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Section 1 – INTRODUCTION

(Last revised 7/24/06)

1.1 GENERAL

The following module establishes guidelines, which will assist in the development standards set forth by the City of Jacksonville. The methods, procedures, design factors, formulas, graphs, and tables presented in this manual are intended to establish minimal guidelines for the solution of drainage problems involving determinations of the quantity of runoff, rate of flow, method of collection, storage, and conveyance of storm water.

Alternative design methods may be considered by the Engineer/Designer on a case-by-case basis; however, there should not be extensive variations from the criteria and procedures within this division without the expressed approval of the Public Services Director.

1.1.1 PUBLIC SERVICES DIRECTOR

The Public Services Director shall be responsible for interpretation and implementation of the stormwater management and design criteria for the City of Jacksonville. Approval from other applicable agencies may be required.

1.1.2 CITY OF JACKSONVILLE STORMWATER MANAGEMENT

It is the policy of the City of Jacksonville that all developed land within the City Limits has adequate stormwater facilities and controls to ensure the protection and safety of life and property. The City may accept stormwater management systems for maintenance if the system provides drainage for streets that have been accepted for maintenance by the City and have been designed and constructed in accordance with the provisions of the subdivision ordinance, the North Carolina *Erosion and Sediment Control Planning and Design Manual*, and this manual.

1.1.3 PERMITS

A. **Plan approvals, Permits**: Prior to commencing construction, all plan approvals applicable permits shall be obtained. A preconstruction conference with the City Inspector must also be held prior to commencing any construction.

B. **Encroachment Permits:** An encroachment permit will be required from any Contractor or Developer wishing to excavate or place storm drainage structures on either a NCDOT or Municipal public right-of-way.

C. **Pavement Cuts**: Pavement cuts in streets shall be repaired in accordance with the specific requirements of public agency on whose street or roadway the utility is being placed, as well as any other applicable requirements dictated in the approved encroachment permit. Open cut crossings shall otherwise adhere, as applicable, to specification **Section 02275, Trenching, Backfilling & Compaction of Utilities.**

D. Developer must obtain all other State and Local permits, as applicable (Air Quality, Erosion, and Sedimentation Control, Zoning, etc.)

E. **Plan Review and Observation Fees:** All plan review and observation fees must be paid prior to approval of project. Refer to the current City fee schedule for applicable fees.

1.1.4 WETLANDS, WATERSHEDS, BUFFERS

All stream impacts by crossings, pipe placement, excavation, regrading, clearing, maintenance, etc. shall be subject to the applicable US Army Corps of Engineers 404 and DWQ 401 permit requirements in affect at the time of the permit application. Construction within jurisdictional wetlands and buffers shall conform to the applicable permit requirements of the issuing agency.

1.1.5 EROSION AND SEDIMENTATION CONTROL AND NPDES MONITORING, CONTROLS, AND LIMITATIONS FOR PERMITTED DISCHARGES

The Project Engineer shall submit a sedimentation and erosion control plan to the appropriate authority and obtain all necessary construction permits. The Contractor shall follow all local and state requirements regarding sedimentation and erosion control. Construction methods shall minimize sedimentation and erosion.

It is the Contractor's responsibility to periodically monitor the Stormwater Discharge Outfall points at the specified frequency and maintain reports as outlined in these specifications.

A. **Final Limitations and Controls for Stormwater Discharges**

During the period beginning on the effective date of the permit and lasting until expiration, the Owner (Permittee) is allowed and authorized to discharge stormwater associated with construction activity. Such discharges shall be controlled, limited, and monitored as specified below.

1) The Contractor shall implement the Erosion & Sedimentation Control plan, which has been approved by the approval authority. The approved plan is considered a requirement or condition of the general NPDES permit. Deviation from the approved plan, or approved amendment to the plan, shall constitute a violation of the terms and conditions of this general permit except that deviation from the approved plan will be allowed:

    a. To correct an emergency situation where sediments are being discharged off the site, or

    b. When minor modifications have been made for the purpose of improving the performance of the erosion and sedimentation control measures and notification of the minor modification has been made to the Division of Land Resources (or approved local program).

       Such a deviation from the approved plan shall be noted on the approved plan maintained at the job site. During active construction, a copy of the approved plan shall be maintained on the site.

2) Equipment utilized during the construction activity on a site must be operated and maintained in such a manner as to prevent the potential or actual pollution of the surface or ground waters of the state. Fuels, lubricants, coolants, and hydraulic fluids, or any other petroleum products, shall not be discharged onto the ground or into surface waters. Spent fluids shall be disposed of in a manner so as not to enter the waters, surface, or ground, of the state and in accordance with applicable state and federal disposal regulations. Any spilled fluids shall be cleaned up to the extent practicable and disposed of in a manner so as not to allow their entry into the waters, surface or ground, of the state.

3) Herbicide, pesticide, and fertilizer usage during the construction activity shall be consistent with the Federal Insecticide, Fungicide, and Rodenticide Act and shall be used in accordance with label restrictions.

4) All wastes composed of building materials shall be disposed of in accordance with North Carolina General Statutes, Chapter 130A, Article 9 – Solid Waste Management, and rules governing the disposal of solid waste (North Carolina Administrative Code Section 15A NCAC 13B).

5) The Contractor, for the Permittee, shall control the management and disposal of litter and sanitary waste from the site such that no adverse impacts to water quality occur.

B. **Minimum Monitoring and Reporting Requirements**

Minimum monitoring and reporting requirements are as follows unless otherwise approved in writing by the Director of the Division of Water Quality.

1) All erosion and sedimentation control facilities shall be inspected by or under the direction of the permittee (the Owner).

   a. At least once every seven calendar days (at least twice every seven days for those facilities discharging to waters of the State listed on the latest EPA approved 303(d) list[1] for construction related indicators of impairment such as turbidity or sedimentation),

   b. And within 24 hours after any storm event of greater than 0.5 inches of rain per 24-hour period.

   The Contractor shall maintain a rain gauge on the site and a record of the rainfall amounts and dates shall be kept by the Contractor.

2) Once land disturbance has begun on the site, stormwater runoff discharges shall be inspected by observation for stormwater discharge characteristics as defined below at the frequency in stated above to evaluate the effectiveness of the pollution control facilities or practices. If any visible sedimentation is leaving the disturbed limits of the site, corrective action shall be taken immediately to control the discharge of sediments outside the disturbed limits.

Stormwater Discharge Characteristics	Monitoring Type[1]	Monitoring Location[2]
Clarity	By observation	SDO
Floating Solids	By observation	SDO
Suspended Solids	By observation	SDO
Oil Sheen	By observation	SDO
Other obvious indicators of stormwater pollution	By observation	SDO

Footnotes:
[1] Monitoring Type: The monitoring requires a qualitative observation of each stormwater outfall. **No analytical testing or sampling is required**.
[2] Sample (observation) location: **SDO**= **S**tormwater **D**ischarge **O**utfall

3) The operator (Contractor) shall keep a record of inspections and forward copies of these reports to the Public Services Director. Visible sedimentation found outside of the disturbed limits shall be recorded and a brief explanation kept with the records as to the measures taken to control future releases. Any measures taken to clean up the sediment that has left the disturbed limits shall also be recorded. These records shall also be made available to DWQ or an authorized agent upon request. If the Public Services Director discovers sedimentation outside the limits of disturbance, the Contractor will be notified in writing and requested to remediate the situation.

[1] *The latest approved list may be obtained from the Division of Water Quality, or from the following website location: http://h2o.enr.state.nc.us/su/construction303d.*

4) All records of monitoring shall be turned over to the City along with the "red lined" record water and/or sewer drawings.

C. **Schedule of Compliance**

1) The Contractor shall comply with Final Limitations and Controls specified for stormwater discharges once disturbance has begun on the site and until completion of development and the establishment of a permanent ground cover.

2) During construction and until the completion of development and the establishment of a permanent ground cover, the Contractor shall provide the operation and maintenance necessary to operate the stormwater controls at optimum efficiency.

1.1.6 PIPE MATERIAL APPLICATIONS

A. **General**: Use pipe and methods of joining in accordance with the following:

Table 1.1

PIPE MATERIAL	USE CONDITIONS
Plain Concrete Pipe (ASTM C14)	18" min, not permitted in traffic areas, can be used for side drains
Reinforced Concrete Pipe (ASTM C76)	18" min, for driveways and roadways
Corrugated Aluminum Alloy Pipe (Round or Arch)	18" min. Type 1A not permitted
Aluminum Coated Metal Pipe	Not allowed
Double walled corrugated HDPE Pipe	Not permitted in traffic areas, can be used for side drains

1.1.7 MAXIMUM PIPE LENGTH BETWEEN STRUCTURES

To permit maintenance of pipe drainage systems, unless otherwise approved by the Public Services Director, the maximum length of pipe runs shall not exceed the distances provided in Table 1.2 without a catch basin or manhole junction box.

TABLE 1.2

PIPE MATERIAL	SIZE (inches)	MAXIMUM LENGTH (feet)
Plain Concrete Pipe	15 to 24	425
Reinforced Concrete Pipe	15 to 48	425
	54 and 60	800[1]
	66 and larger	1000[1]
Double walled HDPE Pipe	15 to 48	425

[1]This length may be exceeded with approval of the Public Services Director on a case-by-case basis.

1.1.8 STRUCTURE PLACEMENT REQUIREMENTS:

A DRAINAGE STRUCTURE BOX IS REQUIRED AT ALL PIPE INTERSECTIONS VERTICAL, HORIZONTAL, OR CHANGE IN SIZE.

1.1.9 LATERAL TAPS/BRANCHES (NOT PERMITTED WITHOUT JUNCTION BOX)

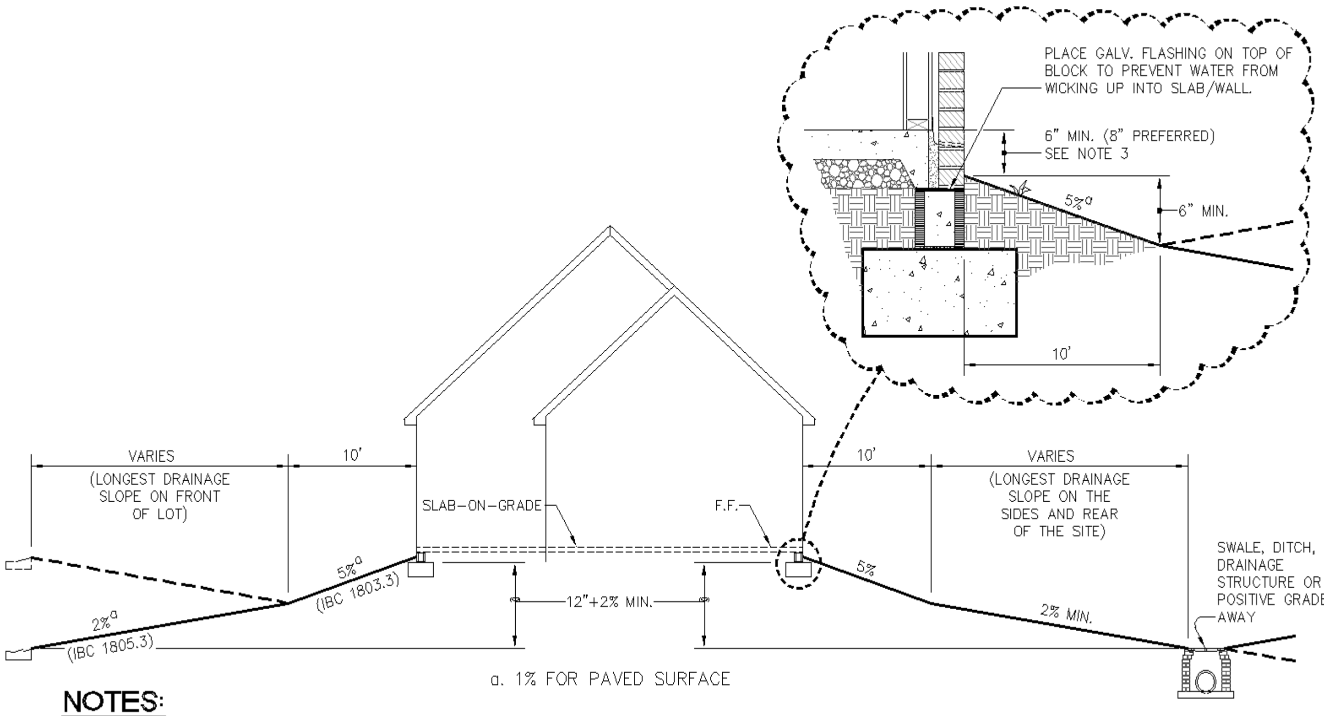
1.1.10 STRUCTURES IN RELATION TO STREAMS/FLOOD PLAINS:

Storm drainage manholes, pipe, or other drainage structures shall be located so that they will not interfere with free discharge of the flood flows of the stream to which they are proposed to tie. Portions of manholes above grade subject to hydrodynamic forces of flooding shall be designed to resist the flood forces with a safety factor of 2.5. Considerations shall be given for impact from debris.

