Camden County, North Carolina

Stormwater Drainage Design Manual

10/23/15

Camden County, NC
PO Box 190 Camden, NC 27921

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Division 1: Foreword

1. Camden County's unique topography creates challenges for stormwater management. Unlike most other areas of North Carolina, Camden County has some of the flattest terrain anywhere in the state. Typically, slopes can range from 0% to 2% over vast areas. Agricultural fields can take several days to recover from a modest storm event. Because the terrain is so flat, rain from storms tends to be held on undeveloped or agricultural lands and depending on the intensity and length of storm, water can stand in the fields several inches deep for long periods of time. This standing water naturally attenuates the flow from the fields and allows the stormwater to seep into the ground, or be discharged, into the adjoining ditches and streams at a low rate. Camden County farmers have mastered how to hold rainwater on fields through the installation of small drainage pipes within the crop fields' ditch system or by using adjustable weirs to dam up the runoff in the ditches. The flat topographic features combined with water retaining techniques reduce the runoff from farmed fields to a fraction of what is typically expected.

2. Development of the land changes not only the impervious area and compaction of the soil, but it also affects the area's natural attenuation. The change is because homes and buildings are built upon a raised area so that water will drain away from the structure toward drainage ditches and swales. Development activities also compact the soil and decrease its ability to infiltrate the rain water. The natural attenuation, once experienced over an area is displaced and the runoff is forced down stream. Even a single-family home on a large tract will have some minor impact on the overall drainage basin. Large developments, consisting of dozens of lots, may have significant impact on the drainage basin depending upon the location and topography of the development. Commercial development also has the potential to have impact on the drainage basin. Design professionals should keep these factors in mind in the preliminary design of a project to accommodate the additional runoff generated from developments.

Division 2: Introduction/Executive Summary

1. This Stormwater Drainage Design Manual for Camden County is intended to provide guidance to design professionals in the development of residential, commercial, and industrial projects in the County. The intent of this manual is to supplement design guidelines already in effect through the County's Unified Development Ordinance, the North Carolina Department of Transportation (NCDOT), FEMA Flood Insurance Studies for the County, and the North Carolina Department of Environmental and Natural Resources (NCDENR) Division of Energy, Mineral and Land Resources Stormwater Best Management Practices Manual (http://portal.ncdenr.org/web/lr/bmp-manual) and the Erosion and Sediment Control Planning and Design Manual (http://portal.ncdenr.org/web/lr/erosion) As such, this document should be construed as a supplement to the County's criteria and state agencies providing direction for stormwater management. Use of this stormwater manual is mandated by the County's Stormwater Management Ordinance in which this drainage manual is referenced. The methods outlined in the manual are not the only methods acceptable for use. Any deviations from these methods, however, must still meet or exceed the intended results and be reviewed and approved by the County.

2. This Stormwater Drainage Design Manual is a dynamic document. As better understandings or new techniques are accepted in the design community, the Stormwater Drainage Design Manual will be reviewed and edited to include new or better information. This drainage manual is also intended to address the goals listed in the County's Coastal Area Management Land Use Plan. The goals of the Coastal Area Management Land Use Plan are to develop a public facilities manual, to set policy for private development requirements, and set the criteria necessary for an overall stormwater management plan for the County. The Stormwater Design Drainage Manual directly addresses these goals.

Division 3: Drainage Law

1. The following paragraphs are from the North Carolina Division of Highways Guidelines for *Drainage Studies and Hydraulic Design 2012*.

https://connect.ncdot.gov/resources/hydro/Pages/Guidelines-Drainage-Studies.aspx

"North Carolina long adheres to the civil law rule in regard to surface water drainage. This will obligate owners of lower land to receive the natural flow of surface waters from higher lands. It subjects a landowner to liability wherever he interferes with the natural flow of surface waters to the detriment of another the use and enjoyment of his land. Since almost any use of land involves some change in the drainage and water flow, a strict application of civil law principles was impractical in a developing society. Thus, a more moderate application of this rule to allow a landowner reasonable use of his property evolved."

2. The North Carolina Supreme Court formally adopted the rule of reasonable use with respect to surface water drainage and abandoned the civil law rule Pendergrass v. Aiken in August 1977. The adopted reasonable rule allows each land owner to make reasonable use of his land even though, by doing so, he alters in some way the flow of surface water thereby harming other landowners, liability being occurred only when this harmful interference is found to be unreasonable and causes substantial damage."

Division 4: County Ordinances and NCDOT Criteria

The following paragraphs are from the County's **Unified Development Ordinance** to provide an overview to the pertinent sections pertaining to drainage criteria. .

§ 151.232 DESIGN STANDARDS AND CRITERIA.

(F) Drainage.

(1) Each subdivision shall provide adequate storm drainage for all areas in the subdivision. A combination of storage and controlled release of stormwater run-off is required. The release rate of stormwater from all developments shall not exceed the ten-year stormwater run-off from the area in its natural state (post-development vs. pre-development). All free flowing storm drainage systems shall be designed to accommodate the run-off generated by a ten-year design storm or State Department of Transportation (NCDOT) standards if more restrictive and the system will be maintained by NCDOT if the system is located within the NCDOT right-of-way. Plans must show, at minimum, the following information:

- *(a) All culvert inverts, including driveway culverts;*
- *(b) Direction of flow;*
- *(c) Elevation data of drainways, ditches, swales and the like to outlet;*
- *(d) Drainage calculations for drainway design within boundaries of proposed subdivision and off-site, if appropriate; and*
- *(e) Total pre-development and post-development run-off in CFS (cubic foot per second) volume leaving development area.*

(2) Plans must address maintenance of the drainage system and who will be the responsible party to ensure proper maintenance is performed on the drainage system. The plan will be reviewed and inspected by county planning and technical review staff.

§ 151.400 DRAINAGE.

(A) Stormwater drainage. Each residential/non-residential subdivision or commercial site plan shall provide adequate storm drainage certified by a North Carolina registered engineer, a North Carolina Licensed Surveyor, or landscape architect (with proven experience in stormwater drainage) for all areas in the subdivision.

A combination of storage and controlled release of stormwater run-off is required. The release rate of stormwater from all developments shall not exceed the ten-year stormwater run-off from the area in its natural state (post-development vs. pre-development). All free-flowing storm drainage systems shall be designed to accommodate the run-off generated by a ten-year design storm or North Carolina Department of Transportation (NCDOT) standards if more restrictive. The following information must be provided:

- *(1) Elevation survey of entire tract with topo lines at one-foot intervals;*
- *(2) All culvert inverts*
- *(3) Direction of flows;*
- *(4) Downstream analysis (cross-sections) of drainage way to outlet (creek, stream, river and the like);*

(5) Stormwater storage analysis (storing the differential between the outlet ditch capacity at bank full and the 100-year storm event throughout the proposed development area) and show minimum lot elevations;

(6) Drainage calculations for drainway design within boundaries of proposed subdivision and off-site, if appropriate;

(7) Show total pre-development and post-development run-off in CFS (cubic feet per second) volume leaving development area;

(8) Along all existing drainage ways within proposed development areas, swales (minimum 6:1 side slopes) are preferred over traditional ditches. Maintenance easements ***(over)*** *the width of the swale shall be centered over the swale;*

(9) There shall be a 30 foot drainage/maintenance easement on all lead ditches that carry water upstream through the development to the outfall.

(10) If swales are not utilized, then all ditches and canals will require minimum of 30 feet of open space from the top of bank on one side or the other (maintenance area); and

(10) Developer will be responsible for upgrading drainage system to outlet subject to obtaining permission from all property owners adjacent to the watercourse outlet. **(See Section 7.12)**

(B) Plans must address maintenance of the drainage system and who will be the responsible party to ensure proper maintenance is performed on the drainage system. The plan will be reviewed and inspected by County Technical Staff members.

(Ord. passed 12-15-97; Am. Ord. 2007-03-04, passed 4-16-07; Am. Ord. 2008-03-02, passed 3-17-08; Am. Ord. 2009-02-02, passed 3-16-09)

§ 151.401 DEVELOPMENTS MUST DRAIN PROPERLY.

(A) All developments shall be provided with a drainage system that is adequate to prevent the undue retention of surface water on the development site. Surface water shall not be regarded as unduly retained if:

(1) The retention results from a technique, practice or device deliberately installed as part of an approved sedimentation or storm water runoff control plan; or

(2) The retention is not substantially different in location or degree than that experienced by the development site in its pre-development stage unless the retention presents a danger to health or safety.

(B) No surface water may be channeled or directed into a sanitary sewer.

