the site planning and design process, a designer should have a good understanding of the post-construction stormwater runoff rates, volumes and pollutant loads that they will need to manage on the development site. Low impact development practices should be used, to the maximum extent practical, to reduce these post-construction stormwater runoff rates, volumes and pollutant loads on the development site. Additional information about these low impact development practices, including information about their proper application and design, can be found in Section 4.0.

When applying low impact development practices to a development site, it is important that they be treated just like stormwater management practices. They should be placed in drainage or maintenance easements and included in all stormwater management system inspection and maintenance plans.

All of the low impact development practices recommended for use in Jasper County have been assigned quantifiable stormwater management credits that can be used to help satisfy the reduction of the calculated runoff reduction volume. Table 4.1 (page 4-52 through 4-56) summarizes all of these credits.

6.2.5 Step 5: Check to See If Stormwater Management Criteria Have Been Met

By distributing runoff reducing low impact development practices across a development site, and applying the associated stormwater management credits, it is possible to significantly reduce post-construction stormwater runoff rates, volumes and pollutant loads. Therefore, at this point in the process of developing and assessing a stormwater management concept plan, the reduction of the runoff reduction volume should be checked.

Depending on the number and type of low impact development practices that have been used, the post-construction stormwater runoff rates, volumes and pollutant loads generated on the development site may have been significantly reduced. If so, the need for larger and more costly stormwater management practices, such as wet ponds and stormwater wetlands, may have been significantly reduced or may have been eliminated altogether.

6.2.6 Step 6: Apply Stormwater Management Practices

Once it has been determined that the runoff reduction volume cannot be reduced exclusively through the use of green infrastructure practices, the next step in the process of developing a stormwater management concept plan is to use stormwater management practices to further manage stormwater runoff rates, volumes and pollutant loads on the development site.

Stormwater management practices (also known as structural stormwater controls, structural stormwater best management practices or structural stormwater BMPs) are engineered facilities designed to *intercept and manage* post-construction stormwater runoff rates, volumes and pollutant loads. The stormwater management practices recommended for use in Jasper County have been divided into two groups: (1) general application practices; and (2) limited application practices. The stormwater management practices are described further in Section 5.0.

After low impact development practices have been distributed across the development site, and it has been determined that the runoff reduction volume cannot be satisfied exclusively through the use of green infrastructure practices, a designer should be able to begin applying stormwater management practices to the site to further manage post-construction stormwater runoff rates, volumes and pollutant loads. Stormwater management practices should be placed downstream of any previously applied green infrastructure practices to form what are known as "stormwater management trains".

When applying stormwater management practices to a development site, they should be placed in drainage or maintenance easements and included in all stormwater management system inspection and maintenance plans. Additional information about the use of stormwater management practices, including information about their proper application and design, can be found in Section 5.0.

All of the stormwater management practices recommended for use in Jasper County have been assigned quantifiable stormwater management credits corresponding to the stormwater management benefits that they provide. These credits can be used to help satisfy the runoff reduction volume criteria or water quality treatment criteria. Table 5.1 (page 5-42 through 5-44) summarizes all of these credits.

6.2.7 Step 7: Check to See If Stormwater Management Criteria Have Been Met

Once stormwater management practices have been applied to a development site, site planning and design teams should check to make sure that the runoff reduction volume or water quality criteria have been completely satisfied. If the criteria have not been met, designers will need to go back to the stormwater management concept plan and apply additional low impact development and stormwater management practices to further reduce and manage post-construction stormwater runoff rates, volumes and pollutant loads on the development site.

On many development sites, the process of developing a stormwater management concept plan will be an iterative process. When compliance with the criteria is not achieved on the first try, designers should return to earlier steps in process to explore alternative site layouts and different combinations of green infrastructure and stormwater management practices. By periodically checking to see if the criteria that have been met, they can significantly reduce the amount of time that this iterative site design process may take.

6.2.8 Step 8: Finalize Stormwater Management Concept Plan

Once the criteria have been completely satisfied, the next step in the process of developing a stormwater management concept plan is to finalize the plan. The final version of the stormwater management concept plan should illustrate the layout of the proposed development project and should show, in general, how post-construction stormwater runoff will be managed on the development site. The stormwater management concept plan should include all of the information of the stormwater management plan as discussed in Section 2.0.

Jasper County Rainfall Frequency Spectrum Analysis

A.1 Introduction

On average, approximately 104 storm events with measureable rainfall occur in Jasper County per year. Most of these storm events are quite small, but a few can generate several inches of rainfall or more. A Rainfall Frequency Spectrum (RFS) analysis is used to estimate the relative percentage of various rainfall events. This Appendix presents a RFS analysis for Jasper County, based on rainfall data collected at the Town of Ridgeland.