1.1.11 PROJECT GRADING

All buildable areas shall be reasonably graded in such a way as to provide for positive drainage away from building sites in accordance with paragraphs 1803.3 *Site Grading* and 1805.3.4 *Foundation Elevation* of the 2000 NC Building Code, 2002 edition with NC amendments, latest revision (see Figure 1.1 of building code below) and will be enforced by the City Code Enforcement Officials).

FIGURE 1



NOTES:

1. CAUTION SHOULD BE EXERCISED WHEN GRADING WITHIN 10' OF HOUSE TO ALLOW FOR POTENTIAL BUILDUP OF LANDSCAPING NEXT TO HOUSE WHICH MAY RAISE GRADE AND RETARD OR RETAIN SURFACE RUNOFF!
2. GUTTER WITH DOWN SPOUTS ARE VERY BENEFICIAL AT PREVENTING DEPOSITION OF ROOF RUNOFF AT FOUNDATION.
3. NO TIMBER ON STRUCTURE, UNLESS TREATED, IS PERMITTED WITHIN 8" OF EXTERIOR GRADE.

CODE REQUIREMENTS for MINIMIZING FOUNDATION SUBSIDENCE

NOT TO SCALE N.C. REV. 4-14-03

Section 2 – PLAN SUBMITTALS

The purpose of this section is to establish the design procedures and criteria for storm drainage design on systems either owned or maintained by the City of Jacksonville or those systems otherwise required to meet certain criteria related to stormwater management (e.g., dry or wet detention basins, Best Management Practices, etc.). It is also the purpose of this section to outline the minimal plan submittal requirements for plan review and approval of both City-owned and private Stormwater facilities, as applicable.

2.1 SUBMITTAL REQUIREMENTS

Seven complete sets of site plan drawings and **two** complete sets of sitework calculations shall be submitted to the City of Jacksonville Public Services Department, Attn: Public Services Director for review and approval. The submission shall include:

2.1.1 CERTIFICATION REQUIREMENTS

The following certifications shall appear on the first Stormwater Management sheet in the plan set.

2.1.2 DESIGNER'S CERTIFICATION

"I hereby certify that, to the best of my ability, this plan has been prepared in accordance with the latest City of Jacksonville Manual of Specifications and Standard Details and City Code."

Signature:__________________________
Printed Name and Title:________________
Date:_______Registration Number: ______

2.1.3 OWNER'S/DEVELOPER'S CERTIFICATION

"I/We hereby certify that all site construction, drainage and grading will be done pursuant to this plan and that the applicable Stormwater Management conditions and requirements of the City of Jacksonville, the State of North Carolina and the Federal Government and its agencies are hereby made part of this plan."

Signature:__________________________
Printed Name:_______________________
Title:___________________Date:________

2.1.4 CHECKLIST OF STORMWATER STANDARDS

The following checklist shall be submitted with all plans submitted for City approval.

CITY OF JACKSONVILLE

Checklist for Stormwater Standards

FOR CITY USE ONLY:

Project Number:______________________
Number of Plan Sets Received:__________
Date Received:_______________________
Reviewer's Name:_____________________

Please provide complete documentation and details where applicable. NO PLAN SUBMITTAL will be complete unless all information is filled out completely. Indicate ***"Not Applicable"*** where appropriate.

Name of Development:_______________________________________

Owner Information:

Name: ____
Address:____
____
Phone Number:________________Fax Number: ___________
e-mail address:_______________________________________

Developer Information:

Name: ____
Address:____
____
Phone Number:________________Fax Number: ___________
e-mail address:_______________________________________

Designer Information:

Name of Company:____________________________________
Address:____
____
Project Designer:_______________Registration Number:______
Phone Number:________________Fax Number: ___________
e-mail Address:_______________________________________

Name of Receiving Stream: ________________________________

Parcel Identification Number (PIN): ___________________________

Plan Requirements (Indicate ***"N/A"*** where appropriate)**:**

Yes	No	N/A	Sheet No.	Description	Remarks
□	□	□	_______	Development Name	_______
□	□	□	_______	Owner	_______
□	□	□	_______	Design Firm	_______
□	□	□	_______	Sealed, Signed and Dated	_______
□	□	□	_______	Sheet Number	_______
□	□	□	_______	Date	_______
□	□	□	_______	Revision Numbers and Dates along with a list of all revisions made	_______
□	□	□	_______	Designer's Certification	_______
□	□	□	_______	Owner's/Developer's Certification	_______
□	□	□	_______	North Arrow	_______
□	□	□	_______	Property Lines	_______
□	□	□	_______	Legend	_______
□	□	□	_______	Vicinity Map	_______
□	□	□	_______	Scale (min. at 1"=50')	_______
□	□	□	_______	General Description of Project	_______
□	□	□	_______	General Description of Erosion Controls	_______
□	□	□	_______	General Description of Stormwater Management Facilities	_______
□	□	□	_______	Project Schedule, Narrative, Sequence of Construction	_______
□	□	□	_______	Adjacent Property Owners	_______
□	□	□	_______	Existing Streets, Buildings, etc.	_______
□	□	□	_______	Wooded Limits	_______
□	□	□	_______	Wetland Limits	_______
□	□	□	_______	Water Quality Buffers	_______
□	□	□	_______	Proposed Public Drainage Easements shown	_______
□	□	□	_______	Land Use of Surrounding Areas	_______
□	□	□	_______	Original Contours (2-foot intervals)	_______
□	□	□	_______	Proposed contours (2-foot intervals) or sufficient number of spot elevations	_______
□	□	□	_______	Actual Field Survey	_______
□	□	□	_______	City/USGS Topographical Data	_______
□	□	□	_______	Existing Streams, Lakes, etc.	_______
□	□	□	_______	Size and Location of Existing Culverts	_______
□	□	□	_______	Size and Location of Proposed Culverts	_______
□	□	□	_______	Limits of Drainage Area	_______
□	□	□	_______	Limits of Construction, Clearing & Grading	_______
□	□	□	_______	Existing & Proposed Improvements (including utilities and protective measures)	_______
□	□	□	_______	Delineation of FEMA 100-yr Floodplain w/i 200 feet of project, 100 year BFE shown	_______

□	□	□	_______	Location and elevation of the lowest floor in all proposed and existing buildings	_______
□	□	□	_______	Location of Stormwater Management Facilities (includes details, plan, profile, and cross sections)	_______
□	□	□	_______	Maintenance plan for stormwater management facilities	_______
□	□	□	_______	Submitting 7 Set of Plans	_______

Calculation Requirements

Note: Drainage structures should be designed to handle all upstream flow when the basin is fully built out.

Yes	No	N/A	Sheet No.	Description	Remarks
□	□	□	_______	Development Name	_______
□	□	□	_______	Owner	_______
□	□	□	_______	Design Firm	_______
□	□	□	_______	Sealed, Signed and Dated	_______
□	□	□	_______	Capacity of receiving channel downstream of channel, pipe or basin system	_______
□	□	□	_______	Total area, impervious area, CN, Tc, Q_{pre} and, Q_{post} for 10-year/25-year/100-year storms as applicable	_______
□	□	□	_______	25-year (where required) flows at cross-street drainage structures	_______
□	□	□	_______	10-year and 100-year flood routing analysis through all detention/retention facilities	_______
□	□	□	_______	Design flows and velocities in open channels	_______
□	□	□	_______	Quality control computations	_______
□	□	□	_______	Soils/Geotechnical Report/Analysis (for infiltration facilities)	_______
□	□	□	_______	Submit 2 Sets of Calculations	_______

Piped Systems*: (For Residential Streets)

Yes	No	N/A		Description	Remarks
□	□	□	_______	Analyzed and designed for 10-yr Storm	_______
□	□	□	_______	Designed for 25-year (where required) flows at cross-street drainage structures	_______
□	□	□	_______	Minimum Velocity = 2.5 FPS	_______
□	□	□	_______	Headwall or Flared End Sections	_______
□	□	□	_______	Energy Dissipater Calculations	_______
□	□	□		Capacity of receiving channel downstream of channel or pipe system	

□	□	□		Gutter spread limited to ½ lane width from the face of the curb, for a rainfall intensity of 4 inches per hour	

Open Channel Systems:

Yes	No	N/A		Description	Remarks
□	□	□		Capacity analyzed and designed for 10-yr Storm	
□	□	□		Lining Designed for 2-yr Storm	
□	□	□		Side Slopes 3 to 1 or flatter	
□	□	□		Minimum Bottom Width = 3 Feet	
□	□	□		Velocity Check (Liners provided, if needed)	
□	□	□		Capacity of receiving downstream channel	

Other Plan Submittals:

The following permits or items may need to be considered by the designer. Check off those that are applicable to this project. All below shaded items are to be submitted to the City. Other items shall be submitted upon request only.

Yes	No	N/A		Description	Remarks
□	□	□		Maintenance plan for all stormwater facilities	
□	□	□		Landscaping details for stormwater management BMP's	
□	□	□		Name and address of entity responsible for maintenance	
□	□	□		Submit Erosion & Sedimentation Control Plan to City of Jacksonville	
□	□	□		Submit permits to NCDOT for encroachments and driveways	
□	□	□		US Army Corps of Engineers 404 permits	
□	□	□		Comply with water supply watershed protection ordinance	
□	□	□		Complete survey of threatened or endangered species	
□	□	□		NCDENR, Water Quality permits	

* Contact Public Services Director for requirements if other than Residential Streets.

Comments:

Submittal Worksheet for Dry Detention, Wet Retention, Extended Detention Wetland Basins, and other BMP Facilities:

The City of Jacksonville will follow the City Code and the North Carolina Department of Environment and Natural Resources, Division of Water Quality Stormwater *Site Planning Guidance Manual* and the *Stormwater Best management Practices Handbook* with regard to Dry Detention, Wet Retention Basin, Extended Detention Wetland Basins and other BMP's within the City's jurisdiction. Please provide complete documentation and details where applicable. A complete stormwater management plan submittal includes a worksheet for each basin, design calculations, plan and specifications showing all basin and outlet structure details, and a fully executed operation and maintenance agreement. An incomplete submittal package will result in a request for additional information and will substantially delay final review and approval of the project. Indicate "Not Applicable" where appropriate if design is a dry detention basin.

I. Project Information (please complete the following information):

Project Name: ____

For projects with multiple basins, specify which basin this worksheet applies to:____________________

Basin Bottom Elevation	________	ft.	(average elevation of the floor of the basin)
Permanent Pool Elevation	________	ft.	(elevation of the orifice invert out)
Temporary Pool Elevation	________	ft.	(elevation of the outlet structure invert in)
Permanent Pool Surface Area	________	sq. ft.	(water surface area at permanent pool elevation)
Drainage Area	________	ac.	(on-site and off-site drainage to the basin)
Impervious Area	________	ac.	(on-site and off-site drainage to the basin)
Permanent Pool Volume	________	cu. ft.	(combined volume of main basin and forebay)
Temporary Pool Volume	________	cu. ft.	(volume detained on top of the permanent pool)
Forebay Volume	________	cu. ft.	(volume detained on top of the forebay pool)
SA/DA used	________		(surface area to drainage area ratio)
Diameter of Orifice and Number	____in./____		(draw down orifice diameter and number of)

II. Required Items Checklist

The following checklist outlines design requirements per the North Carolina Stormwater Best Management Practices Handbook (NCDENR, Division of Water Quality, April, 1999). Initial in the space provided to indicate the following design requirements have been met and supporting documentation is attached. *If a requirement has not been met, attach an explanation of why.*

Applicant's Initials	Dry Detention Basin (standard detail 640.01)
________	Impervious areas used for sizing is based on expected final build out of the development and any offsite runoff that drains to the pond.
________	The basin length to width ratio is 3:1 or greater or correctly spaced baffles placed to lengthen the flow path between the inlet and outlet.
________	A 20-foot vegetation buffer to the maximum surface water elevation is provided.
________	Flood control goal: Pond outflow from principle outlet structure must not exceed the 10-year storm pre-development flow. or 25 year storm in areas with a history of localized flooding problems.
________	Basin side slopes are no steeper than 3:1.
________	Emergency spillway safely passes the 100-year storm with velocity less than 3 fps across stabilized spillway designed per NCDENR regulations with a minimum of a 1-foot freeboard.
________	The basin designed using 2-yr Storm for channel adequacy.
________	The storage for flood control located above the temporary storage pool.
________	Outlet structure checked for buoyancy.
________	Splitter plate and trash rack provided on principle outlet structure.
________	Anti-seep collar on outlet pipe
________	Access is provided for maintenance
________	Design checked and certified for structural integrity and floodplain impacts for the 100-yr Storm
________	A site specific operation and maintenance (O&M) plan is provided

Applicant's Initials	
________	A vegetation management/mowing schedule is provided in the O&M plan
________	A debris check is specified in the O&M plan after every storm event
________	Semi-annual inspections are specified in the O&M plan
________	The Operation & Maintenance checklist is specified in the O&M plan to be performed after every storm event.
________	A responsible party is designated in the O&M plan