(C) Whenever practicable, the drainage system of a development shall coordinate with and connect to the drainage systems or drainage ways on surrounding properties or streets.

(D) Use of drainage swales rather than curb and gutter and storm sewers in subdivisions is provided for in §§ 151.170 through 151.184. Private roads and access ways within unsubdivided developments shall utilize curb and gutter and storm drains to provide adequate drainage if the grade of the roads or access ways is too steep to provide drainage in another manner or if other sufficient reasons exist to require the construction.

(E) Construction specifications for drainage swales, curbs and gutters and storm drains are contained in Appendix C to this chapter. (Ord. passed 12-15-97)

§ 151.402 STORMWATER MANAGEMENT.

(A) All developments shall be constructed and maintained so that adjacent properties are not unreasonably burdened with surface waters as a result of the developments. More specifically:

(1) No development may be constructed or maintained so that the development unreasonably impedes the natural flow of water from higher adjacent properties across the development, thereby unreasonably causing substantial damage to the higher adjacent properties; and

(2) No development may be constructed or maintained so that surface waters from the development are unreasonably collected and channeled onto lower adjacent properties at the locations or at the volumes as to cause substantial damage to the lower adjacent properties.

(B) Any development that requires a CAMA major development permit or a sedimentation and erosion control plan shall be subject to the state stormwater runoff policies promulgated in 15A NCAC 02H.0101 et seq., unless exempted by those regulations.

(Ord. passed 12-15-97)

The County Code is provided for the design professional's convenience. However, the designer should not construe that these paragraphs are the only applicable codes.

The **North Carolina Department of Transportation** issued guidance for new subdivision in the State. The following paragraphs are quoted from the **"NORTH CAROLINA DEPARTMENT OF TRANSPORATION SUBDIVISION ROADS MINIMUM CONSTRUCTION STANDARDS"**

MINIMUM DESIGN AND CONSTRUCTION CRITERIA
FOR SUBDIVISION ROADS

CONSTRUCTION REQUIREMENTS

A. DRAINAGE

The Division of Highways shall review all drainage prior to acceptance of any facility to the State System. Drainage, utility, or public easements, are not considered a portion of the highway facility. All storm drainage shall be adequate so that the road and rights of way may be maintained without excessive cost, and not cause flooding on private property from storm runoff of the design frequency. Permanent drainage easements may be established by the designer; however, the NCDOT does not accept maintenance responsibility for the easement outside of the roadway right-of-way. The minimum design frequency shall be as follows but may be increased at the recommendation of the State Hydraulics Engineer.

1. Storm sewer collector - 10 years
2. Cross drainage for Secondary Routes - 25 years
3. Cross drainage on primary and N.C. routes will be 50 years.
4. Minimum Cross Pipe diameter is 18", Minimum Driveway Pipes diameter is 15".
5. All drainage shall be consistent with criteria found in *NCDOT - Guidelines for Drainage Studies and Hydraulic Design*.

www.ncdot.org/doh/preconstruct/highway/hydro/

Note: Use of hydraulic design forms found in *Guidelines for Drainage Studies and Hydraulic Design* will expedite the design review process. In areas where ditch grades or quantities of flow deem it impracticable to establish and maintain vegetation, an erosive resistant

lining such as paving, matting or rip rap may be required. Subsurface drainage shall be adequate to maintain a stable subgrade.

When road crossings are within areas designated as flood hazard areas under the Federal Flood Insurance Program, the design must be approved by the responsible local governing agency for its consistency with local flood zoning ordinances. Structural stormwater controls shall be located outside the right-of-way.

The following guidance was provided by the NCDOT Regional Office:

Cross Lines should be designed to pass the 25 years storm and keep the max head 1.5 feet below the shoulder point.

Subdivision Ditches should be designed to contain the 5 year storm within their banks (i.e. equal to or below the shoulder point). Driveway pipes shall be designed to convey the 10 year storm.

The 1.5 feet max head below the shoulder point only applies to Cross Line sizing. The roadway elevation for subdivision roads need only to be high enough to meet the 5 year storm ditch containment criteria.

Division 5: Infill Projects

Infill projects are challenging because typically there is a practical need to elevate the area to shed runoff from the project and comply with criteria necessary to allow development. Fill can be needed to meet regulatory flood protection elevations. However, this fill activity can have negative impact on adjoining property. The new fill can push additional runoff onto the adjacent land and exacerbate marginal drainage conditions there. High groundwater tables and poorly drained soils require development to be elevated to create grade separation between the surface and the seasonal high water table. This is needed to provide vertical separation between the surface and the saturation zone to ensure proper drainfield function.

Infill development may also occur on lands which are elevated higher than adjacent properties. In these cases care must be taken to ensure runoff is not directed onto neighboring properties in a manner which causes hardship on the adjacent property. Diversions, redirection of runoff or onsite detention may be needed to avoid or minimize impacts on neighbors.

The Unified Development Ordinance sets forth the requirements for the use of fill in conjunction with development activities. It is the intent of Camden County to allow the use of fill when it is necessary and appropriate but, to apply sufficient controls to the application of fill, such that it does not aggravate flooding conditions on adjacent lots or in neighboring properties. The use of fill is allowed as outlined in the in this Section 5 and any additional standards included in the Unified Development Ordinance § 151.404.

§ 151.404 MANDATORY STANDARDS FOR LAND DISTURBANCE ACTIVITIES.

(A) The provisions of this section (§ 151.404) shall apply to any application for a building permit where any land disturbing activity is proposed regardless of the size of disturbed area. A fill permit is required when filling/grading above any adjacent grade is proposed.

(B) (B)Land disturbing activities, excluding clearing, grubbing and vegetable gardens, shall not be permitted within ten feet from any property line with the exception of drainage and stormwater improvements and underground utilities. Landscaping and fences located within this area are permitted as long as they do not impede the flow of

stormwater. Land disturbance on front (street) property lines for driveways shall be limited to culvert, drainage, and driveway improvements and shall comply with all provisions of this section.

(C) Fill is not allowed within ten feet of any side or rear property line. Fill is not allowed with ten feet of the front (street) property line except for driveway improvements and as approved by the county.

(D) Stormwater ponds, either wet or dry, shall not be located within the ten foot no fill zone, except as approved by the county

(E) A lot shall not be filled/graded higher than the adjacent grade except for the following:

1) *When Albemarle Regional Health Services (ARHS) determines that fill is necessary for a septic system to function property, the fill area shall be limited to the septic system and drainfield areas and the maximum fill shall not exceed 24 inches.*
2) *An additional 12 inches of fill above the septic system and drainfield fill may be allowed for the house pad to ensure adequate flow from the building to the septic system.*
3) *When fill is required to raise the lot elevation to the base flood elevation.*
4) *When fill is essential to meet the required pad elevation as shown on an approved preliminary plat/grading plan.*

(F) All fill shall be established at a slope not to exceed 3:1 (three feet horizontal run for every one foot vertical rise). The toe of the slope shall meet the ten foot setback requirement from all property lines. A permanent ground cover, sufficient to prevent erosion, must be established on all fill slopes as follows:

1) *Prior to issuance of the certificate of compliance for construction projects; or*
2) *For projects where land disturbance activity has ceased for more than six months, whichever occurs first.*

(G) Bulkheads or retaining walls shall not be allowed as a method to stabilize or contain fill, except bulkheads established for the purpose of shoreline protection and as otherwise permitted by the county. This shall not include retaining walls used to stabilize or contain existing natural grade when a driveway or walkway is cut into a lot at an elevation lower than existing natural grade.

(H) Any lot requiring a fill permit shall install erosion and sediment control measures to prevent sediment from leaving the site. The erosion and sediment control measures shall be implemented on the site prior to the commencement of land disturbing activities and shall be continuously maintained during the land disturbance phase of development.

(I) In the cases of natural grade differences greater than nine inches between adjoining lots of the subject property, the county may require (based on size and shape of lot) a stormwater management plan prepared by a state licensed engineer, land surveyor, or landscape architect that deviate from these requirements. The stormwater plan shall verify that the proposed development will not create flooding or nuisance conditions on the lower adjacent lots. In no case shall the rear and side yard no fill zones be encroached upon with fill.

(J) A fill permit issued by the North Carolina Division of Water Quality shall be required to fill any 401 wetlands.

(K) A fill permit issued by the U.S. Army Corps of Engineers shall be required to fill any 404 wetlands.

Division 6: Stormwater Management Plan Requirements

Commercial and Industrial developments disturbing less than one half (½) acre shall meet the requirements provided in the following Section 1. Residential developments disturbing one acre and more and all Commercial and Industrial developments disturbing one half (½) acre and more shall meet the requirements of both Section 1 and Section 2 of this Division.