The RFS analysis presented in this Appendix is based on approximately 60 years of historical rainfall data collected in Ridgeland including 1941 through 1999 and 2009 through 2010. The analysis was conducted based on the methodology presented in technical Guidance on Implementing Section 438 of the Energy Independence and Security Act (USEPA, 2009).

A.2 Rainfall Frequency Spectrum (RFS) Analysis

The RFS analysis for Japer County included the following steps:

1. Obtaining the daily rainfall data for Ridgeland via the National Climactic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html).
2. Sequentially list positive rainfall values (i.e. greater than 0.0 inches).
3. Eliminate values less than 0.1 inches (it is assumed that these small events do not produce runoff).
4. Using the data set from Step 3, calculate the percentile value (using the EXCEL percentile function, representing the k^{th} percentile of a value in a range) for various percentile values of interest i.e. 85th, 90th, 100th, etc.
5. Plot and/or summarize the percentile values.

Figure A-1 illustrates the positive rainfall values greater or equal to 0.1 inch used in the RFS analysis. Figure A-2 graphically illustrates the RFS analysis for Jasper County. Table A-1 below summarizes the results of the RFS analysis for common percentile values (Savannah, GA results are included for comparison).

As shown in this analysis the percentage of rainfall event in Jasper County that are less than 1.16 inches account for 85% of all rainfall events. Thus the rainfall amount that should be used in the volume reduction calculations shall be 1.16 inches. For ease of use and to be conservative, this value shall be rounded up to **1.2 inches**.

Location	Data Points (>=0.1in)	Percentile							
		50	75	80	85	90	95	99	100
Ridgeland, Jasper Co., SC	4541	0.40	0.81	0.96	**1.16**	1.45	2.00	3.34	7.75
Savannah, Chatham Co., GA	4367	0.42	0.84	0.96	1.15	1.37	1.94	3.34	8.47

References

U.S. Environmental Protection Agency, 2009. *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act,* EPA 841-B-09-001; December 2009. www.epa.gov/owow/nps/lid/section438

Figure A-1

Daily Rainfall

Ridgeland, Jasper County, SC

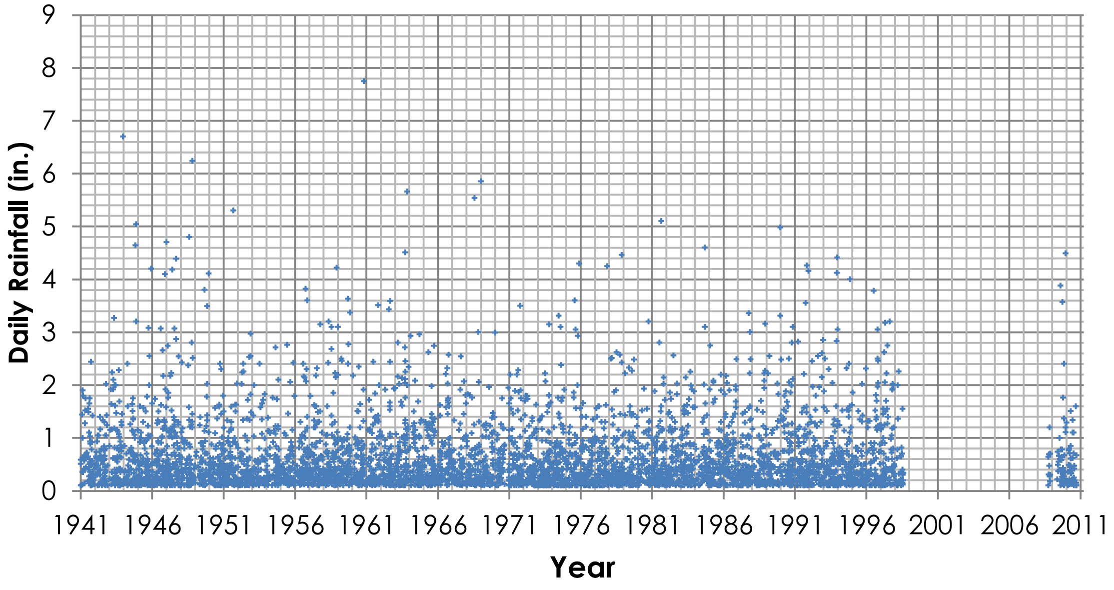
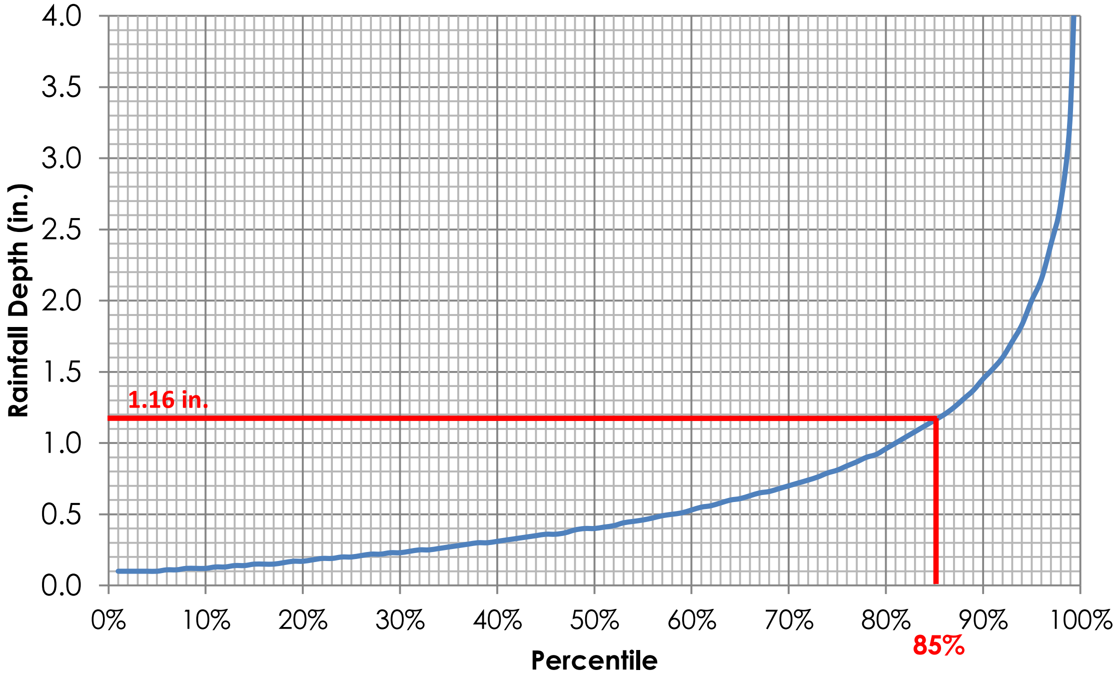