Applicant's Initials	**Wet Detention Ponds** (items to be added to Dry Detention pond requirements to yield a Wet Detention Pond)
________	SA/DA is based on minimum 85% TSS removal (based on Coastal Counties Tables).
________	The temporary pool, located above the permanent pool, sized to detain the runoff volume from the 1st inch of runoff ("first flush"). The 1st inch draws down in a minimum of 2 to 5 days.
________	Minimum permanent water quality pool depth is 3 to 6 feet with minimum of 3 feet.
________	The forebay volume is approximately equal to a minimum of 20% of the total basin volume
________	Sediment storage is provided in the permanent pool
________	The storage for flood control located above both the permanent and temporary (1st inch of runoff) water quality pools.
________	A submerged and vegetated 10' wide perimeter shelf provided (below the normal pool elevation) at a slope not exceeding 6:1. Inward from edge of shelf, basin side slopes are no steeper than 3:1.
________	An emergency basin drain with gate valve is provided to drain the basin sufficient to drain the pond in 24 hours for riser repairs and sediment removal.
________	A minimum 30-foot vegetated filter is provided at the outlet
________	A specific sediment clean-out benchmark is listed (elevation or depth) in the O&M plan

Applicant's Initials	**Extended Detention Wetlands (standard detail 640.01)** (additional items applicable to Extended Detention Wetland Basins)
________	Determine the surface areas of the pond using 3 foot depth (this does not mean the pool depth will be 3 feet deep! It is for pool area computation only)
________	70% of pool area is designed as a marsh with a depth of 0 to 18" with an almost equal distribution of area (35% and 35%) between 0 to 9" and 9" to 18".
________	A small pool (15% of the surface area) is located at the outlet to prevent sediment form interfering with the outlet structure functions.
________	15% forebay
________	Plant specification and installation of plants shown (it is not necessary to plant cattails as they will volunteer on their own).
________	Contour pond using 0.5 foot contours.
________	The shelf from the normal pool elevation contour inward needs to be 6:1 on the perimeter only. Once away from the shelf areas, contours can vary as desired. Minimum shelf width = 10 feet.

Applicant's Initials	**Pocket Wetlands in combination with Grassed Swales**
________	Sizing process follows wet detention basin guidelines but shall incorporate Table 2.1 (below). An average of 2 feet is assumed.

Table 2.1
Surface Area to Drainage Area Ratios for Sizing Pocket Wetlands

Imperviousness (%)	SA/DA (%)
<70	0.75
70	0.80
75	0.85
80	0.91
85	0.96
90	1.02
95	1.07
100	1.12

_______________ Capture the runoff from the 1-year 24 hour storm and release it over a period of 48 hours **or**,
_______________ Capture the runoff from the 1-inch storm and allow it to draw down over a period of 2 to 5 days.
_______________ Average depth no more than 2 feet.
Pond area distribution:
_______________ High Marsh (0-6 inch depth) = 50%
_______________ Low Marsh (6-12 inch depths) = 40%
_______________ Open water (>18 inch depth) = 10%
_______________ Cleanout access provided
_______________ Drain provided to completely drain the basin for cleanout
_______________ Peak flow control to accommodate 10-year storm pre-development flow, and 25-year storm when required.
_______________ Vegetation plan prepared by a NC licensed professional Landscape Architect, Engineer, or Architect giving special consideration to the species specified due to frequent inundations.
_______________ The plans must specify that the wetland must be stabilized within 14 days of construction with final vegetation or temporary means until vegetation can become established.
_______________ Plunge pool, riprap or other measure provided at inlets to prevent re-suspension of sediments.
_______________ Pocket wetlands that receive runoff from anything other than vegetated filters or swales must incorporate a forebay.
_______________ O&M specifies that the top few inches of sediment is stockpiles so that it can be replaced over the surface of the wetland after completion of sediment removal to reestablish through its own seedbank.
_______________ O&M specifies cleanout at 6 inches.

III. A Checklist for Other BMP Measures (please complete the following information):

Applicant's Initials	Level Spreaders
_______________	Entire system passes the 10-year storm without causing erosion, gullies, or rills.
_______________	Slope of the natural ground away from or parallel to the level spreader is relatively smooth in the direction toward the stream so that flow will not re-concentrate.
_______________	Minimum length = 10 feet; maximum length = 300 feet
_______________	Level spreader is level
_______________	Type and amount of vegetative cover considered

Applicant's Initials	Grassed Swales
_______________	Longitudinal slope 2% to 4%.
_______________	Checkdams provided for slopes >4%
_______________	Side slopes greater than or equal to 3:1
_______________	Maximum runoff velocity = 2 fps for the 2-year peak runoff
_______________	Design must pass the peak runoff rate from a 10-year storm
_______________	Length of swale shall be at least 100 feet per acre of drainage area
_______________	Swales constructed on permeable, noncompacted soils preferred
_______________	Seasonal high water at least 12 inches below the bottom of the swale
_______________	Swale does not carry dry-weather flows or constant flows of water
_______________	Swales to have short contact time or short grass height

Applicant's Initials	Sand Filter (standard detail 642.01)
	Sediment Chamber:
_______________	Volume = 540 ft^3 per acre of drainage
_______________	Minimum 18 inches deep
_______________	Surface area of at least 360 ft^2/acre
_______________	Positive drainage to chamber either in conduit or surface drainage
_______________	No outlet except to sand chamber
_______________	Outlet to the sand chamber to result in sheet flow

Sand Filter Chamber:

- Volume = 540 ft^3 per acre of drainage
- At least 18 inches of sand particles of less than 2mm average diameter
- A surface area of at least 360 ft^2/acre
- An outlet positioned and sized such that the sand chamber will drain completely in 24 hours.
- No single outlet pipe sized greater than 6 inches, in order to provide a minimum of 12 inches of sand above pipe.
- Access to both chambers sufficient for all maintenance activities
- Structure able to withstand any load expected to occur (water quantity, sediment quantity, and surface loading).

Applicant's Initials	**Bioretention Areas (standard details 641.01 through 641.06)** (Design generally complies with the requirements of DWQ's *Stormwater Best Management Practices*, Section 4.0 – *Bioretention Areas*)

- Minimum functional width of 15 feet (25 feet preferable)
- Minimum length 40 feet. For widths equal or greater than 20 feet, the length of the bioretention area should be at least 2 times the width (to permit sheet flow to be dispersed over a greater distance).
- Maximum depth of ponded area = 6 inches
- Minimum depth of planting soil = 4 feet
- Bioretention area < 5 acres. 0.25-acre to 1.0-acre bioretention basins sizes may be required where high erosive velocities occur.
- Drainage area sized for sheet flow for the 10-year storm.
- Sheet flow into basin < 5 fps. If not, provisions made to prevent erosion of vegetated areas.
- [a] Bioretenton area = 5% of the drainage area multiplied by the Rational "C" coefficient when sand bed used. See standard detail 641.01.
- [a] Bioretenton area = 7% of the drainage area multiplied by the Rational "C" coefficient when sand bed is not considered appropriate. See standard detail 641.01.
- Runoff entering bioretention area in form of sheet flow.
- First flush accomplished through curb openings of 3 feet width with a diversion block in front of the curb opening and using a drainage area of 1 acre (based on commercial land use with runoff coefficient of 0.8 using HEC-12). Multiple curb openings provided when longitudinal curb slope exceeds 7%.
- Maximum sheet flow velocity for planted ground = 3 fps; for mulched cover, 1 fps. (Note: velocity from 3-foot curb opening draining a 1-acre commercial tract is 0.5 fps and thus non-erosive to either type of cover).
- Water table > 6 feet from the land surface desired.
- Grassed buffer strip and sand bed (Desired where space constraints allow). See standard detail 641.02.

[a] Sizing rule based on the bioretention area infiltration precipitation events of 0.5 to 0.7 inches occurring over a 6-hour time period.

Applicant's Initials	**Infiltration devices (standard detail 643.01)**

- Geotechnical study: Soils tested and shown to infiltrate a minimum of 0.52 inches/hour at the bottom of the device
- Infiltration devices must capture and infiltrate runoff from the first 1.5 inches of rainfall for SA classified waters and 1.0 inch of rainfall in all other areas
- Drawdown of runoff must occur within 5 days.
- Pretreatment devices such as catch basins, grease traps, filter strips, grassed swales and sediment traps must be used to protect infiltration devices from clogging.
- All infiltration devices should be sited a minimum of 30 feet from surface water, and 50 feet from Class SA waters and 100 feet from any water supply wells.
- The bottom of the infiltration device should be a minimum of 2 feet above the seasonal high water table, with greater separation desirable
- The bottom of the infiltration device must be a minimum of 3 feet above any bedrock or impervious soil horizon

______	The bottom of the device must be lined with a layer of clean sand with an average depth of 4 inches.
______	The sides of an infiltration trenches must be lined with Geotextile filter fabric
______	The rock used in infiltration trenches must be free of fines (washed stone) and have as large a void ratio as possible.
______	Infiltration devices must be designed as off-line BMP's. excess runoff by-passes the system
______	Basin not constructed on fill material unless approved by the Public Services Director
______	At least one piezometer should be included in the design (others may be required by the Public Services Director).
______	Infiltration trenches wide and shallow. Ratio of side to bottom areas less than 4:1. sides and bottom lined with filter fabric to prevent clogging.
______	Infiltration basin not located close to building foundations or other sensitive structures.

Applicant's Initials	**Porous Concrete Pavements (see standard detail 644.01)**
______	Must capture and infiltrate runoff from the first 1.5 inches of rainfall for SA classified waters and 1.0 inch of rainfall in all other areas
______	Design concrete porosity is 17% to 30%
______	Storage volumes indicated on plans/calculations and volumes account for slope of pavement structure
______	Pavement slope designed to be as flat as possible with slopes not exceeding 5%
______	Minimum depth of seasonally high water table is greater than 3 feet.
______	Drainage time for storm is minimum 12 hours to maximum of 72 hours, recommended at 24 hours
______	Run-on to the pavement from offsite areas is not allowed. Adjacent fine grained soils prevented from surface grading to porous pavement
______	On-site soils tested for porosity, permeability, and cation exchange.
______	Minimum infiltration rate of subsoil is greater than 0.25 inches per hour
______	Geotextile fabric provided on subgrade to prevent migration or transportation of fine grained soils
______	Maintenance issues covered in an operations and maintenance plan

Applicant's Initials	**Downspout Dispersion blocks**
______	A vegetated flowpath at least 50 feet in length as measured from the downspout to the downstream property line, structure sensitive steep slope, stream, wetland, or other impervious surface
______	The vegetated flowpath must be covered with well-established lawn or pasture, landscaping with well-established groundcover, or native vegetation with natural groundcover.
______	Flows shall not be directed onto sidewalks
______	A maximum of 700 square feet of roof area may drain to each splashblocks
______	A splashblock or a pad of crushed (2 ft wide by 3 ft long by 6 in deep) shall be placed at each downspout discharge point
______	No erosion or flooding of downstream properties may result
______	Splashblocks may not be placed on slopes greater than 20% or above erosion hazard areas without evaluation by a qualified geotechnical engineer and approval of the City
______	For sites with septic systems, the discharge point must be down slope of the primary and reserve drain field areas. This requirement may be waived by the City if site topography clearly prohibits flows from intersecting the drain field or where site conditions indicate that this is unnecessary
______	If the vegetated flowpath (measured as defined above) is less than 25 feet on a subdivision single-family lot, a perforated stub-out connection may be used in lieu of downspout dispersion.

[a] Sizing rule based on the bioretention area infiltration precipitation events of 0.5 to 0.7 inches occurring over a 6-hour time period.

2.1.5 ADDITIONAL REQUIREMENTS

Approval of Stormwater Management Plans and Calculations by the City of Jacksonville does not complete the City of Jacksonville review process. All other applicable City Departments, State, and Federal agencies must also approve the plan as warranted. It shall be the sole responsibility of the Owner/Developer/Designer to acquire all applicable approvals.

Section 3 – HYDROLOGIC ANALYSIS

The purpose of this section is to establish standard procedures and criteria for the performance of hydrologic analyses in the City of Jacksonville.

3.1 DETERMINATION OF RUNOFF

The determination of runoff may be the single most important factor in the planning, design, and construction of drainage facilities. If the estimate of storm runoff is incorrect, the constructed facilities may be undersized or oversized. An improperly designed drainage system may be uneconomical, cause flooding, interfere with traffic, and may be a general nuisance in the affected area. However, determination of runoff can only be approximated using sound engineering processes to represent physical and climatic factors to best model the system.