Section 1. Stormwater management plan required for all developments

1. All development plans are required to submit a stormwater management plan for approval. The stormwater management plan shall consist of:
    1.1. Cover Page: Project name; project address; name of developer and owner; name, address, and phone number of engineer landscape architect, surveyor of record; professional's engineer's seal; date of report.
    1.2. A location map;
    1.3. A boundary plat of the tract or parcel;
    1.4. A topographic survey of the project indicating existing conditions, showing at least one-foot contours as prescribed by the subdivision ordinances. Spot elevations to better define ditch inverts and top of bank shall be provided. The topographic survey shall be performed by a licensed engineer or surveyor;
    1.5. The width of right-of-way and name of the adjoining street or road;
    1.6. Proposed elevations of the tract, or parcel;
    1.7. Existing and proposed drainage systems sizes, type, material, amount of sediment buildup and inverts which affect the on-site hydraulic conditions;
    1.8. Existing and proposed flow patterns and flow directions;
    1.9. FEMA Maps and/or previously approved drainage studies documenting the 100-year storm elevation so that the building grade elevation of any proposed buildings may be set above it.
    1.10. All swales should have a maximum 6:1 side slopes. Swales are defined as drainage conveyance man-made structures between 0" and 24" deep, as measured from the invert to the adjoining top of bank. Where swales cannot

be utilized, ditches or similar conveyance features shall have side slopes no steeper than 4:1 in residential areas and 3:1 in commercial or industrial areas.

1.11. Driveway culverts shall be sized to allow the conveyance of the 10 year storm. The maximum hydraulic loss for the estimated 10 year storm flow is 0.2 feet for projects disturbing less than one acre. A more detailed analysis in accordance with Section 2 shall be provided for projects exceeding more than an acre of soil disturbance.

1.12. Closed drainage systems shall meet NCDOT Guidelines for Drainage Studies and Hydraulic Design.

1.13. Conveyance systems draining over 300 acres shall be designed for the 25 year storm.

Section 2. Additional requirements for larger developments

2. Residential development activities which disturb one acre (1 acre) and more and commercial and industrial development disturbing one half (½) acre and more shall comply with the following criteria in addition to the conditions set forth in Section 1:

2.1. All driveway culverts, ditches, swales, and drainage conveyance systems both open and enclosed shall be designed based upon the 10-year storm. Calculations for the on-site/internal drainage system are required to substantiate the hydraulic grade line (HGL) for the 10 year design storm.

2.2. Acceptable hydraulic grade lines for 10-year storm designs in open drainage systems shall be no higher than 0.25 feet (3") below the edge of pavement.

2.3. Acceptable hydraulic grade lines for 10-year storm designs in closed drainage systems shall be no higher than 0.5 feet (6") below the flow line of the gutter pan.

2.4. All cross pipes and driveway culverts shall be provided with headwalls or end sections in accordance with NCDOT standards (310.02-.04 or 838.01). HDPE pipe shall be provided with end sections specifically manufactured for the pipe.

2.5. All cross pipes and driveway culverts shall be provided with erosion control in accordance with NCDOT 876.02.
https://connect.ncdot.gov/resources/Specifications/2012%20Roadway%20Standard%20Drawings/Division%2008%20-%20Incidentals.pdf

2.6. The developer is responsible for making all improvements necessary to comply with these policies.

2.7. Ditch bottom elevation profiles shall be provided. Ditch bottom profile elevations will serve as the control for installation of all initial and future culvert invert elevations within the development. Profiles may be shown on road profiles.

2.8. Drainage considerations will begin at the "sketch plan" phase of development. **Potential developers should meet on-site with county representatives to review drainage requirements prior to submittal of sketch plans**.

2.9. Drainage calculations demonstrating that the pre-development flow rate from the site does not exceed the post development rate in cubic feet per second shall be submitted. The flow rate will be judged immediately downstream of the project.

2.9.1. Calculations shall include an analysis of the hydraulic tailwater from downstream conditions that result in upstream ponding and flooding.

2.9.2. The drainage analysis shall also include upstream and downstream drainage to identify the maximum flow and/or hydraulic gradeline.

2.9.2.1. The limiting factor may be a ditch, culvert, dam, weir or road.

2.9.2.2. If a culvert or similar feature is not the limiting factor in the upstream or downstream analysis, then the downstream analysis shall continue to an adequate outfall defined in Division 7 paragraph 12.

2.9.2.3. Where off-site evaluations are limited by private property concerns approximations may be made using LiDAR (Light Detection and Ranging) and visual observations.

2.9.2.4. The upstream analysis should consider the drainage capacities of the existing upstream drainage system and compute the hydrograph throughout the SCS Type III 24 hour storm.

2.9.2.5. All drainage components within the proposed development that transport upstream flow must equal or exceed the

existing upstream drainage discharge rate for the storm event under consideration.

2.9.2.6. Areas with out-of-bank flow for 1 year – 1 day storm events must be noted and displayed as “areas of concern” on plats.

2.10. The post development runoff rate shall be held to the pre-development runoff rate for the 10 year storm and the 1 year storm events. When runoff from a project flows under a Primary, Secondary or Interstate a 50 year storm shall also meet the criteria. Dynamic calculations documenting compliance shall be provided as an element of the preliminary plat application.

2.11. The length of storm shall be at least 24 hours. A longer time may be necessary to insure that the declining limb of the basin is included in the analysis.

2.12. The rainfall depth shall be based upon NOAA rainfall data which is accessible at: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nc for the project’s location.

2.13. A United States Department of Agriculture – Natural Recourses Conservation Services (USDA-NRCS or NRCS) soils map of the proposed development shall be submitted to the County. The professional is directed to the USDA WEB Soils Survey. An Area Of Interest (AOI) analysis shall be provided of the development area. The reported soil types and hydraulic soil group shall be used to develop NCRS hydrographs. The County, at its sole discretion, may allow the developer to conduct a soils evaluation of the proposed site in lieu of the NRCS evaluation. Such an evaluation shall be performed by a registered soil scientist.

2.14. The requirement to retain the post development runoff rate to the pre-development runoff rate may be waived by the County if the post development retained outflow rate and timing of the discharge increases the downstream hydraulic grade line. This outcome is possible in the middle and lower reaches of the County’s main creeks and is typically a result of delaying the attenuated peak flow from the project.

2.15. The requirement to hold the post-development runoff to pre-development levels may also be waived in those developments which outfall directly to a major water body such as the mouth of the Joyce Creek, Pasquotank River, or directly into the Albemarle Sound. These major water bodies are considered adequate outfalls.

2.16. When commercial and industrial developments are less than four acres (4 ac.), modified routing calculations using critical duration times may be accepted for review as a substitute for a 24-hour analysis. These analysis algorithms, also named "Modified Rational Methods", must be submitted 30 days in advance of a project application for review and concurrence by the County. Approval of alternative calculation methods will be solely based on the discretion of the County. A more rigorous analysis may still be needed and required.

2.16.1. The 10-year storm shall be used to size BMPs for 4-acre or less commercial and industrial developments.

2.16.2. The hydraulic grade line for the 10-year storm shall be calculated and brought to the outfall point of the development.

2.16.3. The designer may use ½ of the rise of the 10-year storm at the outfall point as constant tailwater for the modified on-site BMP volume calculation for developments less than 4 acres.

2.17. In support of the requirement to limit the post runoff rate to the pre-development rate, an existing conditions drainage map showing the existing drainage area and existing land use shall be provided.

2.18. The existing drainage area map shall be of sufficient topographical detail to clearly show the existing patterns and existing drainage ways and outfalls for the site as it exists.

2.19. A proposed drainage area map shall be provided. The map shall show the proposed drainage areas retention/detention ponds and stormwater outfall pattern for the proposed development.

2.20. Topographic surveys of existing culverts and ditches to an adequate or defined outfall shall be provided.

2.21. Proposed developments that have ditches or canals that transport upstream flow must maintain the flow characteristics of the conveyance. Both the

existing bank-full upstream flow and the 25 year design storm shall be analyzed.

2.22. The designer shall consider the existing conditions area upstream of the subject development in all calculations and determine the probable rate and pattern of flow that is a complete runoff hydrograph.

2.23. The designer should consider the effects of existing and natural attenuation in the calculations when deriving the bank full flow. When a culvert restricts flow from an upstream area the flow through the culvert shall be evaluated using at least 0.2 feet of head loss. Tailwater and land slope must be considered when calculating open channel flow using Manning and similar equations to predict bank-full flow.