Figure A-2

Rainfall Frequency Spectrum Analysis

Ridgeland, Jasper County, SC



B.1 Introduction

To better illustrate the step by step process that can be used to create and assess a stormwater management plan, a simplified example project will be examined. The example project includes is a 3.00 acre site as illustrated in Figure B-1. The site's existing conditions include an existing cleared field and a stand of existing native trees. A small drainage channel on the lower portion of the site (in the existing tree line) carries off-site flows (and on-site flows) to the culvert under the road. The soils on the site belong to hydrologic soil group (HSG) C.

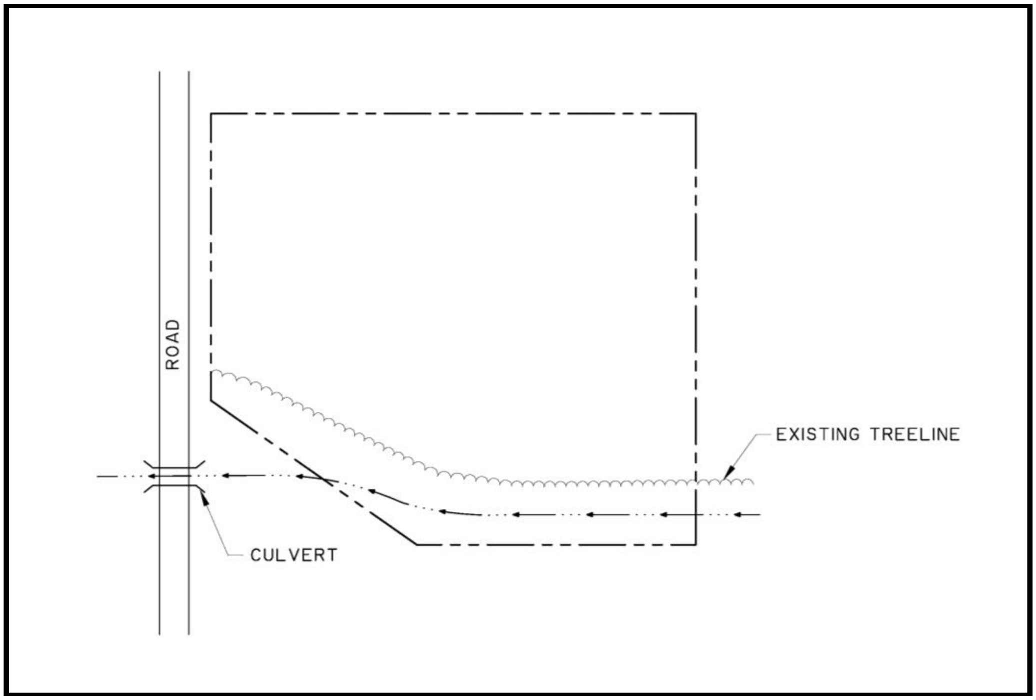


Figure B-1
Example Project Existing Conditions

The proposed improvements for the site include a building, front parking lot and driveway, side parking lot and driveway, and various sidewalks. The proposed improvements are illustrated in Figure B-2, and include approximately 1.29 acres of impervious area.

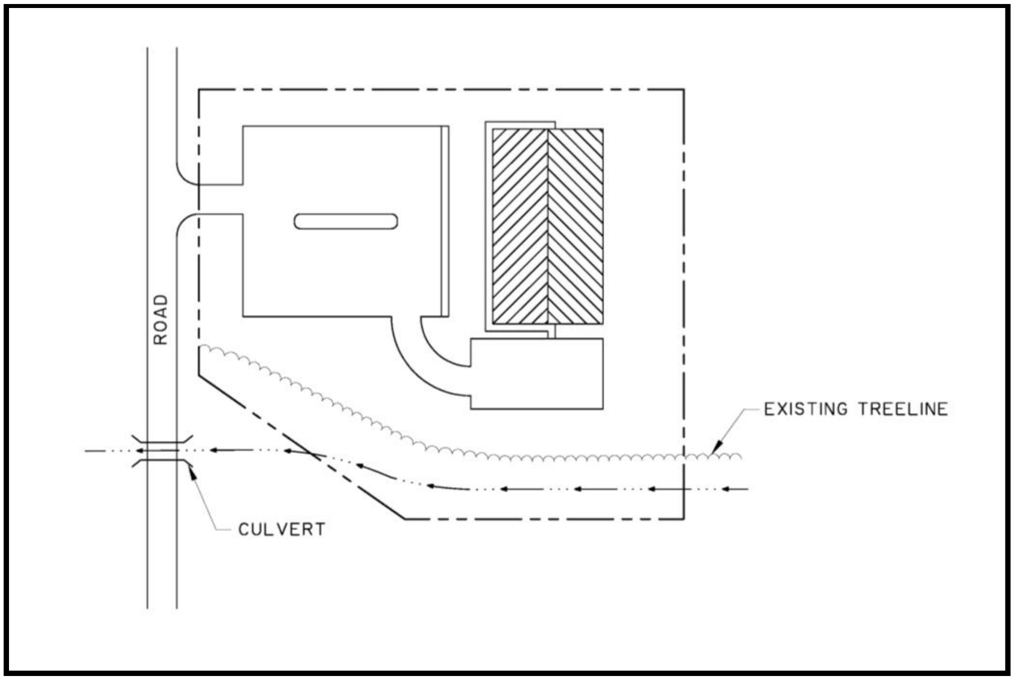


Figure B-2
Example Project Proposed Improvements

B.2 Example Stormwater Management Plan

The iterative, eight-step process outlined in Section 6.0 can be used to create and assess a stormwater management concept plan as follows:

- Step 1: Use Better Site Planning Techniques
- Step 2: Use Better Site Design Techniques
- Step 3: Calculate Stormwater Runoff Control Volume
- Step 4: Apply Low Impact Development Practices
- Step 5: Check To See If Stormwater Management Criteria Have Been Met
- Step 6: Apply Stormwater Management Practices
- Step 7: Check To See If Stormwater Management Criteria Have Been Met
- Step 8: Finalize Stormwater Management Plan

Each step in the process is discussed for the development and assessment of a conceptual stormwater management plan in the sections below.

B.2.1 Step 1: Use Better Site Planning Techniques

Better Site Planning Techniques (Section 4.5) include the protection of primary and secondary conservation areas. The design team for the example project recognized that the existing trees and drainage feature on the lower portion of the site where a candidate for conservation protection. A 0.55 acre conservation area was established for that would protect the existing trees and drainage feature on the site. The conservation area is illustrated in Figure B-3.