There are many methods currently available to estimate peak flow rates. Hydrograph methods are almost exclusively used to generate runoff hydrographs. Hydrograph analysis is performed when flow routing is important such as in the design of stormwater detention, other water quality facilities, and pump stations. They can also be used to evaluate flow routing through large storm drainage systems to more precisely reflect flow peaking conditions in each segment of complex system. See the latest editions of the NC Department of Transportation *Guidelines for Drainage Structures*, latest revision, USDOT Federal Highway Administration *Urban Drainage Design Manual*, Hydraulic Engineering Circular No. 22 or the *NC Erosion and Sediment Control Planning and Design Manual*.

3.1.1 HYDROLOGICAL ANALYSIS OF WATERSHEDS SMALLER THAN 50 ACRES

A. **RATIONAL METHOD**

For small drainage areas (less than 50 acres in size) that have a drainage system unaffected by complex hydrologic situations, such as ponding areas and storage basins, the widely used Rational Method provides a useful means of determining peak storm runoff rates for small watersheds.

B. **HYDROGRAPH DEVELOPMENT FOR SMALL WATERSHEDS**

In situations requiring determination of a complete flood hydrograph, and not just a peak discharge, a different method should be utilized such as the SCS TR-20 method. Engineers wishing to use other alternative design techniques should consult the City of Jacksonville Public Services Director prior to design.

3.1.2 HYDROLOGICAL ANALYSIS OF WATERSHEDS FROM 50 TO 640 ACRES

Hydrological analyses involving watersheds of greater than or equal to 50 acres and less than 640 acres may be completed using either the Malcom Method to develop runoff hydrographs.

A. MALCOM'S METHOD OF HYDROGRAPH DEVELOPMENT

Malcom's Method for hydrograph development is useful in the design of facilities, which require an analysis over time. This procedure can be used in conjunction with the Soil Conservation Service (SCS) Method or the Rational Method. This methodology utilizes a pattern hydrograph to obtain a curvilinear design hydrograph which peaks at the design flow rate and which contains a runoff volume consistent with the design rainfall. The pattern hydrograph is a step function approximation to the dimensionless hydrograph proposed by the Bureau of Reclamation and the Soil Conservation Service [SCS, 1972].

This method is commonly used in designs that require storage areas, detention/retention basin design, ponding areas, or simply when a system needs to be routed in order to determine a peak elevation for any given storm event.

3.1.3 HYDROLOGIC ANALYSIS OF WATERSHEDS LARGER THAN 640 ACRES

For areas less than 2000 acres, the SCS Tabular or Synthetic Hydrograph or Snyder's Synthetic Unit Hydrograph (HYDRAIN includes this design alternate See HEC-19 for detailed direction in this procedure.) method may be used for determining volume of flow and peak discharge. HEC-1 may also be used for basin areas larger than 640 acres (1 sq. mi.). Hydrograph methods can be computationally involved so computer programs such as HEC-1, TR-20, TR-55, and HYDRAIN may be utilized.

A. PRECIPITATION DATA

Design storm rainfall can be described in terms of area of study, frequency, duration and distribution of intensity with time. The distribution of design rainfall with respect to time is handled by the HEC-1 program by assuming a symmetrical, single-peaked design hyetograph (storm distribution). The engineer's choice of storm frequency and duration is dependent upon the physical characteristics and location of the watershed, as well as the study objectives. In most cases, design computations will be based on a 24-hour duration storm event. See the North Carolina Erosion & Sedimentation Control Planning and Design Manual for I-D-F curves and 24-hour Rainfall data Wilmington or utilize TP-40 to develop I-D-F curves for the Jacksonville area.

3.1.4 COMPUTER MODELING

Computer models, such as PondPack, can be used by engineers to analyze and design simple and complex watershed networks. They can be used to analyze pre- and postdeveloped watershed conditions and pond sizes, compute outlet rating curves with tailwater effects, pond infiltration, pond detention times and analyze channels. Several other comprehensive stormwater models have the ability to generate pollutant loads and the fate and transport of the pollutants, such as Stormwater Management Model (SWMM) and Storage, Treatment, Overflow, Runoff-Model (STORM).

Section 4 – OPEN CHANNEL DESIGN

The purpose of this section is to establish standard procedures and criteria for Open Channel Design for the City of Jacksonville.

4.1 INTRODUCTION

Open channels, where allowed, shall be designed according to the following criteria. The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off-site areas, assuming ultimate development in accordance with the current zoning regulations and the Comprehensive Land Use Plan.

4.1.1 OFF-ROAD DRAINAGE SYSTEM

The design of the off-road drainage system shall include the watershed affecting the subdivision and shall be extended to a watercourse or drainage way adequate to receive the storm drainage. Swales and channels shall be constructed true to definition and shall join the contours of the surrounding topography in such a manner that will create a gently rolling natural appearance. Side drainpipes along side property lines shall be extended to the back drainage easement.

When the drainage system is outside of the road right-of-way, the subdivision shall make provision for dedicating an easement to the City of Jacksonville to provide for the future maintenance of said system.

4.1.2 REQUIRED DOCUMENTATION FOR OPEN CHANNEL DESIGNS

The following information must be submitted to the City of Jacksonville for the design of open channels, but is not limited the following:

A. Vicinity Map: A vicinity map of the site and subject reach.

B. Site Map: A detailed map of the area and subject reach.

C. Watershed Map: A watershed map showing existing and proposed drainage area boundaries along with all sub-area delineations and all areas of existing or proposed development.

D. Discharge Calculations: Discharge calculations specifying the methodology and key assumptions used, along with computed discharges at key locations. The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off site areas, assuming ultimate development in accordance with the current zoning regulations and the Land Use Plan.

E. Hydraulic Calculations: Hydraulic calculations specifying the methodology used. All assumptions and values of design parameters must be clearly stated.

F. Plotted Cross-Sections: Typical existing and proposed cross-sections.

4.2 OPEN CHANNEL DESIGN

The proper hydraulic design of a channel is of primary importance in insuring that flooding, sedimentation and erosion problems do not occur. The following general criteria should be used in the design of open channels:

4.2.1 DESIGN FREQUENCIES FOR OPEN CHANNEL DESIGN

The design criteria for storm drainage shall be based upon the data prepared by NC Department of Transportation *Guidelines for Drainage Structures*, latest revision, USDOT Federal Highway Administration *Urban Drainage Design Manual*, Hydraulic Engineering Circular No. 22, the *NC Erosion and Sediment Control Planning and Design Manual,* the SCS *National Engineering Field Manual for Conservation Practices*, or other acceptable calculation procedures.

All open channels in the City of Jacksonville shall be designed to contain the peak runoff from the frequency storm shown below in Table 4.1, which includes the design to have sufficient freeboard to provide for adequate drainage of lateral storm sewers. The drainage system shall be adequate and properties over which the surface waters are conveyed, from the development site to discharge point shall not be adversely affected.

Table 4.1

Condition	Minimum Design Frequency
Normal Runoff	10-year
Cross-drainage and drainage areas >1 square mile	25-year
Adjacent buildings structures	100-year

In those cases where channel modifications are necessary to control increased flow from proposed development, proposed water surface profiles are restricted such that the 100-year flood profile under existing conditions shall not be increased. If the capacity of the existing channel downstream of the project is less than the 100-year design discharge, consideration shall be given for more frequent events to ensure that the severity and frequency of down stream flooding is not increased.

4.2.2 CHANNEL GEOMETRY, SLOPE & VELOCITY

A. CHANNEL SIDE SLOPE

In grass-lined channels, the normal maximum side slope will be 3 horizontal to 1 vertical (3:1), which is the practical limit for mowing equipment. In some areas, local soil conditions may dictate the use of side slopes flatter than 3:1 to ensure slope stability.

B. **CHANNEL BOTTOM WIDTH**

In grass-lined channels, the minimum channel bottom width shall be 2 feet. In concrete-lined channels, the minimum bottom width shall be 2 feet except where concrete lined roadside ditches are used where "V" shaped ditches are permissible.

C. **CHANNEL FLOW-LINE SLOPE**

Slope of the channel flow-line (invert) is generally governed by topography and the energy head required for flow. Since flow-line slope directly affects channel velocities, channels should have sufficient grade to prevent significant siltation. However, slopes should not be so large as to create erosion problems. In the City of Jacksonville, unless approved by the Public Services Director, the minimum recommended longitudinal slope shall be 0.4 percent (0.004). The use of flatter slopes must be approved by the Public Services Director. The maximum channel invert slope will be limited by the maximum flow velocities given in Table 4.2. Appropriate channel drop structures may be used to limit channel invert slopes in steep areas.

D. **CHANNEL FLOW VELOCITIES**

Excessive flow velocities in open channels can cause erosion and destabilize side slopes, and may pose a threat to safety. Velocities, which are too low, may allow the deposition of sediment and subsequent channel clogging. Table 4.2 provides desirable average and maximum permissible design velocities based on 10-year storm peak runoff rates for newly vegetated or armor-lined channels.

Table 4.2
Flow Design Velocities for Newly Vegetated and Armored Channels

Channel Description	Average Velocity (Feet Per Second)	Maximum Velocity (Feet Per Second)
Grass Lined: Predominantly Clayey Soils	3.0	5.0
Grass Lined: Predominantly Sandy Soils	2.0	4.0
Rip-Rap Lined	5.0	8.0
Concrete Lined	6.0	10.0

4.2.3 CHANNEL PROTECTION

A. **DRAINAGE WAYS**

The subdivision shall adequately protect all ditches and drainage ways to the satisfaction of the City. Ditches and open channels shall be stabilized, seeded, and mulched, sodded or armored, depending on grades and types of soils. As a general rule, ditches and channels, when permitted, with grades up to 1 percent shall be seeded and mulched; with grades of 1 to 4 percent, sodded; and with grades over 4 percent, armored. Seeding, sodding, and armoring operations shall be in compliance with the NCDOT *Standard specifications for Roads and Structures*, latest edition. It is not sufficient to have planted according to these specifications. There must be a good stand of permanent grass to meet this requirement. Calculation shall be made to determine the need for riprap outlet protection at pipe outlets.

The watercourse or ditch easement shall be wide enough to contain said ditch with ample clearance for the operation of maintenance equipment. The minimum easement width shall be 20 feet.

B. DOWNSTREAM PROTECTION

Stream banks and channels downstream from the development shall be protected from increased degradation by accelerated erosion caused by increased velocity of runoff from the construction activity.

The construction activity shall be planned and conducted in such a manner that the velocity of storm water runoff in the receiving watercourse at the point of discharge resulting from the 10-year storm after development shall not exceed the greater of:

1) The velocity as determined from the velocity in Table 4.3 below, or

2) The velocity in the receiving watercourse determined for the 10-year storm prior to development.

   If neither 1 nor 2 can be met, the channel below the discharge point shall be designed and constructed to withstand the expected velocity.

   Measures applied alone or in combination to satisfy the intent of this paragraph are acceptable if there are no objectionable secondary consequences. Innovative techniques and ideas will be considered and may be used when shown to have the potential to produce successful results. Some alternatives are to:

   a. Avoid increases in surface runoff volume and velocity by including measures to promote infiltration to compensate for increased runoff from areas rendered impervious.

   b. Provide energy dissipaters at outlets of storm drainage facilities to reduce flow velocity at the point of discharge from the development; these may range from simple riprap sections to complex structures.

   c. Protect watercourses subject to accelerated erosion by improving cross-sections and/or providing erosion resistant lining.

   The following is a table for maximum permissible velocity for the stormwater discharges into existing stabilized vegetated or armored channels:

Table 4.3 Maximum Permissible Velocities for Existing Stabilized Vegetated or Armored Channels	
Material	**Maximum Permissible Velocity (fps)**
Fine Sand (noncolloidal)	2.5
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (colloidal)	5.5
Alluvial Silts (noncolloidal)	3.5
Material	**Maximum Permissible Velocity (fps)**
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Pans	6.0
Rip Rap Lined	8.0
Concrete Lined	10.0
Note: For sinuous channels, multiply allowable velocity by 0.95 for slightly sinuous channels; by 0.9 for moderately sinuous; and by 0.8 for highly sinuous channels.	

C. CHANNEL EROSION CONTROL

Erosion protection is necessary to insure that channels maintain their capacity and stability and to avoid excessive transport and deposition of eroded material.

Erosion and Sedimentation Control Plans, permit applications, and fees shall be submitted in accordance with City Ordinance. **The City of Jacksonville has local review authority for erosion and sedimentation control plans. Plans must be submitted to the Public Services Department.**

All Erosion and Sediment Control Plans measures shall be designed in accordance with the North Carolina Sediment Control Law and the City of Jacksonville's erosion control ordinance, whichever is more stringent. The Designer is to reference the *North Carolina Erosion and Sediment Control Handbook,* latest edition. This manual contains valuable information and tools for developing plans to minimize soil erosion and prevent sedimentation pollution associated with land-disturbing activities. The designer is to also reference this Manual of Specifications, Standards, and Design with regard to certain erosion control details required to be made part of the erosion and sedimentation control plan.

Erosion and Sedimentation Control plans, permit applications and fees shall be submitted to the City of Jacksonville Public Services Department for review and approval.

Section 5 – CULVERT DESIGN

The purpose of this section is to establish standard procedures and criteria for Culvert Design for the City of Jacksonville.