2.24. The designer shall demonstrate that the post development drainage system does not impede upstream drainage in any way.

2.25. At least one soil boring indicating the type of soil and seasonal high water elevation for each Best Management Practice, BMP, (retention pond constructed wetland, etc.) shall be provided. The boring shall be provided by a licensed engineer, soil scientist or geologist. Soil borings must be at least six feet deep, or extend at least 2 feet below the lowest excavation of the BMP. Soil limitations for the BMP will be presented. Where BMPs are over ½ acre, an additional boring shall be supplied for each ½ acre thereafter. The following items shall be provided in the soils report:

2.25.1. The estimated high seasonal water table with and without drainage improvements;

2.25.2. The elevation at which the ground water is encountered. The elevation shall be measured 24 hours after the boring is made.

2.25.3. The texture and thickness of soil horizons using USDA, or the Unified Soil Classification Systems;

2.25.4. Soil color and redoximorphic features;

2.25.5. Estimated saturated hydraulic conductivity.

2.26. The master drainage plan must demonstrate that the drainage system is adequate to prevent undue retention of surface water on the developed site.

Standing water shall drain from rear and side swales in 48 hours or less. Standing surface water may be allowed if:

2.26.1. The retention is a result of the stormwater retention design or;

2.26.2. The retention system is not substantially different than the existing or pre-developed condition unless such retention presents a danger to the public health or safety.

2.27. Drainage studies shall demonstrate that the retention systems recover at least 70% of their maximum 10 year storage within 72 hours from the beginning (hour 0) of a Type III storm.

2.28. Side and rear residential lot swales shall have a minimum grade of 0.3%.

2.29. Drainage conveyance systems shall be provided with drainage easements of adequate width to contain and provide for future maintenance.

2.29.1. Drainage maintenance easements will be provided for all ditches and swales.

2.29.2. Drainage ditches shall have an easement that covers the ditch and a maintenance travel way. For ditches which are contained within the limits of the project this easement shall encompass the ditch and extend 5 feet beyond one side and 30 feet beyond the other side of the ditch. If a ditch is located on a property line the development shall provide an easement over the portion within its limits and a 30 foot wide easement beyond the top of bank onto the project area.

2.29.3. Swales will have a 10 foot easement that extends 5 feet on each side of the centerline.

2.30. The drainage system of the development shall be coordinated with and tie into existing drainage ways or systems.

2.31. All developments shall be constructed and maintained so that adjacent properties are not unreasonably burdened with surface waters or waters directed toward them from developments.

2.32. New developments shall be constructed or maintained so that they do not unreasonably impede the natural flow of water from high and adjacent properties across the development to an outfall.

2.33. No developments shall be constructed and maintained so that surface waters are unreasonably collected and channeled onto lower receiving properties at such locations or at such volumes as to cause substantial damage to such lower properties.

2.34. Channeling runoff into swamps and creeks shall be in accordance the North Carolina Administrative Code 15A NCAC 02B .0230 ACTIVITIES DEEMED TO COMPLY WITH WETLANDS STANDARD

(4) maintenance of drainage ditches, provided that spoil is removed to high ground, placed on top of previous spoil, or placed parallel to one side or the other of the ditch within a distance of 20 feet and spoils are placed in a manner that minimizes damages to existing wetlands; and ditch maintenance is no greater than the original depth, length and width of the ditch;

(5) construction of temporary sediment control measures or best management practices as required by the NC Sediment and Erosion Control Program on a construction site, provided that the temporary sediment control measures or best management practices are restored to natural grade and stabilized within two months of completion of the project and native woody vegetation is reestablished during the next appropriate planting season and maintained;

and 15A NCAC 02B .0231 WETLAND STANDARDS

(a) General. The water quality standards for all wetlands are designed to protect, preserve, restore and enhance the quality and uses of wetlands and other waters of the state influenced by wetlands. The following are wetland uses:

(1) Storm and flood water storage and retention and the moderation of extreme water level fluctuations;

(2) Hydrologic functions including groundwater discharge that contributes to maintain dry weather streamflow and, at other locations or times, groundwater recharge that replenishes the groundwater system;

(3) Filtration or storage of sediments, nutrients, toxic substances, or other pollutants that would otherwise adversely impact the quality of other waters of the state;

(4) Shoreline protection against erosion through the dissipation of wave energy and water velocity and stabilization of sediments;

(5) Habitat for the propagation of resident wetland-dependent aquatic organisms including, but not limited to fish, crustaceans, mollusks, insects, annelids, planktonic organisms and the plants and animals upon which these aquatic organisms feed and depend upon for their needs in all life stages; and

(6) Habitat for the propagation of resident wetland-dependent wildlife species, including mammals, birds, reptiles and amphibians for breeding, nesting, cover, travel corridors and food.

(b) The following standards shall be used to assure the maintenance or enhancement of the existing uses of wetlands identified in Paragraph (a) of this Rule:

(1) Liquids, fill or other solids or dissolved gases may not be present in amounts which may cause adverse impacts on existing wetland uses;

(2) Floating or submerged debris, oil, deleterious substances, or other material may not be present in amounts which may cause adverse impacts on existing wetland uses;

(3) Materials producing color, odor, taste or unsightliness may not be present in amounts which may cause adverse impacts on existing wetland uses;

(4) Concentrations or combinations of substances which are toxic or harmful to human, animal or plant life may not be present in amounts which individually or cumulatively may cause adverse impacts on existing wetland uses;

(5) Hydrological conditions necessary to support the biological and physical characteristics naturally present in wetlands shall be protected to prevent adverse impacts on:

(A) Water currents, erosion or sedimentation patterns;

(B) Natural water temperature variations;

(C) The chemical, nutrient and dissolved oxygen regime of the wetland;

(D) The movement of aquatic fauna;

(E) The pH of the wetland; and

(F) Water levels or elevations.

(6) The populations of wetland flora and fauna shall be maintained to protect biological integrity as defined at 15A NCAC 2B .0202.

2.35. Land that has been cleared for development and upon which construction has not commenced shall be protected from erosion and sediment transport by appropriate techniques designed to vegetate the area within thirty (30) days (seeding, etc.) after the land is disturbed or as designated by a state permit.

2.36. Sediment shall be retained on the site of the development. Protective measures in accordance with the State of North Carolina's Erosion and Sediment Control Planning and Design Manual shall be used and maintained.

2.37. Erosion and sedimentation facilities shall be maintained to insure that they continue to function properly throughout the construction of the project.

2.38. Stormwater control structures must be able to operate without any adjustments after installation and shall be able to handle the designed stormwater flow for all required storm events. The designer shall also consider the effects of excessive storms and provide for graceful failure of the drainage system. Semi-pervious rock weirs are desired and should be designed for maximum bank-full flow as a channel restriction or submerged weir.

2.39. Fifty foot wide undisturbed vegetated buffer strips are required adjacent to natural banks of all watercourses, water bodies or wetlands. No construction activities will be allowed in these buffers, except to allow an outfall of minimum disturbance width.

2.40. Natural wetlands shall be protected from construction activities. At locations where activities within wetlands are designed the developer shall acquire applicable permits from the state and federal agencies.

2.41. Proposed ditches and swales shall have vegetated bottoms and sides except LID practices.

2.42. Erosion and Sedimentation Control shall be provided for stormwater projects. A copy of the Sedimentation and Erosion Control Permit issued by the N.C. Division of Land Quality (Washington Regional Office) shall be provided.

2.43. Natural wetlands as defined by the U.S. Army Corp of Engineers shall be denoted on the survey plan of the site.

Division 7: Drainage Stormwater Study Requirements

1. Stormwater Drainage studies and other storm drainage computations shall be performed by registered, professional engineers, landscape architects, or registered land surveyors in North Carolina, who are qualified in hydrology and hydraulics. The professional may be requested to provide a resume of drainage projects to demonstrate proficiency. When requested this shall be provided before any plans are submitted to the County.
2. The Rational Formula may be used in an analysis in which the drainage area for the catchment involved is less than 20 acres. Typically, the Rational Formula may be used to design storm sewers, culverts, swales and ditches of sub-catchments in a development.
3. Catchments, detention or retention systems with areas of more than 4 acres shall be analyzed using SCS 24-hour hydrographs for pre-development and post-development conditions.
4. Hydrographs based on Natural Resources Conservation Services (NRCS) or formerly the Soil Conservation Services (SCS) methods shall be used to develop runoff patterns.
5. The storm distribution pattern shall be as recommended by NOAA.
6. The design tailwater for subcatchments using the Rational Formula shall be based upon the computed elevation in the receiving BMP or drainage system. The elevation shall be based upon dynamic analysis and be at a time equal to the time of concentration in the sub catchment's summed travel time at the point of discharge into the dynamic feature.
7. The determination of pre-development runoff hydrographs shall be based on existing conditions prior to any development activities. Should the land owner clear or disturb property to obtain a higher curve number, the previous curve number before land disturbing activities took place shall be used.
8. Curve numbers will be based upon NRCS data supplied in the Urban Hydrology for Small Watersheds Technical Release Number 55 (Win T.R. 55), latest edition. Determination of soil groups to estimate curve numbers (CN) shall be based upon Camden County's soils maps or as mapped by a soil scientist. An Area of Interest

(AOI) report shall be provided documenting the project's soil types and hydrologic groups. Should several soil groups exist within the project, a weighted CN shall be computed. The weighted CN calculation shall also take into account proposed land use(s). Win TR-55 will document a weighted CN calculation.