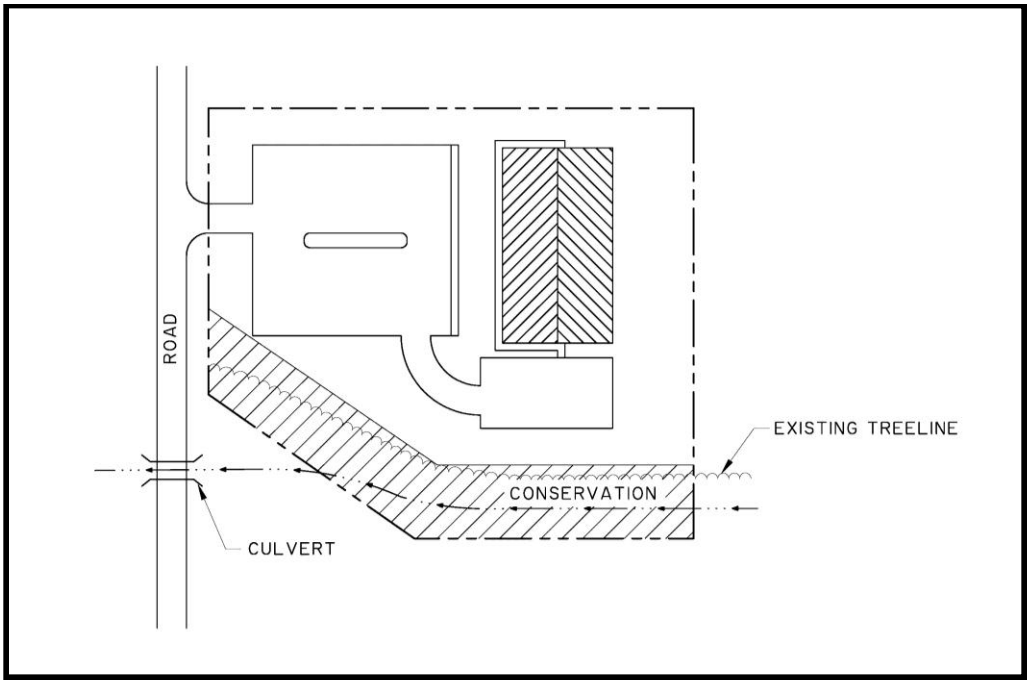


Figure B-3
Example Project Conservation Area

B.2.2 Step 2: Use Better Site Design Techniques

Better Site Design Techniques (Section 4.6) are techniques that can be used by a designer to limit the amount of cleared, disturbed pervious area and impervious area for a development site. The techniques encourage the designer to assess various components of the development (i.e., clearing and grading, road widths, parking lot footprint, etc.) to revise planned disturbed areas and impervious areas to be smaller. In the example project, no better site design techniques were applied.

B.2.3 Step 3: Calculate Stormwater Runoff Control Volume

Site Data
Site Area, A = 3.00 acres
Post-Development Impervious Area = 1.29 acres
Soils = HSG C
85th Percentile Rainfall Event, P = 1.2 inches (from Appendix A)

Calculate Site Imperviousness (I)
I = (Impervious Area ÷ Total Area) × 100%
I = (1.29 ac ÷ 3.00 ac) × 100%
I = 43%

Calculate Runoff Coefficient (R_v , Equation 3-23)
$R_v = 0.05 + 0.009(I)$
$R_v = 0.05 + 0.009(43)$
$R_v = 0.44$

Calculate Required Runoff Reduction Volume (RR_v , Equation 3-22)

$RR_v = (P)\ (R_v)\ (A) \div (12)$

$RR_v = (1.2\text{ in})\ (0.44)\ (3.00\text{ ac}) \div (12\text{ in/ft})$

$RR_v = 0.132$ acre-feet

Calculate Better Site Planning and Better Site Design Credits

The better site planning and better site design credits (that are not self-crediting) can be considered as a subtraction from the overall project area (and the required runoff reduction volume could be recalculated based on the revised area). Alternatively, the credits can be considered as a reduction in the required runoff reduction volume (RR_v). For this example, the credit ($RR_{Vcredit}$) in required runoff reduction volume was calculated and a revised runoff reduction volume was calculated.

$RR_{Vcredit} = (P)\ (R_v)\ (A) \div (12)$

$V_{credit} = (1.2\text{ in})\ (0.44)\ (0.55\text{ ac}) \div (12\text{ in/ft})$

$V_{credit} = 0.024$ acre-feet

The revised required runoff reduction volume (RR_v), after credit for better site planning and better site design, is:

$RR_{v\text{-revised}} = RR_v - V_{credit}$

$RR_{v\text{-revised}} = 0.132$ acre-feet – 0.024 acre-feet

$RR_{v\text{-revised}} = 0.108$ acre-feet

B.2.4 Step 4: Apply Low Impact Development Practices

Low Impact Development (LID) Practices (Section 4.7) include practices that are alternatives to impervious surface and also include practices that receive (and store) runoff from impervious areas and disturbed pervious areas. The design team for the example project choose to make the main parking lot a pervious pavement system and to include bioretention and a grass swale as shown in Figure B-4.