5.1 INTRODUCTION

A drainage system shall be designed and constructed by the developer to provide for the proper drainage of the surface water of the subdivision and the drainage area of which it is part. The storm drainage system shall follow existing topography as nearly as practical. Additional design information shall be submitted to indicate that provision has been made for the adequate disposal of surface water without any damage to the developed or undeveloped land downstream or below the proposed subdivision. A copy of all drainage computations shall be submitted, clearly stating any assumptions made.

The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off-site areas, assuming ultimate development in accordance with the current zoning regulations and the Land Use Plan.

5.2 PIPE CULVERT DESIGN - GENERAL

Private drainage culverts and public drainage culverts within a subdivision or site development sub-basin shall be designed according to this section.

Pipe culverts shall be aligned parallel to the longitudinal axis of the channel, as much as possible, to insure maximum hydraulic efficiency and to minimize erosion. In areas where a change in alignment is necessary, the change shall be accomplished upstream of the culvert in the open channel. Appropriate erosion protection shall be provided.

Pipe culverts crossing beneath the roadway shall be designed to span from ditch line to ditch line.

5.2.1 ROADWAY DRAINAGE SYSTEM

The road storm drainage system shall serve as the primary drainage system and shall be designed to carry roadway, adjacent land, and building storm water drainage. No storm water shall be permitted into the City's sanitary sewer system.

5.3 PIPE MATERIALS AND SIZE

The minimum pipe size used shall be 18 inches in diameter under roadways to minimize clogging and maintenance for all pipe culverts within City of Jacksonville rights-of-ways and easements.

Table 5.1 **Allowable Materials for Storm Drainage** (15 inches and larger minimum)	
Culverts and Driveways	**Side drains (non-traffic areas)**
-	ASTM C14 Plain Concrete, Class II minimum
ASTM C76 Reinforced Concrete, Class III, wall B minimum	-
Corrugated Aluminum Alloy Pipe, AASHTO M196	-
Double walled HDPE Pipe **(Driveways only)**	Double walled HDPE Pipe

Corrugated metal pipe and aluminum-coated steel pipe will not be allowed.

Headwalls or flared end sections shall be required at all pipe ends.

All pipe culverts to have a minimum pipe cover equal to 12 inches, measured from the proposed finished grade to the top of the pipe. RCP may be used with less cover if approved by the Public Services Director.

5.4 DESIGN FREQUENCY

The design criteria for storm drainage shall be based upon the data prepared by NC Department of Transportation *Guidelines for Drainage Structures*, latest revision, USDOT Federal Highway Administration *Urban Drainage Design Manual*, Hydraulic Engineering Circular No. 22, the *NC Erosion and Sediment Control Planning and Design Manual,* the SCS *National Engineering Field Manual for Conservation Practices*, or other acceptable calculation procedures.

The minimum design frequency for culverts shall conform to Table 5.1, below:

Table 5.1 **Minimum Design Frequency for Storm Drainage Culverts**	
Condition	**Minimum Design Frequency**
Normal Runoff	10-year
Cross-drainage and drainage areas >1 square mile	25-year
Curb and gutters, curb and gutter inlets	A minimum intensity of 4 in./hr. shall be used

5.5 HYDRAULIC DESIGN OF CULVERTS

The City of Jacksonville uses the design procedures of Hydraulic Design Series No. 5 (*HDS-5*) for the design of pipe culverts. *HDS-5* was designed to analyze flow in pipes using many different variables. The procedures in the *Urban Drainage Design Manual*, HEC-22, also may be utilized. HEC-22 utilizes many of the same procedures in pipe culvert analysis with references to HDS-5.

5.6 CURB INLET DESIGN

Curb storm drainage inlets shall be provided at intervals along roadways. Where these inlets connect to drainage pipes, a catch basin shall be installed with the inlet.

The NCDOT *Guidelines for Drainage Structures*, latest revision or the USDOT Federal Highway Administration *Urban Drainage Design Manual*, Hydraulic Engineering Circular No. 22 shall be used for curb inlet design.

For curb and gutters, curb and gutter inlets, a minimum intensity of 4 inches per hour shall be used in all computations.

Inlet spacing and sizing shall be adequate to limit the spread of water to 2 feet into the roadway.

Storm drainage inlets will be placed so that crosswalks will not be flooded during the design storm intensity.

5.7 EROSION CONTROL

Inlet and/or outlet protection is necessary to insure those channels upstream and downstream of pipe culverts maintain stability and to avoid excessive transport and deposition of eroded material.

All erosion and sediment control measures shall be designed in accordance with the *North Carolina Erosion and Sediment Control Planning and Design Manual,* latest revision. This manual contains valuable information and tools for developing plans to minimize soil erosion and prevent sedimentation pollution associated with land-disturbing activities.

Section 6 - DETENTION/RETENTION DESIGN

The purpose of this division is to provide a guide for the design of appropriate storm runoff storage facilities within the City of Jacksonville.

6.1 INTRODUCTION

The introduction of impervious cover and improved runoff conveyance typically increases peak floods over those for existing conditions. Where physical, topographic and economic conditions permit, channel improvements downstream of the development are used to prevent increased flooding. When this is not feasible, other measures such as runoff detention, retention, or extended detention wetlands is required in which the storm runoff is detained and released at an acceptable rate through a flow-limiting outlet structure, thus controlling peak downstream flow.

All detention/retention facilities in the City of Jacksonville shall be designed to attenuate developed condition peak discharges to the existing conditions for the given storm of calculation.

All retention facilities shall capture the first 1 inch of runoff.

Many different methods may be used in the design of stormwater detention/retention facilities and innovative designs will be considered by the Public Services Director provided that the maximum permissible discharge and the storage facility requirements are met. In all cases, the design will be routed for confirmation.

6.2 DESIGNER'S JUDGMENT

The fundamental process of engineering design is one in which the designer selects one or more mathematical models to represent a physical system, manipulates the system components to achieve some desired response under loadings of interest, and specifies the system to be constructed in the field. *It is the responsibility of the designer to determine which model best fits the given situation.* This section provides mere guidelines in the elements of stormwater detention/retention design.

6.3 REGULATIONS

Design and installation of all stormwater detention/retention facilities must comply with all applicable Federal, State, and local laws.

The City of Jacksonville will follow the Division of Water Quality – 401 Wet Detention Basin Design for all detention/retention basins within the City's jurisdiction. A complete stormwater management plan submittal includes a detention/retention basin worksheet for each basin, design calculations, plans, and specifications depicting all basin and outlet structure details, and a fully executed operation and maintenance agreement. (Reference: N.C. Department of Environmental Health and Natural Resources, November 1995 and Administrative Code Section: 15A NCAC 02H .1008, effective December 1, 1995). *General engineering design criteria for all projects* shall be in accordance with 15A NCAC 02H .1008c, latest revision)

Basins which measure greater than fifteen (15) feet in height and have an impoundment capacity greater than 10 acre-feet are subject to the dam safety regulations set forth in the North Carolina Administrative Code, Title 15A, Subchapter 2K – Dam Safety, latest revision.

6.4 DESIGN CONSIDERATIONS

It is recommended that stormwater detention/retention facilities be located on the site from which the runoff to be controlled is generated. However, off-site facilities are acceptable provided that the land area involved with the facility is delineated and officially recorded at the Onslow County Register of Deeds office as a permanent "Stormwater Detention/Retention Easement." The property owner on which the facility is located will also be required to submit to the City a letter of commitment to the maintenance of the facility.

In no case shall a habitable structure be located within the detention/retention area of any stormwater storage facility or within the 100-year 24-hour flood plain of that basin. No utilities (sewer lines, power lines, water lines, etc.) shall be located within or immediately around any detention/retention facility.

6.5 SAFETY CONSIDERATIONS

Adequate safety measures such as warning signs, embankment slopes, fences, grates, and other features should be incorporated into the design of the facility wherever appropriate. At the Public Services Director's discretion, depending on the site conditions, a fence may be required.

6.6 MAINTENANCE

In general, the City of Jacksonville will only be responsible for maintenance of stormwater detention/retention facilities that serve public facilities such as recreational areas and public lands. A Home Owners Association or similar entity shall be set for the purpose of providing basin maintenance. Responsibility for the maintenance of any portion of a facility not designed for flood control will not rest with the City of Jacksonville, nor will the City be responsible for any damage that may occur resulting from flooding of the facility.

For retention basins, a notarized Stormwater Retention Basin Operation and Maintenance Plan shall be submitted with each basin design. Figure 6.1 is a typical Stormwater Retention Basin Operation and Maintenance Plan that may be modified for the specific facility.

6.7 STORMWATER DETENTION/RETENTION PROCEDURE

The general procedure in stormwater detention/retention design is:

1. Determine the Pre-Developed and Post-Developed Discharges
2. Determine the Size of the Proposed Detention/Retention Facility
3. Determine the Characteristics of the Proposed Outlet Structure
4. Route the System

Sample

Figure 6.1 Retention Basin Operation and Maintenance Plan

Stormwater Retention Basin Operation and Maintenance Plan for
(Project Name)
City of Jacksonville, North Carolina

I. Inspect Monthly, or after every runoff-producing rainfall event, whichever comes first:
- Clear and check the outlet orifice, manhole weir, and outlet pipe of any obstructions.
- Check the basin side slopes; remove trash; repair eroded areas before the next rainfall event.
- Check the vegetative filter for sediment accumulation and erosion. Repair as necessary.

II. Inspect quarterly:
- Inspect the collection system (piping, grassed swales) for proper functioning. Check and clear piping for obstructions.
- Replace rip rap at basin outlet structures as necessary.
- Repair broken drainage tiles.
- Repair eroded areas as necessary.

III. Every six (6) months:
- Remove accumulated sediment from the bottom of the outlet structure.
- Check basin depth at various points in the basin. If depth is reduced to 75% of original design depth, sediment shall be removed to at least original design depth.
- Reseed grassed swales, including vegetating filter, as necessary.

IV. General
- Mow the side slopes, not including normally submerged vegetative shelf, according to the season. Maximum grass height will be 6”.
- Cattails and other indigenous wetland plants are encouraged along the basin perimeter; however, they must be removed when cover the entire surface area of the basin.
- The orifice is design to draw down the basin in two to five days. If drawdown is not accomplished in that time, the system may be clogged. The source of the clogging must be found and eliminated.
- All components of the detention/retention basin system must be kept in good working order.
- Emergency drain device (siphon or pump) will be required in the event that the permanent pool needs to be completely drained.

I, ________________________, hereby acknowledge that I am the financially responsible party for the maintenance of this retention facility and that I will perform the maintenance for the facility as outlined above.

Signature: ______________________________________ Date: __________________________
Name, Title
Address, Telephone

I, _________________________, a Notary Public for the State of _________________________, County of ____________________, do hereby certify that ________________________________ personally appeared before me this _______ day of _______, _______, and acknowledge the due execution of the foregoing instrument. Witness my hand and official seal,

____ SEAL:
My commission expires __________________________

6.8 REQUIRED SUBMITTAL DOCUMENTATION

The following information shall be submitted to the Public Services Director for the design of all stormwater detention/retention facilities (as listed in checklist in Section 2.1.4):

1. Vicinity Map
2. Site Plan
3. Grading Plan
4. Runoff Map
5. Runoff Calculations
6. Hydraulic Calculations
7. Soils Report, as applicable
8. Operation and Maintenance Plan, if applicable, (Section 6.6, *Maintenance*)
9. Detention/Retention Basin Worksheet, if applicable (Section 2.1.4)

6.8.1 DETERMINE THE PRE-DEVELOPED AND POST-DEVELOPED DISCHARGES

In most cases, the designer should evaluate the 2-year, 10-year, and 100-year 24-hour storm routed through the facility. Use the method outlined in Section 3 for watersheds greater than 50 acres to determine the peak discharge. To determine the peak discharge for smaller watersheds and developments on small sites, the designer should follow the steps outlined in Section 3.1.1 A and exercise engineering judgment to determine the time to peak and which storm best fits the situation.

The peak discharge should then be substituted into the appropriate equations of Malcom's Method to determine the inflow hydrograph.

Also, determine the inflow hydrograph and volume of the first 1 inch of post developed runoff (the "first flush" volume of runoff must be captured).

6.8.2 DETERMINE THE SIZE OF THE PROPOSED DETENTION/RETENTION FACILITY

The maximum allowable release rate from the detention/retention facility during the storm event shall be less than the rate from the watershed under pre-development conditions. For basins, the emergency spillway must be designed to carry the 100-year storm event without increased upstream or downstream flooding.

An approximation of orifice-base detention/retention facilities can be obtained by a gross linearization of the inflow and outflow hydrographs. As such, the storage volume required to reduce Q_p to Q_o can be estimated by the following equation:

$$S = (Q_p - Q_o)\,T_p \qquad \text{Equation 6.01}$$

Where,

S → Estimated storage required (cf)
Q_p → Peak discharge of the inflow hydrograph (cfs)
Q_o → Peak discharge of the outflow hydrograph (cfs)
T_p → Time to peak of inflow hydrograph (seconds)

Thus, the designer may design a facility with the storage determined in Equation 6.01 as the preliminary facility for hydraulic storage calculations.