9. The computed Curve Number for agricultural fields shall be reduced by 4 to compensate for the water retaining measure used in the County. For example, if the agricultural field is found to have a Curve Number of 83 as computed by Win TR-20 or Win TR-55, a value of 79 (83-4) shall be used.
10. The calculations shall include any existing shallow ponding in fields or wooded areas (natural attenuation) within the existing discharge rate calculation.
11. The existing runoff rate from the development area using the SCS methods described above may exceed the capacity of the existing outfall system. The drainage study shall include an analysis of the outfall system to determine the limiting component along the outfall and ascertain the hydraulic grade line for the various design storms. The hydraulic grade line analysis shall continue to a point of adequate outfall.
12. An adequate outfall shall be defined as:
    a. A station in the County's creeks and rivers where a previously approved study has computed storm elevations;
    b. Where the invert of the receiving channel is less than elevation 2.0 NAVD 1988;
    c. A design point where the project's area is less than 0.5% of the total contributing drainage area.
    d. Direct outfall into a major water body.
13. Drainage studies for all developments shall include the one and one half inch, the one year, ten-year, and one hundred-year analysis for storm events. The post development release rate for the 1 year, and 10 year storms shall not exceed the pre-developed rate as measured immediately downstream. The fifty- year storm may be required if the outfall passes under a Primary, or Secondary road.
14. All new residential subdivision roads associated with the development will be judged as adequately drained if the 10-year storm does not rise above 0.25' (3") below the edge of pavement. Additionally, the maximum static elevation of the 100-year flood

shall not inundate the lowest centerline point of any proposed road by more than 0.75' (9 inches).

15. Drainage calculations for the 100-year storm may include the subdivision roadways for storage and conveyance of the stormwater.
16. Once the 100-year storm is calculated for a new development, the final lot grade adjacent to proposed buildings shall be above the calculated 100-year storm. The calculated 100 year storm elevation for the BMP shall replace the reported FEMA elevation if it is higher.
17. Master drainage stormwater studies for developments shall include and make a part of the analysis any previous subdivision of the property which occurred within five years of the proposed major development. Analysis of the pre-development condition shall exclude impervious areas and cut and fill from these recently subdivided parcels. Any retrofitting of the previously subdivided parcels will be the responsibility of the developer/land owner. Any easements necessary for and from the retrofitting shall be acquired from any current private property owners at the developer/land owner's expense.
18. Master drainage stormwater studies shall use the US Environmental Protection Agency's Stormwater Management Model (SWMM) program 5.0, latest version and shall provide all models to the County for review and approval. Commercially available software which uses the SWMM computation engine, such as XP-SWMM or PC SWMM, may also be used.
19. If XP-SWMM or XP Storm are used, their encrypted version shall be provided for review. Additionally, the approved version shall be translated to EPA-SWMM for archival purposes. Submittals which used PC-SWMM shall be translated to EPA-SWMM 5.0 for review and archival purposes.
20. Neither EPA-SWMM nor PC-SWMM compute SCS hydrographs which are required by Division 7.4. They do allow an infiltration option which uses Curve Numbers. To comply with Division 7.4 the modeler may use WinTR-55 or 20 to compute hydrographs and input the hydrographs into the EPA-SWMM model as direct inflows at nodes. Alternatively, the modeler may calibrate EPA-SWMM's hydrographs using its infiltration procedures and manipulating the subcatchment parameters to emulate the SCS hydrographs. The modeler must demonstrate that at least 25% of the

subcatchments are calibrated. Once a correlation is achieved the modified parameters shall be used on the remaining subcatchments.

21. A table is provided in Appendix I as a guide to help the designer relate the SCS hydrographs with SWMM's Green Ampt runoff method.

Division 8: Stormwater Best Management Practice Design Criteria

1. The storm water management plan shall comply with the requirements of the State of North Carolina for controlling stormwater quality.
2. Development within the Area of Environmental Concern (AEC) as defined by the N.C. Division of Coastal Management, shall adhere to the stormwater management standards of the N.C. Division of Coastal Management, or any successor agency. The standards of the N.C. Division of Coastal Management shall take precedence over the standards included in this ordinance, provided, however, that the developer shall also be required to adhere to the specific standards included in this ordinance that are not in conflict with the standards of the N. C. Division of Coastal Management.
3. These County requirements shall in no way eliminate or modify North Carolina water quality requirements for development.
4. The following order of preference shall be considered in designing on-site stormwater management measures:
   - 4.1 Constructed wetlands.
   - 4.2 Open vegetated swales and natural depressions.
   - 4.3 Infiltration.
   - 4.4 Retention (permanent pool) structures [Retention ponds shall be provided with a minimum 10 foot wide aquatic bench].
   - 4.5 Detention (no permanent pool) structures.
5. The order of preference shall be modified where necessary, to accommodate requirements of the State of North Carolina for controlling stormwater quality.
6. Constructed wetlands should complement, and in some cases replace, traditional ditch-drainage systems required for residential and commercial development on flat landscapes. This type of BMP improves water storage and water management associated with residential and commercial development. This BMP also creates better biodiversity for mosquito control, and eliminates the need for protective measures (fencing) associated with traditional retention and detention ponds and

structures. Furthermore, developers and land-use planners may use this BMP to create effective and aesthetically pleasing stormwater management plans.

7. Artificial watercourses shall be designed, considering soil type, so that the velocity of flow is low enough to prevent erosion, or minimize it to the maximum extent practicable.
8. To ensure adequate storm flow in a densely planted wetland (assuming 100% plant coverage), the design should use a roughness coefficient ≥ 0.1 (Manning's (n)).
9. Constructed wetlands should have 6:1 slopes and be shaped to blend into the surrounding landscapes.
10. Constructed wetlands should be meandering, following old drain ways or depressions that served as natural drainage prior to development.
11. Water control structures must be maintenance free and not require adjustments to handle stormwater flow. Semi-pervious rock weirs are desired and should be designed for maximum bank-full flow as a channel restriction or submerged weir.
12. Detention and retention ponds may be used to detain increased and accelerated runoff caused by development or redevelopment if the runoff is discharged to a water body, watercourse or wetland. Water shall be released from ponds into water bodies, watercourses or wetlands at a rate and in a manner approximating the natural flow that would have occurred before development.
13. Stormwater management plans can be rejected by the County if they incorporate structures and facilities that will demand considerable maintenance, will be difficult to maintain, or utilize numerous small structures if other alternatives are physically possible.
14. The drainage system and all stormwater management structures within the County (including both public and private portions) will be designed to the same engineering and technical criteria and standards. The review will be the same whether the portion of the drainage system will be under public or private control or ownership.
15. Any storm water project shall be accompanied by a description of the proposed method of providing storm water drainage. The developer shall provide a drainage system that diverts stormwater runoff away from surface waters and incorporates best management practices to minimize water quality impacts.

16. It shall be unlawful for any person to pave, stabilize or otherwise make impervious any area adjacent to or draining over any public right-of-way without obtaining an approval from the County. The grading, drainage and material used adjacent to the public right-of-way shall be approved by the County.
17. Due to ground water considerations, all storage calculations for retention ponds and constructed wetlands must start at the elevation of the drainage outlet, or static water level controlled by the downstream drainage system.

Division 9: Floodplain and Floodway Management

1. No filling or construction within the floodway or non-encroachment zones will be allowed. Excavation in and clearing of the floodway and non-encroachment zones will be allowed with the approval of the County. Floodway will be defined as those areas on the FIRM maps for Camden County, depicted as floodway areas in zone AE FM. Non-encroachment area will be defined as designated in Table 10 - Limited Detailed Flood Hazard Data in the Flood Insurance Study dated 2004 and FIRM map updates.