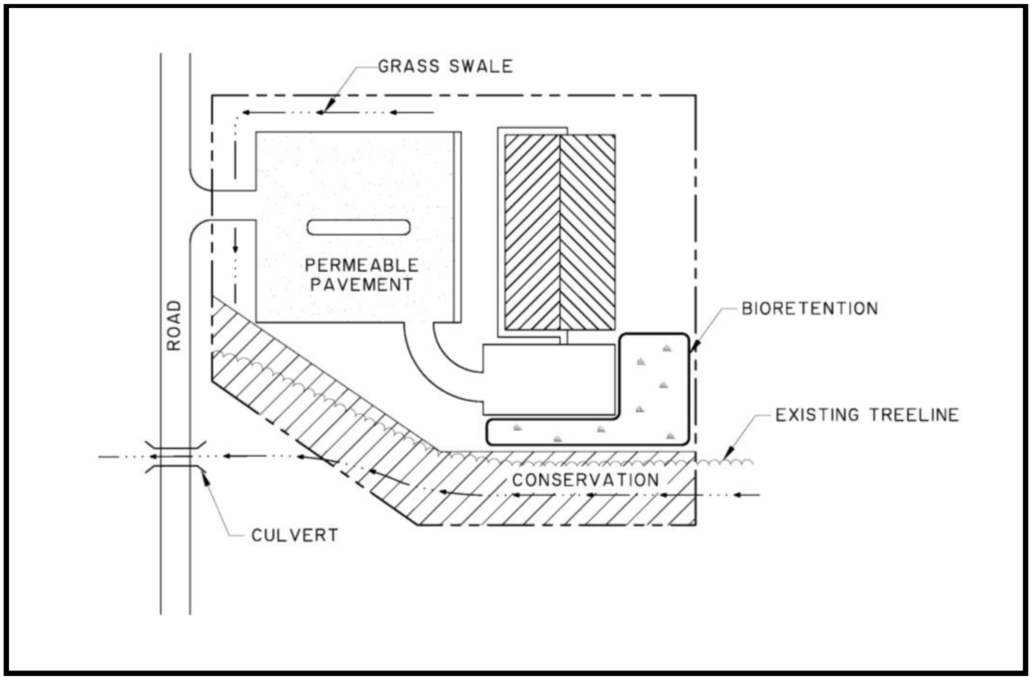


Figure B-4
Example Project Low impact Development Practices

The contributing drainage area for each LID practice was determined as illustrated in Figure B-5 as follows: pervious pavement – drainage area (DA) A; bioretention area - DA_B; and grass swale - DA_C. The various types of areas within each drainage area is summarized in Table B-1

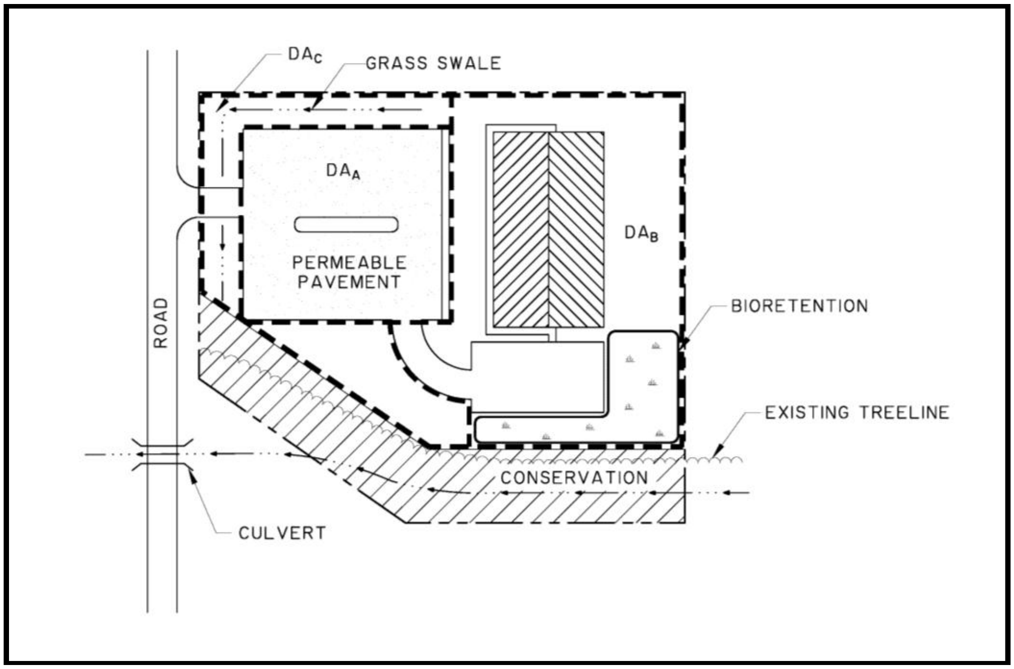


Figure B-5
Example Project Drainage Areas

Table B-1
Summary of Drainage Areas

Description	Impervious Area (ac)	Pervious Area (ac)	Total Area (ac)
DA_A	0.65	0.00	0.65
DA_B	0.62	0.68	1.30
DA_C	0.02	0.25	0.27