6.8.3 DRAINAGE PIPE DETENTION

If drainage structures are to be designed for use a detention facility, the use of Table 6.01 may be helpful when calculating the cross-sectional area of the partially filled pipes at various depths.

6.8.4 DETENTION/RETENTION BASINS

In many cases, the detention/retention storage facility is a natural stream valley or an excavated basin. The basin should also meet the requirements as described in the worksheet in Section 2.1.4:

- Length to width ratio greater than 3:1
  If local topography makes the excavation of a long narrow pond impossible, correctly spaced baffles can lengthen the flow path between the inlet and outlet.

- Side slopes no steeper than 3:1

A representative set of storage volumes can be computed by applying the average-end-area method vertically from contour to contour. If storage versus stage is plotted on log-log axes, the resulting line is usually straight, suggesting that the reservoir stage-storage function may be adequately represented by a power-curve fit of the form:

$$S = K_s Z^b \qquad \text{Equation 6.02}$$

Where,

S → Storage Volume (cf)
Z → Stage (ft) from the bottom of the basin

Table 6.01 Area, Wetted Perimeter, and Hydraulic Radius of Partially Filled Circular Pipe

$\frac{d}{D}$	$\frac{area}{D^2}$	$\frac{wet.per.}{D}$	$\frac{hyd.rad.}{D}$	$\frac{d}{D}$	$\frac{area}{D^2}$	$\frac{wet.per.}{D}$	$\frac{hyd.rad.}{D}$
0.01	0.0013	0.2003	0.0066	0.51	0.4027	1.5908	0.2531
0.02	0.0037	0.2838	0.0132	0.52	0.4127	1.6108	0.2561
0.03	0.0069	0.3482	0.0197	0.53	0.4227	1.6308	0.2591
0.04	0.0105	0.4027	0.0262	0.54	0.4327	1.6509	0.2620
0.05	0.0147	0.4510	0.0326	0.55	0.4426	1.6710	0.2649
0.06	0.0192	0.4949	0.0389	0.56	0.4526	1.6911	0.2676
0.07	0.0242	0.5355	0.0451	0.57	0.4625	1.7113	0.2703
0.08	0.0294	0.5735	0.0513	0.58	0.4723	1.7315	0.2728
0.09	0.0350	0.6094	0.0574	0.59	0.4822	1.7518	0.2753
0.10	0.0409	0.6435	0.0635	0.60	0.4920	1.7722	0.2776
0.11	0.0470	0.6761	0.0695	0.61	0.5018	1.7926	0.2799
0.12	0.0534	0.7075	0.0754	0.62	0.5115	1.8132	0.2821
0.13	0.0600	0.7377	0.0813	0.63	0.5212	1.8338	0.2842
0.14	0.0668	0.7670	0.0871	0.64	0.5308	1.8546	0.2862
0.15	0.0739	0.7954	0.0929	0.65	0.5404	1.8755	0.2881
0.16	0.0811	0.8230	0.0986	0.66	0.5499	1.8965	0.2899
0.17	0.0885	0.8500	0.1042	0.67	0.5594	1.9177	0.2917
0.18	0.0961	0.8763	0.1097	0.68	0.5687	1.9391	0.2933
0.19	0.1039	0.9020	0.1152	0.69	0.5780	1.9606	0.2948
0.20	0.1118	0.9273	0.1206	0.70	0.5872	1.9823	0.2962
0.21	0.1199	0.9521	0.1259	0.71	0.5964	2.0042	0.2975
0.22	0.1281	0.9764	0.1312	0.72	0.6054	2.0264	0.2987
0.23	0.1365	1.0003	0.1364	0.73	0.6143	2.0488	0.2998
0.24	0.1449	1.0239	0.1416	0.74	0.6231	2.0714	0.3008
0.25	0.1535	1.0472	0.1466	0.75	0.6318	2.0944	0.3017
0.26	0.1623	1.0707	0.1516	0.76	0.6404	2.1176	0.3025
0.27	0.1711	1.0928	0.1566	0.77	0.6489	2.1412	0.3032
0.28	0.1800	1.1152	0.1614	0.78	0.6573	2.1652	0.3037
0.29	0.1890	1.1373	0.1662	0.79	0.6655	2.1895	0.3040
0.30	0.1982	1.1593	0.1709	0.80	0.6736	2.2143	0.3042
0.31	0.2074	1.1810	0.1755	0.81	0.6815	2.2395	0.3044
0.32	0.2167	1.2025	0.1801	0.82	0.6893	2.2653	0.3043
0.33	0.2260	1.2239	0.1848	0.83	0.6969	2.2916	0.3041
0.34	0.2355	1.2451	0.1891	0.84	0.7043	2.3186	0.3038
0.35	0.2450	1.2661	0.1935	0.85	0.7115	2.3462	0.3033
0.36	0.2546	1.2870	0.1978	0.86	0.7186	2.3746	0.3026
0.37	0.2642	1.3078	0.2020	0.87	0.7254	2.4038	0.3017
0.38	0.2739	1.3284	0.2061	0.88	0.7320	2.4321	0.3008
0.39	0.2836	1.3490	0.2102	0.89	0.7384	2.4655	0.2996
0.40	0.2934	1.3694	0.2142	0.90	0.7445	2.4981	0.2980
0.41	0.3032	1.3898	0.2181	0.91	0.7504	2.5322	0.2963
0.42	0.3130	1.4101	0.2220	0.92	0.7560	2.5681	0.2944
0.43	0.3229	1.4303	0.2257	0.93	0.7612	2.6061	0.2922
0.44	0.3328	1.4505	0.2294	0.94	0.7662	2.6467	0.2896
0.45	0.3428	1.4706	0.2331	0.95	0.7707	2.6906	0.2864
0.46	0.3527	1.4907	0.2366	0.96	0.7749	2.7389	0.2830
0.47	0.3627	1.5108	0.2400	0.97	0.7785	2.7934	0.2787
0.48	0.3727	1.5308	0.2434	0.98	0.7816	2.8578	0.2735
0.49	0.3827	1.5508	0.2467	0.99	0.7841	2.9412	0.2665
0.50	0.3927	1.5708	0.2500	1.00	0.7854	3.1416	0.2500

d → depth of flow in pipe

D → diameter of pipe

Source: “Concrete Pipe Design Manual,” [American Concrete Pipe Association, 1992]

There are two ways to determine the values K_s and b in Equation 6.02. Both ways depend upon the assumption that the logarithm of storage is linear with the logarithm of stage.

1. *Linear-Regression Estimation of Stage-Storage Parameters:*
   Determine the linear regression for the natural log of each accumulated volume and stage. In the stage-storage function, the independent variable (x-axis) is $\ln Z$, and the dependent variable (y-axis) is $\ln S$. The value of the exponent, b, is the regression coefficient of the independent variable, (the x-coefficient). The value of the coefficient, K_s, is the antilogarithm of the intercept (the regression constant).

2. *Algebraic Estimation of Stage-Storage Parameters:*
   After plotting storage versus stage on log-log axes, the designer may select two representative points on the curve, preferably in the upper end of the range of stage, and compute values of K_s and b. Writing the logarithmic form of Equation 6.02 for two points simultaneously yields:

$$b = \frac{\ln\left(\frac{S_2}{S_1}\right)}{\ln\left(\frac{Z_2}{Z_1}\right)} \qquad \text{Equation 6.03}$$

$$K_s = \frac{S_2}{Z_2^{\,b}} \qquad \text{Equation 6.04}$$

6.8.5 RETENTION AND DETENTION BASINS

Retention basins differ from *detention* basins in that retention basins have a permanent storage of water. In addition to the guidelines for detention/retention basins set forth in Section 6.8.4, retention basins should also be designed to include:

- Minimum 10 ft. wide vegetated perimeter shelf at 6:1 or less
- Vegetation to permanent pool elevation
- Emergency drain provided
- Permanent pool depth between 3 and 6 feet
- Drawdown in 2 to 5 days
- First 1 inch of runoff captured
- Forebay 20% of total basin volume (Note: If you have 2 forebays in one pond, the sum of the volume of the forebays may not exceed 20% of the total basin volume. Distribute the volume, based on the area tributary to each forebay, so that the total comes to approximately 20%).
- 85% Average Annual Removal of Total Suspended Solids (Table 6.02)

To determine the *minimum surface area* at normal pool (SA) for the basin:

1. Determine the total drainage area for the basin (DA).
2. Calculate the percent impervious area for this watershed.
3. Estimate a desired normal pool depth.
4. From Table 6.02, determine the SA/DA ratio for the given watershed.
5. Divide the SA/DA by 100.
6. Multiply this value by the total drainage area for the basin (DA). This value is the *minimum pond area* at normal pool depth for the given watershed.

Table 6.02 provides the ratio (in percent) of the surface area of a given basin (SA) at various normal pool depths to the drainage area of the watershed (DA) at various levels of imperviousness. Intermediate values may be linearly interpolated.

Table 6.02 - SA/DA (in Percent) for Wet Detention Basins
Designed to remove 85% TSS Removal (1" first flush storm) NC Coastal Counties

Impervious %	3.0 ft.	3.5 ft.	4.0 ft.	4.5 ft.	5.0 ft.	5.5 ft.	6.0 ft.	6.5 ft.	7.0 ft.	7.5 ft.
10%	0.9	0.8	0.7	0.6	0.5	-	-	-	-	-
20%	1.7	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.5
30%	2.5	2.2	1.9	1.8	1.6	1.5	1.3	1.2	1.0	0.9
40%	3.4	3.0	2.6	2.4	2.1	1.9	1.6	1.4	1.1	1.0
50%	4.2	3.7	3.3	3.0	2.7	2.4	2.1	1.8	1.5	1.3
60%	5.0	4.5	3.8	3.5	3.2	2.9	2.6	2.3	2.0	1.6
70%	6.0	5.2	4.5	4.1	3.7	3.1	2.9	2.5	2.1	1.8
80%	6.8	6.0	5.2	4.7	4.2	3.7	3.2	2.7	2.2	2.0
90%	7.5	6.5	5.8	5.3	4.8	4.3	3.8	3.3	2.8	1.3
100%	8.2	7.4	6.8	6.2	5.6	5.0	4.4	3.8	3.2	2.6

Source: [NCDNR, Division of Water Quality]

The designer may then design a retention basin of greater size than the *minimum pond area* at normal pool depth for which storage volumes can be computed.

6.8.6 DETERMINE THE CHARACTERISTICS OF THE PROPOSED OUTLET STRUCTURE

Tentatively size the outlet structures as described in Section 5.5 using Inlet/Outlet control based on HDS-5. The maximum release rate must be limited to the rate of runoff discharged prior to site development.

All outlet devices must be constructed in adherence to current construction standards as described in the City of Jacksonville's Manual of Specifications, Standards, and Design. Alternative outlets not referred to in this publication may be approved at the discretion of the Public Services Director. Such approval must be specifically requested upon submittal of the drainage plan.

The stage-discharge function represents the most important aspect of the hydraulic performance of the outlet structure in its influence on the outflow hydrograph. The stage-discharge function is derived by hydraulic analysis of the outlet structures, which usually can be considered as orifices and weirs. For a sample of stages throughout the expected range of water level depths in the detention/retention facility, the total outflow downstream of the outlet structure is computed for each value of stage, and stage versus total discharge is plotted.

6.8.7 WEIRS

Roads, emergency spillways, and manholes are typical examples of weirs. The discharge calculations for weirs can be calculated using the following weir equation, Equation 6.05.

$$Q = C_w L H^{3/2} \quad \text{Equation 6.05}$$

Where,

Q → Discharge (cfs)

C_w → Weir coefficient (reference any hydrology book), default value is 3.0.

L → Length of weir (ft), measured along the crest

H → Driving head (ft), measured vertically from crest of weir to water surface at a point far enough upstream to be essentially level.

6.8.8 ORIFICES

The flow through orifices, such as culverts and draw-down orifices, can be computed using the following *orifice* equation:

$$Q = C_d A \sqrt{2gh} \quad \text{Equation 6.06}$$

Where,

Q → Discharge (cfs)

C_d → Coefficient of discharge (see Table 6.03)

A → Cross-sectional area of flow at the orifice entrance (Sq. Ft.)

g → Acceleration of gravity (32.2 ft/sec^2)

h → Driving head (ft), measured from centroid of orifice area to water surface

Table 6.03 Values of Coefficient of Discharge, C_d

Entrance Condition	C_d
Typical default value	0.60
Square-edged entrance	0.59
Concrete pipe, grooved end	0.65
CMP, mitred to slope	0.52
CMP, projecting from fill	0.51

Source: [Malcom, 1989]

6.8.9 ROUTE THE SYSTEM

Routing of the flood proceeds by time steps. At each step during the passage of the inflow hydrograph through the system, the outflow is computed. The result is a list of values of outflow at stated times – the outflow hydrograph.