2. Excavation and filling in the floodplain areas, areas noted as AE in the FIRM maps, may be only be allowed with FEMA approval. Cut and fill for new development in the floodplain will only be acceptable if the net volume available with https://msc.fema.gov/portal/advanceSearch in the floodplain remains the same. The volumes will be judged from one foot contour to the next. No credit will be provided for excavation below the normal water elevation of the creek or below the ground water table, whichever is higher. The engineer will provide the areas and volumes at one foot contour intervals for the existing conditions and demonstrate through volume calculations that the proposed condition equals or provides more storage volume for the development. The calculation and demonstration shall begin at the normal elevation, or invert elevation, and proceed by even one foot increments to the FIRM reported base flood elevation for the immediate area. The cut and fill within the floodplain area must take place within the general confines of the development or within 500' of the river station shown on the FEMA maps.

3. Filling the flood plain for redevelopment projects will be allowed so that proposed structure finished floor elevation may be raised to achieve at least the minimum elevation dictated by County's Flood Damage Prevention Ordinance. Adjacent connected facilities such as parking lots shall be graded to transition reasonably from the higher proposed elevations to existing grades at the edge of the project.

4. Item 2 of this Division shall be construed to apply to the portions of the County's creeks and rivers which have riverine hydraulic characteristics. Large portions of the County are contained in Flood Zone AE which are contiguous to expansive water bodies such as the Albemarle Sound and the lower and wider portions of the Pasquotank River and Joyce Creek. These lower portions typically experience wind driven wave action. Filling in these areas to attain structure and connected facilities elevations in accordance with the County's Flood Damage Prevention Ordinance will be allowed.

5. A development which lies within the AE Flood zone and is within a portion of a creek or river which has riverine hydraulic characteristics may fill one time only up to five percent (5%) of the flood zone area within the parcel's boundary. This is a onetime only occurrence and supersedes Item 2 of this Division but not Division 5 Infill Projects. This exception is provided to allow a reasonable engineering design of a property and a connection or roadway from one area to another. This exception should not be construed to include floodways and non-encroachment zones. Filling over five percent (5%) will require a balance of cut and fill as dictated by Item 2 of this Division.

Division 10: Stormwater Management Permitting

1. A County approved stormwater drainage study will be required to process a preliminary plan through the Camden County Technical Review Committee (TRC) prior to review by the Camden County Planning Commission and the Camden County Board of Commissioners.
2. Sedimentation and erosion control and stormwater management permits from NCDNR are required prior to preliminary plan approval.
3. Final plat approval will not be granted until an as-built plan of the constructed drainage system is received and approved by the Camden County Director of Planning or his agent. The as-built plan, certified by a licensed land surveyor, shall document that the drainage improvements outlined in the drainage study and incorporated into the approved preliminary plans are constructed and installed in accordance with the study and plans.
    - 3.1 An appointee of the Manager shall verify through an onsite visual inspection that the as-built survey is accurate. The as-built drainage plan shall show: the lines of all streets and roads;
    - 3.2 lot lines and lot numbers;
    - 3.3 location of all ditches, including road and outfalls, culverts and related drainage structures;
    - 3.4 the inverts of ditches, culverts, and swales;
    - 3.5 proposed building pad, grade;
    - 3.6 driveway culvert material sizes and inverts.
    - 3.7 ponds and lakes top of bank and normal water surface location and elevation.
4. The as-built plans shall show all fire hydrants within the subdivision with benchmark elevations established on the top nut.
5. The percent grade on all proposed ditches and swales shall be indicated to nearest 0.01%.
6. Indicate the roadway ditch invert at each lot corner.
7. Indicate on each lot the minimum driveway culvert size that provides for property drainage and meets NCDOT requirements.

8. All necessary easements and stormwater maintenance requirements shall be included on the final plat.

Division 11: Lot Grading

1. Minimum desirable slope shall be not less than 1%, minimum acceptable slope shall be not less than 0.5%. Construction plans shall provide sufficient grades, ridge lines and directional arrows to define the proposed drainage pattern of the entire lot. A minimum of seven proposed lot grades shall be provided; four at the corners; two at the side yard midpoints; and one grade located at the center of the lot (rear of typical structure location). Intermediate grades will be defined by linear interpolation of lot grades provided. Note Type A, B, or AB lot drainage for each lot.
3. Overland flow onto adjacent offsite property is generally unacceptable.
4. Commercial/Industrial subdivision plans shall provide lot grading to facilitate drainage until final development of individual parcels.
5. Single Family Detached Lot Grading Policy:
    5.1. Construction plans for all new subdivisions will show proposed lot grades to the nearest 0.1'.
    5.2. An engineer's or land surveyor's certification shall be submitted to the County prior to final plat approval certifying that lot grades are within 0.4' of proposed grades and a minimum positive slope of 0.25% exists in the direction indicated in the approved plan. Certification may be waived in cases where approved drainage plans showing existing grades meet the criteria.
    5.3. Lots shall be graded to within 0.1' of the final grade prior to being certified for a Certificate of Elevation. A minimum grade of 0.5% must be provided on the lot. A certification is required from a Land Surveyor confirming this lot grading. See the County's "Certificate of Elevation Grade Adjacent to Structure and Finished Floor of Structure for Compliance with Final Plat."
    5.4. The as constructed elevations of culverts shall be deemed acceptable if the as constructed invert elevation is within 0.12' of the proposed grade, provided, however, that elevations resulting in a flat or adverse slope will be deemed unacceptable even if within the 0.12' tolerance.

Division 12: Maintenance of Stormwater Improvements

1. The NCDENR BMP Manual's Chapter 7 addresses maintenance of BMPs. All acceptable BMPs are discussed and detailed information about type, frequency, and methods of maintenance are described. http://portal.ncdenr.org/web/lr/bmp-manual The following general guidance is provided as a basis of understanding and procedure. It is important to note that while general maintenance tasks can be outlined, actual maintenance needs will vary according to specific site conditions, particularly the following elements:
    1.1. Landscaping: Certain vegetation may require more attention. Consider using native plants to reduce maintenance needs.
    1.2. Upstream Conditions: Watershed conditions upstream of the facility will affect the amount of sediment and pollutants that must be managed.
    1.3. Safety: Some tasks can be effectively handled by residents; however, a maintenance program should ensure the safety of anyone carrying out tasks. A professional should be hired to do the work when needed.
    1.4. Technical Expertise: BMPs are stormwater treatment and attenuation facilities. While many maintenance needs like litter and debris removal are obvious, some problems may not be detectable to the untrained eye.
    1.5. Financing: A fund should be established by the property owner's association or lot owner to provide for the costs of long-term maintenance needs.
    1.6. Vegetation Management: Vegetative cover serves several purposes in BMPs. It slows the velocity of the runoff, filters sediment from runoff as it is collected in the BMP, and prevents erosion of the banks and bottom of the facility.
2. Grass is generally used around constructed wetlands, retention basins, infiltration trenches and in and around dry detention basins. It must be mowed and maintained. Mowing requirements can be tailored to the specific needs of a site and the neighboring properties. The grass in a BMP may be hardiest if maintained as an upland meadow, cutting no shorter than 6-8 inches. Maintaining a more manicured expanse of grass decreases the effectiveness of the BMP, as well as increasing its maintenance costs. Wetland plants may also be used along the fringe of the BMP in

areas where conditions are favorable. Some of these types of plants may inhabit the area naturally.

3. Debris and Litter Removal: Regular removal of debris and litter is efficient and effective, having several benefits:
   3.1. Reduces the chance of clogging in outlet structures, trash racks and other components.
   3.2. Prevents possible damage to vegetated areas.
   3.3. Reduces potential mosquito breeding habitats.
   3.4. Maintains facility appearance.
   3.5. Reduces conditions for excessive surface algae.
4. Pest Control: Mosquito and other insect breeding grounds can be created by standing water. The most effective control technique in retention basins is to prevent stagnant areas. Prompt removal of floating debris helps. In larger basins, it may also be possible to maintain stocks of fish that feed upon mosquito larvae. The wave action created by surface aerators increases oxygen levels and also discourages mosquito breeding.
5. Animal burrows will also deteriorate the structural integrity of an embankment. Muskrats and nutria, in particular, will burrow tunnels up to six inches in diameter. Existing burrows should be filled as soon as possible.
6. Bank Stabilization: It is very important to prevent erosion of the banks and bottom of detention basins (dry ponds) and the visible banks of retention ponds. The easiest way to do this is to keep groundcover healthy. Areas of bare soil will erode quickly, clogging the basin with soil and threatening its integrity. Any bare areas should be re-seeded and stabilized as quickly as possible.
7. The roots of woody growth, such as young trees and shrubs, can also destabilize embankments. Consistent maintenance can control any stray seedlings that take root in an embankment. Woody growth away from the embankment does not generally pose a threat to the stability of the embankment and can play an important role in the health of the vegetative environment. For ease of maintenance, trees and shrubs should be planted outside maintenance and access areas.
8. Sediment removal, or dredging, may be a required maintenance function. Dredging removes the layer of highly enriched materials from the pond's bottom. Removing

this nutrient “bank” prevents phosphorus from releasing back into the water column and consequently being discharged into receiving waters during the next storm. This also helps lower nutrient concentrations in the pond, thus decreasing nuisance algae blooms. Dredging can help to improve water quality by deepening the BMP, providing additional storage capacity.