B.2.5 Step 5: Check To See If Stormwater Management Criteria Have Been Met

Based on the preliminary layout illustrated in Figure B-5, the volume reduction credits for the LID practice were calculated and compared to the required runoff reduction volume (RR_v).

Calculate Permeable Pavement Credit
Since the project site has HSG C soils, it is assumed that an under-drained permeable pavement system will be required. Per Table 4.1, the credit for an under-drained permeable pavement system is 50% of the storage volume provide by the system. The volume provided by the system was calculated based on the following:

Surface Area = 0.65 acres
Depth = 6 inches
Void ratio = 0.32

Note that the depth is the depth of stone reservoir beneath the permeable pavement, not the thickness of the permeable pavement.

V_{credit} = 50% × Storage Volume
V_{credit} = 50% × Surface Area × Depth × Void Ratio
V_{credit} = 50% × 0.65 ac × 6 in × 0.32 ÷ 12 in/ft
V_{credit} = 0.052 ac-ft

Calculate Bioretention Area Credit
Since the project site has HSG C soils, it is assumed that an under-drained bioretention area will be required. Per Table 4.1, the credit for an under-drained bioretention area is 50% of the storage volume provide by the system. The volume provided by the system was calculated based on the following:

Surface Area = 0.15 acres
Ponding Depth = 9 inches
Planting Bed Depth = 12 inches
Void Ratio of Planting Bed = 0.32

V_{credit} = 50% × Storage Volume
V_{credit} = 50% × (Surface Area x (Ponding Depth + (Depth of Planting Bed x Void Ratio)))
V_{credit} = 50% × (0.15 ac × (9 in + (12 in × 0.32))) ÷ 12 in/ft
V_{credit} = 0.080 ac-ft

Calculate Grass Swale Credit
Per Table 4.1 (for HSG C soils), the credit for a grass channel is 12.5% of the runoff volume conveyed by the system. The volume conveyed by the system is calculated by Equation 3-22 and 3-23:

Imperviousness (I)
I = (Impervious Area ÷ Total Area) × 100%
I = (0.02 ac ÷ 0.27 ac) × 100%
I = 7.4%

Runoff Coefficient (R_v , Equation 3-23)
$R_v = 0.05 + 0.009(I)$
$R_v = 0.05 + 0.009(7.4)$
$R_v = 0.117$

Runoff Volume (RR_v , Equation 3-22)
$RR_v = (P)\ (R_v)\ (A) \div (12)$
RR_v = (1.2 in) (0.117) (0.27 ac) ÷ (12 in/ft)
RR_v = 0.003 ac-ft

V_{credit} = 12.5% × Runoff Volume
V_{credit} = 12.5% × .003 ac-ft
V_{credit} = .000 ac-ft (or approximately 16 ft^3, which is negligible for calculation purposes)

Total LID V_{credit} = Permeable Pavement Credit + Bioretention Area Credit + Grass Swale Credit
Total LID V_{credit} = 0.052 ac-ft + 0.080 ac-ft + 0.00 ac-ft
Total LID V_{credit} = 0.132 ac-ft

Since the total LID V_{credit} (0.132 ac-ft) is greater that the revised required runoff reduction volume ($RR_{v\text{-}revised}$) of 0.108 acre-feet, the stormwater management plan meets the volume control portion of the Jasper County stormwater management requirements.

B.2.6 Step 6: Apply Stormwater Management Practices

Since the site meets the volume control portion of the Jasper County stormwater management regulations, no additional stormwater management practice are required to meet the water quality (pollutant load) portion of the Jasper County stormwater management regulations, as long as designed according to manual. However, the site must still meet the peak discharge rate requirements of the Jasper County stormwater management regulations, which require post-development peak rates to be less than or equal to pre-development rates for the 2-, 10-, and 25-year storm events.

The design and assessment of stormwater peak rate attenuation practice is beyond the purposes of this example and is well documented within other resources. However, to continue the example, it is assumed that a stormwater pond (Section 5.5.1) will be required as illustrated in Figure B-6 to comply with the stormwater standards.