Although there are many routing procedures that are accepted by the City of Jacksonville, the recommended technique for reservoir routing is the Storage – Indication Method as described in "*Elements of Urban Stormwater Design*" [Malcom, 1989]. This procedure is based on the continuity principle that states that the rate of change of storage with respect to time is the difference between inflow and outflow:

$$\frac{ds}{dt} = I - O \qquad \text{Equation 6.07}$$

Over a time increment,

$$\frac{\Delta S}{\Delta T} = I - O \qquad \text{Equation 6.08}$$

The incremental change in storage can be estimated as the area of a trapezoidal element:

$$\Delta S_{ij} = (\bar{I} - \bar{O}) \quad \Delta T_{ij} \qquad \text{Equation 6.09}$$

Where,

ΔS_{ij}	→	Change in storage in the time increment i to j
$\bar{I}$	→	Average inflow from time i to time j
$\bar{O}$	→	Average outflow from time i to time j
ΔT_{ij}	→	Time increment

Equation 6.09 can be manipulated to obtain the following equation:

$$I_i + I_j + \left[\frac{2\,S_i}{\Delta T} - O_i\right] = \left[\frac{2\,S_j}{\Delta T} + O_j\right] \qquad \text{Equation 6.10}$$

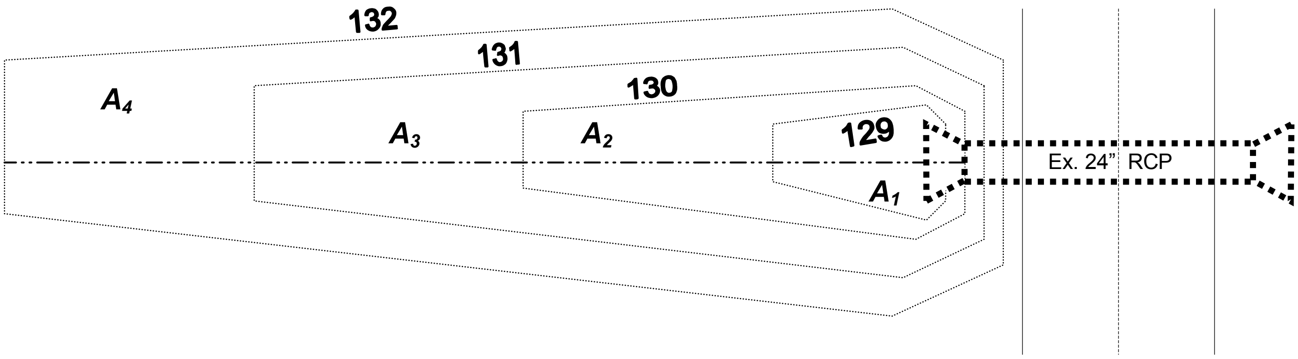
Where,

I_i	→	Inflow at the beginning of the interval
I_j	→	Inflow at the end of the interval
S_i	→	Storage at the beginning of the interval
Sj	→	Storage at the end of the interval
O_i	→	Outflow at the beginning of the interval
O_j	→	Outflow at the end of the interval
ΔT	→	Time increment

Equation 6.10 fits nicely into tabular form for computations, from which the designer may determine the peak discharge from the storage facility.

6.8.10 DESIGN EXAMPLE

Using the given information, route the proposed system such that the post-development rate of runoff does not exceed the pre-development rate of runoff. This is a hypothetical drainage system.



Known:

- Pre-development Q_{10} = 27.0 cfs (calculated using Eq. 3.02)
- Post-development Q_{10} = 39.0 cfs " "
- Ex. 24" Inv. In = 128.20 (taken from field topographical map)
- Ex. 24" Inv. Out = 127.98 " "
- A_1 = 1,250 sf (calculated using existing & proposed topo data)
- A_2 = 4,850 sf " "
- A_3 = 9,950 sf " "
- A_4 = 15,000 sf " "
- Min. Road Elevation = 133.20 (taken from field topographical map)
- Tc of Post-Development = 30 minutes

Solution:

1. *Confirm that the system must be routed,* by determining headwater at existing culvert as described in Section 5.5.
   The existing culvert is found to be under inlet control, with a headwater of 7.47 feet. Since the invert of the existing culvert is at elevation 128.20, this means that ponding at the entrance to the culvert would rise to elevation 135.67. Since the roadway elevation is at 133.2, some type of storage or detention is required.

2. *Compute the inflow hydrograph using the post-developed rate of runoff,* as described in Section 3.1.

3. *Determine the characteristics of the proposed storage area,* as described in Section 6.8.9.
   For the purpose of this example, the Storage – Indication Method was used.

   a) Enter areas at each contour (stage) into a spreadsheet to obtain incremental and accumulated storage, and compute, by linear regression, the stage-storage function (Equation 6.02).

REGRESSION TO DETERMINE STORAGE VOLUME

CONTOUR	Z	AREA (sf)	DELTA S (cf)	ACC S (cf)
128.20	0.00	0.00		0.00
			500.00	
129.00	0.80	1250.00		500.00
			3050.00	
130.00	1.80	4850.00		3550.00
			7400.00	
131.00	2.80	9950.00		10950.00
			12475.00	
132.00	3.80	15000.00		23425.00

Regression Output

Constant		6.75254893
Std Err of Y Est		0.024679926
R Squared		0.999854867
No. of Observations		4.00
Degrees of Freedom		2.00
X Coefficient(s)	2.4701788	
Std Err of Coef.	0.0210440	

$K_s = e^{6.75254893}$

b = X Coefficient

$$S = K_s Z^b$$ (Equation 6.02)

Storage = $856 \ Z^{2.4701788}$

b) Use Eq. 6.06 to determine the discharge through the culvert.

$$Q = C_d A \sqrt{2gh}$$

C_d → 0.60

A → 3.14 Sq. Ft.

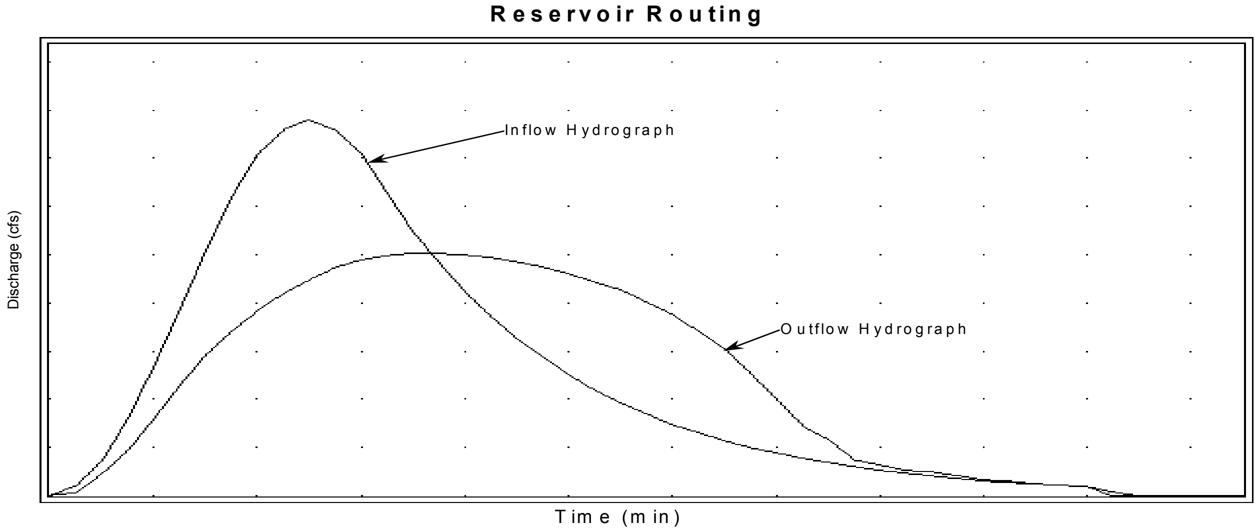
g → 32.2 ft/sec^2

h → varies

Elevation	***Discharge (cfs)***
128.20	0.00
128.70	1.67
129.20	6.40
129.70	11.15
130.20	15.12
130.70	18.52
131.20	21.39
131.70	23.91
132.20	26.20
132.70	28.30
133.20	30.25

4. *Route the 10-yr storm through the basin*, using Equation 6.10.

Time (min)	***Inflow*** (i) (cfs)	***Inflow*** (j) (cfs)	$\frac{2S_i}{\Delta T} - O_i$ (cfs)	$\frac{2S_j}{\Delta T} + O_j$ (cfs)	***Outflow*** (cfs)
6.00	3.72	8.04	0.09	4.95	2.43
9.00	8.04	13.47	2.29	11.85	4.78
12.00	13.47	19.50	7.89	23.80	7.95
15.00	19.50	25.53	17.69	40.86	11.58
18.00	25.53	30.96	33.33	62.72	14.70
21.00	30.96	35.28	55.87	89.82	16.98
24.00	35.28	38.05	83.72	122.11	19.19
27.00	38.05	39.00	115.04	157.05	21.01
30.00	39.00 (Max. Inflow)	38.05	147.25	192.09	22.42
33.00	38.05	35.28	177.14	224.30	23.58
36.00	35.28	31.23	201.71	250.47	24.38
39.00	31.23	27.42	218.48	268.22	24.87
42.00	27.42	24.08	226.91	227.13	25.11
45.00	24.08	21.15	228.12	278.14	25.15 (Max. Outflow)
48.00	21.15	18.57	223.33	273.35	25.01
51.00	18.57	16.30	213.59	263.05	24.73
54.00	16.30	14.32	199.81	248.46	24.32
57.00	14.32	12.57	182.84	230.43	23.80
60.00	12.57	11.04	163.61	209.73	23.06
63.00	11.04	9.69	142.74	187.22	22.24
66.00	9.69	8.51	120.83	163.47	21.32
69.00	8.51	7.47	98.85	139.03	20.09
72.00	7.47	6.56	77.24	114.83	18.79
75.00	6.56	5.76	57.08	91.27	17.09
78.00	5.76	5.06	38.88	69.40	15.26
81.00	5.06	4.44	24.16	49.70	12.77
84.00	4.44	3.90	13.73	33.66.	9.96
87.00	3.90	3.43	7.66	22.07	7.21
90.00	3.43	3.01	3.30	14.99	5.85
93.00	3.01	2.64	2.21	9.74	3.77
96.00	2.64	2.32	1.30	7.86	3.28
99.00	2.32	2.04	1.09	6.26	2.59
102.00	2.04	1.79	0.46	5.45	2.49
105.00	1.79	1.57	0.06	4.29	2.12
108.00	1.57	1.38	0.05	3.42	1.69
111.00	1.38	1.21	0.03	3.00	1.48
114.00	1.21	1.06	0.24	2.62	1.19
117.00	1.06	0.93	0.30	2.51	1.10



5. *Confirm that the routed outflow of 25.15 cfs is less than the pre-developed outflow of 27.00 cfs and that routed outflow does not overtop roadway.*

   Interpolate between elevations for a discharge of 25.15 cfs in table computed in Step 3.b):

Elevation	***Discharge (cfs)***
131.70	23.91
132.20	26.20

$$\frac{x - 131.70}{132.20 - 131.70} = \frac{25.15 - 23.91}{26.20 - 23.91}$$

$$x = 131.97$$

   The maximum elevation of the routed storm is 131.97, which is lower than the existing road elevation of 133.20. Post-development routed discharge does *not* exceed pre-development discharge and the maximum routed elevation is lower than the existing road, therefore, *adequate storage* has been provided.

Section 7 – BEST MANAGEMENT PRACTICES (BMP'S)

7.1 INTRODUCTION

Management of nonpoint source discharge is a stated goal of the 1987 Water Quality Act. An important source of these pollutants is stormwater runoff from urban and developing areas. This runoff has the potential to degrade water quality in all types of waters, including, among others, those classified as water supply watersheds, shellfish areas, and nutrient sensitive waters. The management of stormwater runoff through nonstructural controls (e.g., low-density development) is the preferred method of reducing pollution from urban areas. In cases where low density is not feasible, engineered stormwater controls are viable solutions to reducing pollution. However, proper design, and subsequent management, of these engineered solutions is essential for adequate pollutant removal. Design and review of stormwater BMP's as an engineered solution for stormwater management is the subject of this Water Quality Document.

DWQ's approach to water quality management of stormwater in surface drinking water supply watersheds, the 20 coastal counties and areas near High Quality and Outstanding Resource Waters is based first on minimizing impervious surfaces and; secondly, on treating stormwater runoff from these surfaces. The rules contained in 15A NCAC 02H .1008e for wet detention basins provide information on the appropriate volume of runoff to be controlled and the corresponding basin size configuration. North Carolina Stormwater Management rules also allow for the construction of alternative BMP's that meet the pollutant removal design standard of 85% removal of total suspended solids (TSS). This section, along with the standard details, is meant to supplement the rules in the NCAC by providing design checklists and details, their design criteria, and their assumed TSS removal. These guidelines are not meant to replace the rules. The stormwater BMP's that are covered in this document are assumed as shown in Table 7.1, below.