9. Sediment will accumulate in a BMP and will eventually need to be removed, but facilities vary so much that there are no hard and fast rules about when and how. For planning purposes, sediment removal should be considered on the following intervals:
   9.1. Extended detention basins (dry ponds): every 2-5 years;
   9.2. Retention basins (wet ponds): every 5 –7 years;
   9.3. Dredging of the BMP will be required when the sediment capacity of the system has been reduced by more than 50%.
10. Sediment removal is usually the largest single cost of BMP maintenance; therefore, the owning entity must plan ahead to allow for contractual negotiations, as well as adequate funding. The owning entity must ensure that the sediment is disposed of legally.
11. Wetland BMPs should be maintained to prevent loss of area of ponded water available for emergent vegetation due to sedimentation and/or accumulation of plant material.
   11.1. Sediment forebays should be cleaned every 2 to 5 years, except for pocket wetlands without forebays which are cleaned after a six-inch accumulation of sediment.
   11.2. Water levels may need to be supplemented or drained periodically until vegetation is fully established.
   11.3. Performance enhancement can be obtained by increasing the size of the marsh area, by incorporating multiple pools into marsh area, or by incorporating a network of shallow channels in the marshy area. Constructed wetland systems designed as part of an existing drainage system must be designed to be low maintenance. Wetlands will be designed with a bottom width and side slopes that will accommodate at least one foot of sedimentation without causing a significant tail water effect to upstream drainage. One foot

of sedimentation within the wetland should not result in more than 0.4 ft increase in the hydraulic grade line for in-bank flows.

11.4. Remove volunteer woody vegetation/trees in excess of 2-inches in diameter to promote the original design and balance sunlight and shaded areas in the wetland.

APPENDICES

APPENDIX A: *Computational Techniques*

Rational Formula

The Rational Formula is a popular method used to calculate peak flow from a drainage area. The peak flow is then used to calculate required size of a ditch or culvert based upon the hydraulic capacity to carry flow from the area. The Rational Formula equation is:

$$Q = (C)(I)(A)$$

where:

Q = Rate of runoff in cubic feet per second (1 cubic feet per second ≅ 1 acre inch per hour)

C = Runoff Coefficient representing ratio of runoff to rainfall

I = Intensity of Rainfall estimated in inches per hour.

A = Drainage area in acres.

The intensity is dependent upon the Time of Concentration.

The formula is not dimensionally correct because it is based upon empirical data, a one inch depth of rainfall while applied at the uniform rate in 1-hour to an area of 1-acre will produce 1.008 cubic feet/second of runoff if there are no losses. This makes the numerical value of "Q" nearly equal to the product of "C", "A" and "I."

1.1. The area of the contributing catchment can be determined from studying topographic maps and insuring that the drainage area map for the point analyzed is correct. In studying these topographic maps it is understood that runoff flows perpendicular to contours.

1.2. The runoff coefficients are well documented. Typical values for runoff coefficients can be found in various references. Typically, an impervious area is treated as having a coefficient of 0.9 and soil is estimated to have a coefficient of 0.2. Table 8.03B, from the State's *Erosion & Sediment Control Planning and Design Manual,* provides representative values for various runoff coefficients.

1.3. Drainage designs shall use a weighted coefficient analysis to estimate the proper runoff coefficient for a development. The weighted runoff coefficient calculation shall be based upon the typical soil type and runoff coefficients listed in Table 8.03B found at Appendix C.

1.4. Time of concentration values, used to determine rainfall intensity, are obtained when the maximum discharge of a drainage area is reached. It is the time required for runoff to travel from the most remote point of the drainage area to arrive at the point of interest or point it will drain or exit the drainage area. The most remote point is the point at which the time of flow to the outlet is greatest, not necessarily the greatest linear distance. Typically, the maximum discharge of any point in the drainage system occurs when:

1.4.1. The entire area contributing to the point of interest is activated and flows to the point;

1.4.2. The rainfall intensity is at a maximum, which can be expected for rainfall durations equal to the time of concentration.

1.5. The time of concentration can be the most scrutinized part of the Rational Formula and can have the greatest impact on calculating peak flow for a drainage area. Proper judgment and documentation is imperative on how the time of concentration is determined.

1.6. The designer shall on the existing and proposed drainage area maps indicate the elevations and flow pattern used to calculate time of concentration for the existing and proposed drainage areas.

1.7. The time of concentration may be estimated using the Kinematic Wave equation. Travel times can also be computed along the travel way using Manning's Equations to estimate flow velocity. The Kinematic Wave equation and its computational method can be found in the State's *Erosion & Sediment Control Planning and Design Manual*.

$$t_c = \frac{0.93 L^{0.6} N^{0.6}}{i^{0.4} S^{0.3}}$$

Tc = Time of Concentration (min)

L = Length of Flow (ft.)

N = Roughness Coefficient (dimensionless)

i = Rainfall rate (in/hr)

S = Slope of Flow Path (ft/ft, not %)

N = Roughness Coefficient

The maximum flow length is 200 feet.

1.8. NRCS's Win TR-55 provides a logical method to determine the time of concentration. The program is available free from the NRCS web site The required input consists of the type of flow encountered along the flow path, the travel surface and the length of travel.

1.9. The rainfall intensity used in the Rational Formula shall be based upon point precipitation, frequency estimate from the NOAA Atlas 14. A table which shows the precipitation intensity estimates for Camden Courthouse, North Carolina is provided at Appendix D.

2 *SCS Methods*

SCS Methods may be used to calculate peak discharges for smaller catchments and shall be used to calculate the dynamic analysis of catchments over 20 acres for a 24-hour storm. A Type III storm shall be used in the 24-hour analysis. The United States Department of Agriculture Urban Hydrology for Small Water Sheds Technical Release-55 (WIM TR55 latest release) is the basis for all computations regarding SCS (Natural Resources Conservation Service, NRSC) Methods. The time of concentration used for SCS flow calculations shall be based upon SCS Methods. A shape factor of 200 may be used to develop the hydrograph.

3. Computer Programs for Analysis

3.1 There are many drainage programs capable of performing a dynamic analysis of watersheds. Camden County will accept the Environmental Protection Agency's Stormwater Management Model (SWMM) and other programs which use this program as its driving engine. Other acceptable analysis tools include PCSWMM and XPSWMM. These programs are capable of developing SCS based hydrographs using Type III storms, varying curve numbers and times of concentration. They are capable of routing developed hydrographs to a designated design point and computing elevations and flows.

3.2 Electronic copies of the approved functioning SWMM models shall be provided to the County.

3.3 The design professionals shall use the following rainfall amounts for a 24-hour dynamic analysis or document that the information used is from NOAA for the exact project location:

24-Hour Dynamic Analysis - Rainfall Amounts						
Storm Frequency	2	5	10	25	50	100
Inches of Rain (24-hour period)	3.73”	4.82”	5.73”	7.08”	8.24”	9.52”

APPENDIX B: *Culvert Hydraulics*

1. Downstream tailwater conditions have significant impact on all culverts within Camden County. Almost every culvert within the County functions under the outlet control hydraulic condition. Only in special conditions will inlet control be a limiting factor. Consequently, all culvert analysis shall be based on an outlet control with an inlet control check.
2. The downstream tailwater condition shall be based upon mathematical calculation of channel, ditch, or downstream culvert hydraulics and through hydraulic gradeline calculations brought to the point of interest.
3. Culvert analysis and design shall be based upon the Federal Highway Administration's (FHWA) hydraulic design of culverts. The publication number is FHWA –NHI-01-020 dated September 2001 and revised May 2005. This manual outlines various hydraulic conditions that dictate culvert characteristics and flow capabilities. Several computer aided design tools exist, which base results on the Federal Highway Administration Guidelines. These programs are acceptable for calculations of culvert hydraulics in Camden County when supplied with documentation, from the program, substantiating that the program is based upon approved methods.
4. Design professionals are also encouraged to use the Corps of Engineers Hydraulic Engineering Center (HEC) series of programs developed to calculate the hydraulic characteristics of any catchment. Notably, HEC-RAS is an excellent tool to calculate hydraulic gradelines for a static maximum flow analysis. The results, as required for static analysis, using this program are acceptable.