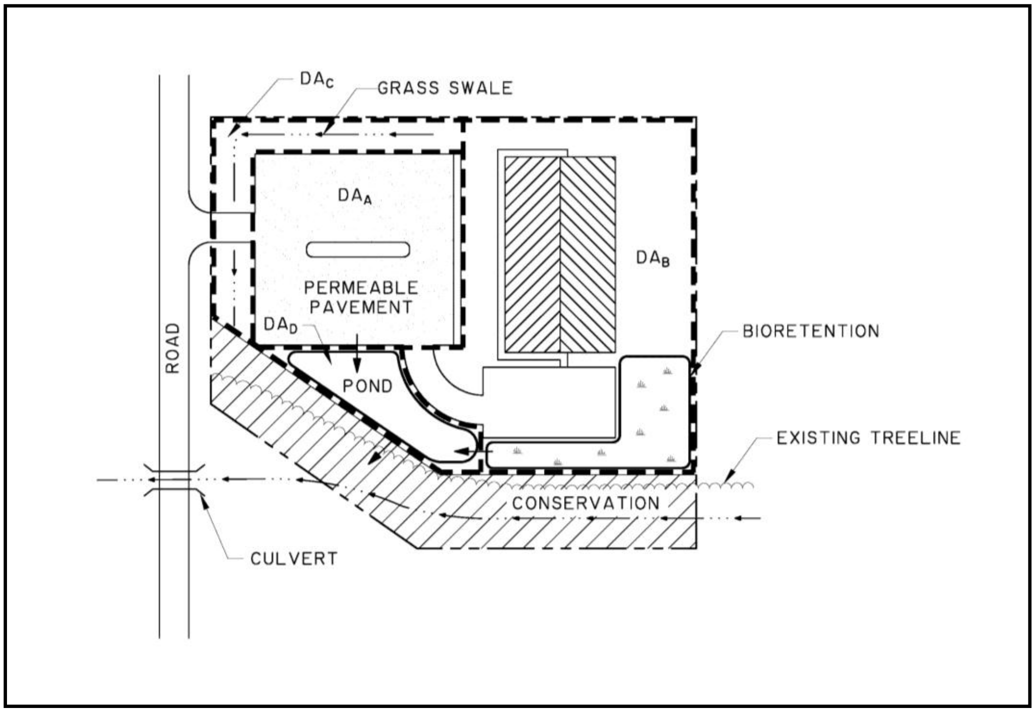


Figure B-6
Example Project Stormwater Management System

B.2.7 Step 7: Check To See If Stormwater Management Criteria Have Been Met

Following the implementation of the stormwater pond, the example project designers would assess the peak rate discharge of the site in post-development and compare it to pre-development rates. For the purposes of this assessment, it is assume that the pond attains the needed peak discharge attenuation to meet the requirements for the 2-, 10-, and 25-year stormwater events.

However, the implementation of the stormwater pond has added to the site's imperviousness and must be accounted for in revised calculators. Assuming that the pond will have a permanent pool (i.e. wet pond) with an area of 0.23 acres, the site imperviousness would be increased.

Calculate Site Imperviousness (I)
$I_{revised}$ = (Impervious Area ÷ Total Area) × 100%
$I_{revised}$ = ((1.29 ac + 0.23 acres) ÷ 3.00 ac) × 100%
$I_{revised}$ = 51%

Calculate Runoff Coefficient (R_v , Equation 3-23)
R_v = 0.05 + 0.009(I)
R_v = 0.05 + 0.009(51)
R_v = 0.51

Calculate Required Runoff Reduction Volume (RR_v , Equation 3-22)
RR_v = (P) (R_v) (A) ÷ (12)
RR_v = (1.2 in) (0.51) (3.00 ac) ÷ (12 in/ft)
RR_v = 0.153 acre-feet

Calculate the Revised Required Runoff Reduction Volume

$RR_{v\text{-revised}} = RR_v - V_{credit}$

$RR_{v\text{-revised}} = 0.153$ acre-feet – 0.024 acre-feet

$RR_{v\text{-revised}} = 0.129$ acre-feet

Since the total LID V_{credit} (0.132 ac-ft) is still greater than the revised required runoff reduction volume ($RR_{v\text{-revised}}$) of 0.129 acre-feet, the stormwater management plan still meets the volume control portion of the Jasper County stormwater management requirements. Had the implementation of the stormwater pond increased the $RR_{v\text{-revised}}$ to a volume greater than what could be provided under the proposed stormwater management approach (LID V_{credit}), then additional controls or better site design practices would have been required.

B.2.8 Step 8: Finalize Stormwater Management Plan

Based on the assessment of the conceptual stormwater management plan illustrated above, the site's stormwater management plan can be finalized and detailed design calculations for all components can be completed.