7.2 ASSUMED TSS REMOVAL EFFICIENCIES

The NC Department of Environment and Natural Resources (NCDENR) has published the technical paper Stormwater Best Management Practices, November 1995. The City of Jacksonville has adapted the information in this publication (herein referred to as the BMP manual) for guidance in designing water quality BMP's. For BMP's designed according to the specifications in the BMP manual, these facilities are assumed to have the following TSS removal efficiencies:

Table 7.1 BMP Facility Assumed TSS Removal	
Device	**Assumed TSS Removal (%)**
Dry Detention	N/A
Wet Detention Ponds	85%
Extended Detention Wetlands	85%
Pocket Wetlands	35%
Sand Filters	85%
Bioretention Filters	85%
Grassed Swales	35%
Extended Dry Detention	50%
Filter Strips	35%
Infiltration Devices	85%

Section 6 of this manual provides the design criteria for both dry and wet detention basins. For design criteria regarding the BMP's listed above, refer to the NCDENR BMP manual. A BMP Checklist has been provided for the engineer, under Section 2.1.4 above, as both a checklist and design guide for each of the measures noted in Table 7.1, above.

The combination of measures to affect an 85% TSS removal is permitted (e.g., Extended Dry Detention Basin plus Grassed Swales).

7.3 OTHER FAVORABLE BMP MEASURES

A. Downspout Dispersion

Downspout dispersion BMP's are splashblocks or gravel-filled trenches that serve to spread roof runoff over vegetated pervious areas. Dispersion attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits.

General design guidelines:

Application: With pre-approval of the Public Services Director, downspout dispersion may be used on subdivision single-family can be used in tandem with other BMP's such as pervious concrete pavement, grassed swales, bioretention filters, etc. to reduce total suspended solids and generally improve water quality.

Additional Design Criteria for Splashblocks:

The following conditions must be met to use splashblocks:

1. Splashblocks may be used for downspouts discharging to a vegetated flowpath at least 50 feet in length as measured from the downspout to the downstream property line, structure sensitive steep slope, stream, wetland, or other impervious surface. The vegetated flowpath must be covered with well-established lawn or pasture, landscaping with well-established groundcover, or native vegetation with natural groundcover. The groundcover shall be dense enough to help disperse and infiltrate flow and to prevent erosion.

2. flows shall not be directed onto sidewalks
3. A maximum of 700 square feet of roof area may drain to each splashblocks
4. A splashblock or a pad of crushed (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each downspout discharge point.
5. No erosion or flooding of downstream properties may result.
6. Splashblocks may not be placed on slopes greater than 20% or above erosion hazard areas without evaluation by a qualified geotechnical engineer and approval of the City.
7. For sites with septic systems, the discharge point must be down slope of the primary and reserve drain field areas. This requirement may be waived by the City if site topography clearly prohibits flows from intersecting the drain field or where site conditions indicate that this is unnecessary.
8. If the vegetated flowpath (measured as defined above) is less than 25 feet on a subdivision single-family lot, a perforated stub-out connection may be used in lieu of downspout dispersion. A perforated stub-out may also be used where implementation of downspout dispersion might cause erosion or flooding problems, either on site or on adjacent lots. This provision might be appropriate, for example, for lots constructed on steep slopes, where downspout discharge could be cumulative and might pose a potential hazard for lower lying lots, or where dispersed flows could create problems for adjacent offsite lots. This provision does not apply to situations where lots are flat and onsite downspout dispersal would result in saturated yards.

B. Porous Concrete pavement

Porous concrete, also known as “no fines concrete,” is a special type of concrete that allows stormwater to pass through it, thereby reducing the runoff form a site. In addition, porous concrete provides runoff treatment through filtration and allows for goundwater recharge. Porous concrete or “No Fines Concrete Paving” is a structural, open textured pervious concrete paving surface consisting of standard Portland cement, fly ash, locally available open graded coarse aggregate (usually No. 78), admixtures, fibers, and potable water. When properly handled and installed, porous concrete has a high percentage of void space (approximately 17% to 22%) which allows rapid percolation of storm water through the pavement.

General design guidelines:

Application: With pre-approval of the Public Services Director, porous concrete pavement may replace conventional pavements or other hard surfaces provided that the grades, subsoil drainage characteristics, and goundwater table conditions are suitable for its use.

1. Porous concrete is not recommended for slopes greater than 5% and best with slopes as flat as possible.
2. The minimum depth to bedrock and seasonally high water table should be 3 feet.
3. The minimum infiltration rate in subsoils should be 0.25 in/hour.
4. Drainage time for the design storm: minimum is 12 hours, preferred is 24 hours, maximum is 72 hours.
5. Run-on to the pavement from offsite areas is not allowed. Pre-treat runoff if sediment is present.

6. On-site soils should be tested for porosity, permeability, and cation exchange. These properties should be considered with designing the Subbase layer.
7. Open and uniformly graded stone (#78) should be used in mix.
8. A non-woven Geotextile fabric should be used if stone base is placed over fine-grained soils such as silts.
9. Maintenance provisions of pavement covered in an operation and maintenance plan. Address, for example routine pavement vacuuming, street sweepers, leaf blowing, power washing, and protection of pavement during construction to prevent degradation of pavement by siltation from erosion until site is stabilized, etc.
10. A pre-approved Contractor experienced in constructing, placement, and curing.

Suitable Applications:

1. Commercial, public and municipal parking lots, including perimeter and overflow parking areas;
2. Low-speed residential roads with light truck traffic
3. residential driveways
4. Bicycle trails, golf cart paths, fill or underlayment for precast, modular paver, or grid systems
5. Vehicular access areas, including roadway shoulders, medians, fire lanes, on-street parking areas, emergency stopping lanes, bus stops, crossovers on divided highways;
6. Areas where additional drainage capabilities are desired with improved with structural capacity such as soccer fields, open space areas, or drainage fields.

Benefits:
1. Allows site precipitation to reach the root systems for plants and vegetation. Porous concrete can be placed over root systems of trees to improve survivability otherwise caused by dehydration.
2. Mimics natural soils filtration throughout the pavement depth, underlying subbase drainage filter, and native soils for improved water quality
3. Reduction of storm water runoff temperatures
4. Increased recharge of groundwater
5. Elimination of typical random cracking patterns commonly found in improperly jointed concrete;
6. Year round construction ability

7.4 DETAILS

The **Standard Details 640.01 through 643.01** are herein made part of this section by reference and should be utilized in conjunction with NCDENR's BMP manual.

7.5 REQUIRED SUBMITTAL DOCUMENTATION

The following information shall be submitted to the Public Services Director for the design of all BMP facilities (as listed in checklist in Section 2.1.4):

1. Vicinity Map
2. Site Plan
3. Grading Plan

4. Runoff Map
5. Runoff Calculations
6. Hydraulic Calculations
7. BMP calculations (covering each applicable element in the checklist for the respective BMP used)
8. Soils Report, as applicable
9. Operation and Maintenance Plan, if applicable, (Section 6.6, *Maintenance*)
10. Worksheet as applicable to the measure(s) employed (Section 2.1.4)

Section 8 - INSPECTION & ACCEPTANCE

8.1 LIMITS OF PUBLIC OWNERSHIP AND MAINTENANCE RESPONSIBILITY:

8.1.1 The following components of the drainage infrastructure will not be maintained by the City of Jacksonville:

A. All drainage easements shall be public to the end of any storm drainage pipe system. All drainage beyond *that point* shall be carried in drainage easements which are *private* and will be owned and maintained by the *individual property owner*.

B. The City of Jacksonville of Jacksonville assumes no liability or responsibility for adjudicating disputes between property owners regarding non-publicly generated storm water.

C. Drainage systems on private property that do not have dedicated easements.

D. Drainage systems maintained by NCDOT as part of its State highway system.

E. **Detention/Retention/Water Quality Pond Areas**: The City will not accept these areas for maintenance; however, the City reserves the right to enter these areas and remove any debris or blockage that is adversely affecting the City's drainage system. This will be done in an emergency situation without notice. Under normal conditions, the City will contact the owner/developer to have said blockages removed. If unable to do so within a reasonable time, the City reserves the right to charge the owner/developer for any expense incurred by the City in doing so.

8.2 NATURAL WATER COURSES:

Natural ditches, streams, creeks and rivers shall not be maintained by the City except to remove debris/blockages that are adversely affecting the City's drainage system.

8.3 LIMITATION OF CONSEQUENTIAL DAMAGE TO PRIVATE FACILITIES LOCATED ON PUBLIC EASEMENTS

All public easements including storm sewer is to remain clear of obstructions. No buildings, fences, trees, shrubs or other obstructions shall be placed in any easement. Driveways, walkways, asphalt and parking lots may be permitted in easements; however, the City reserves the right to remove such asphalt, concrete, base course and sod as necessary to access its facility in the case of emergency. Pavement or concrete will be replaced with a **patch**. Sod will be replaced with Fescue or rye seeding. The City will **not** be responsible for replacing a property owners sod after repairing a drainage line

8.4 INSPECTIONS:

8.4.1 The following items must be inspected during and after installation of storm drainage lines and appurtenances:

A. All boxes and manholes for presence of weep holes, formed inverts, castings, pipe flushed against inside wall of box, steps and location of steps, proper corbelling of brick/block in accordance with the details and specs, wall thickness and depth of manhole.

B. Pipe for cracks.

C. Removal of debris and sediment in both pipe and box.

D. Rip rap outlet protection and filter fabric, stilling basin compliance with plan if applicable.

E. Armor protection of ditches (concrete and/or temporary liners), scour, and erosion.

8.4.2 All inspections must be scheduled at least 24 hours prior to when needed. Inspections will be performed in the order received. Every effort will be made to accommodate the time of request; however, this cannot be guaranteed.

8.4.3 Upon completion of construction the developer shall request a warranty inspection. Upon completion of all punch list items, an acceptable set of record drawings certified by an engineer shall be provided to the City.,

8.5 WARRANTY:

8.5.1 Warranty and Defects Guarantee: Upon the acceptance of facilities, utilities or streets for permanent maintenance, an eighteen month warranty for all improvements shall become effective. This warranty must be satisfactory to the City of Jacksonville. In addition, the subdivider shall provide surety in the amount of 10% of the total construction cost to guarantee the correction of all defects in such facilities, utilities, or streets that occur within the warranty period described above.

For the purposes of this section, the term “defects” refers to any condition in publicly dedicated facilities such as utilities or streets that requires repairs to such improvements over and above the normal amount of maintenance that they would require. If such defects appear, the warranty may be enforced regardless of whether the facilities,were constructed in accordance with the requirements of this ordinance.

8.5.2 During the eighteen month warranty period, the developer shall repair any latent defects which occur. At the end of the eighteen month warranty period the developer shall request a final inspection. Upon successful completion of all warranty items the developer shall be released from maintenance responsibilities for the warranted construction.

8.5.3 Warranty repairs to the following common problems shall be as follows:

A. Street pavement trench failures shall be repaired in accordance with the City Manual of Specifications, Standards, and Design as well as at the direction of the Public Services Director.

B. If more than 3 trench failures occur within a longitudinal distance of 800 feet on any segment of a street, the City may require a 1-inch overlay once repairs have been completed.

C. Cracks in curb and gutter shall be repaired by removing and re-pouring such sections as necessary;

D. All storm sewer systems, ditches and gutters shall be free of debris, dirt or silt;

E. All drainage and street appurtenances shall be in perfect condition and properly exposed.

F. All other defects shall be corrected in accordance with the recommendations of the Public Services Director.

8.5.4 If a developer fails to complete warranty items, future projects of the developer shall not be reviewed by the Department of Public Works and Utilities. In addition, the City may take additional legal action against the developer.

Section 9 – FINANCIAL

9.1 NEW SUBDIVISION AND NEW CONSTRUCTION EXCLUDED

Construction of storm drainage in any new subdivision shall be at the sole responsibility of the developer, shall be provided at his/her expense, and shall be installed by the developer in accordance with the Manual of Specifications, Standards, and Design pursuant to the Subdivision Regulations of the City.

9.2 PRIVATE PROPERTY – OTHER THAN NEW SUBDIVISIONS:

9.2.1 The City will issue permits for any change to the drainage system other than in new subdivisions within the City's corporate limits.

Section 10 – REFERENCES

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10.19 NCDENR, *Erosion and Sediment Control Planning and Design Manual*, November 1988, Revised.

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10.24 Storm Water Pollution Control, 2nd Edition, Roy D. Dodson, PE, McGraw-Hill,1999

10.25 *Surface Water Management Manual,* Volume V, Runoff Treatment BMPs, Tacoma Public Works, Environmental Services, City of Tacoma, January 2003.

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10.27 *Urban Drainage Design Manual,* Hydraulic Engineering Circular No.22, USDOT, Federal Highway Administration, November 1996, FHWA-SA-96-078

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