APPENDIX C: Typical Runoff Coefficients

For the Rational Formula

Table 8.03b

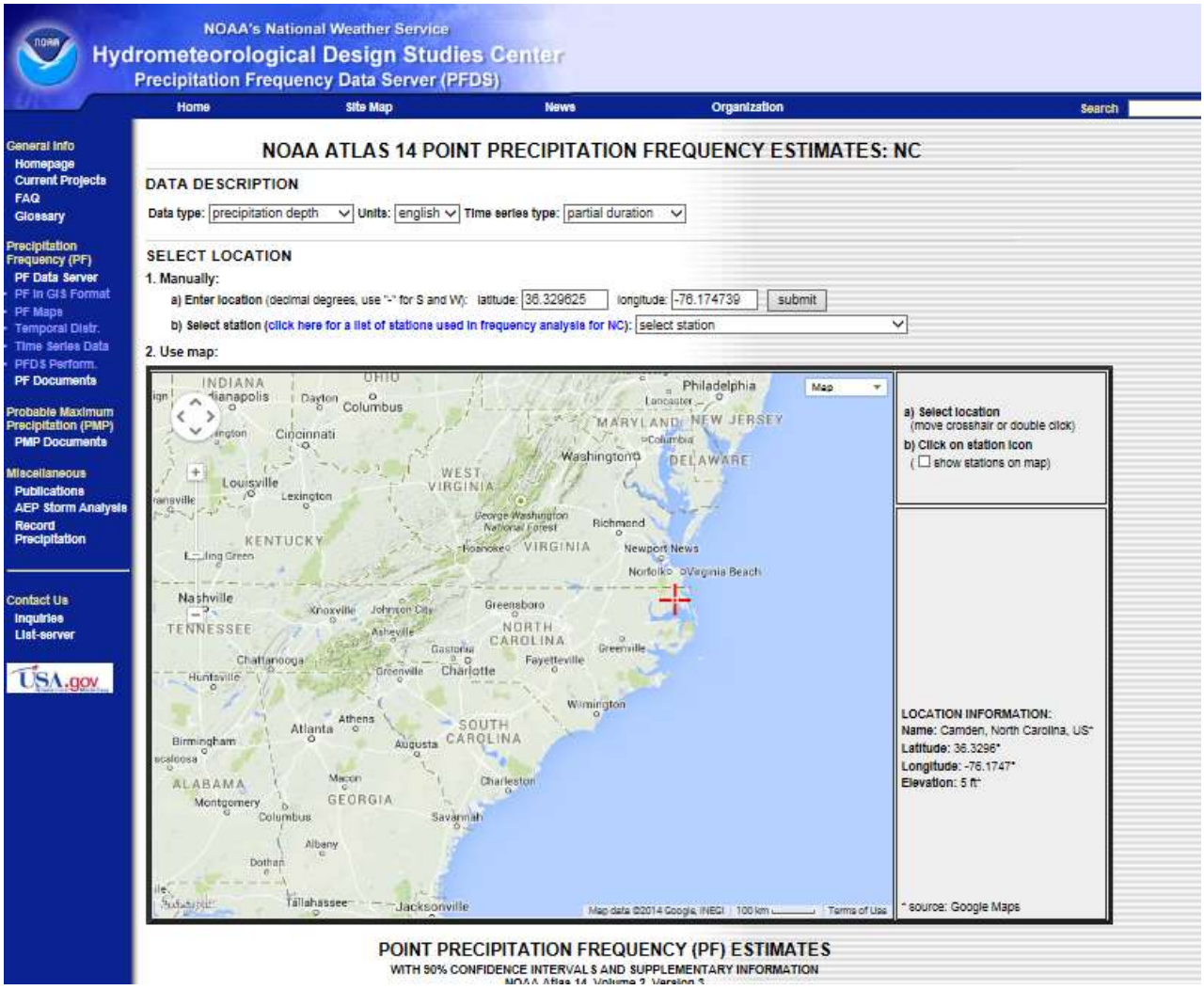
Table 8.03b
Value of Runoff Coefficient (C) for Rational Formula

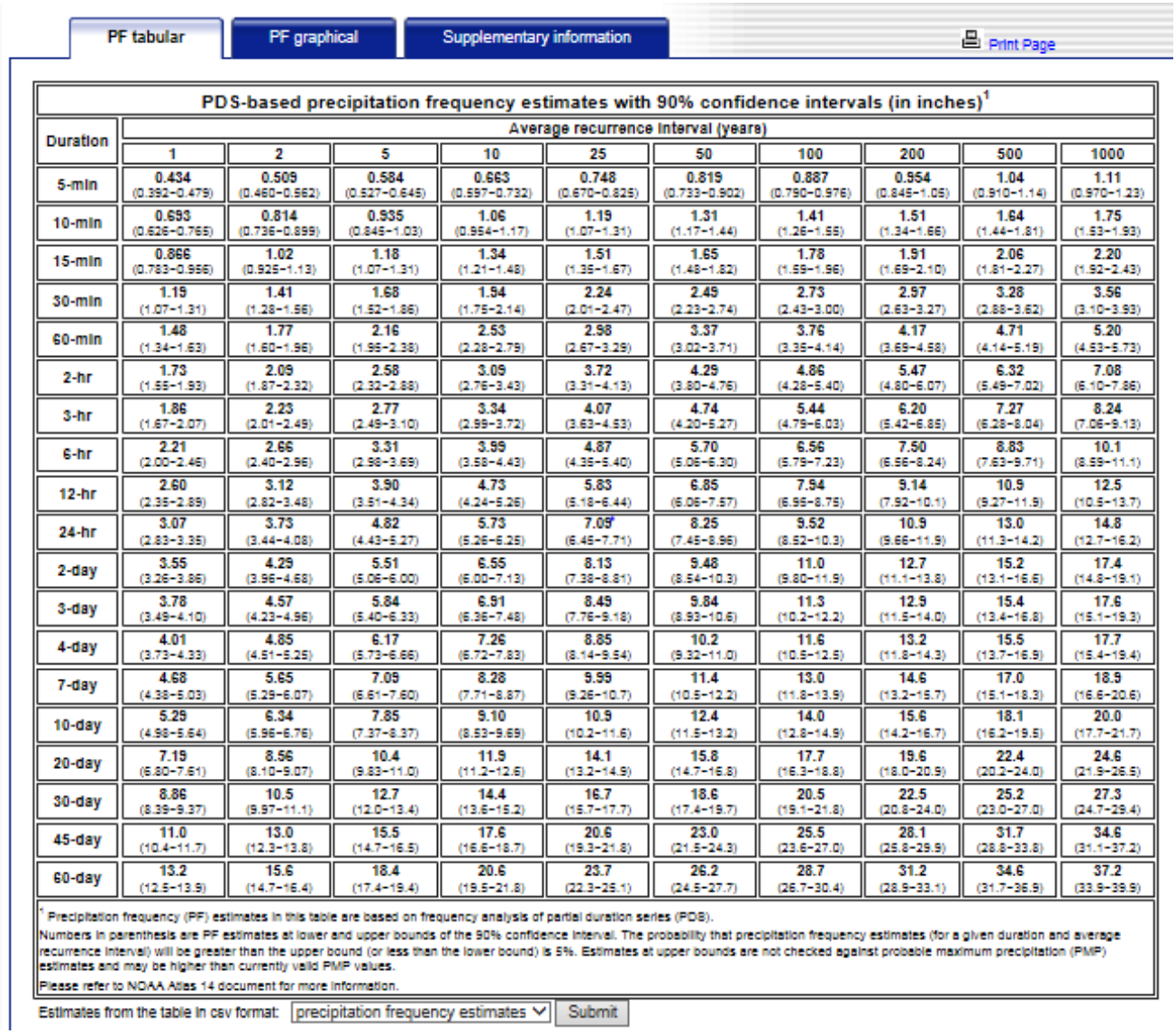
Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, ave., 2-7%	0.10-0.15
Residential:		Sandy soil, steep, 7%	0.15-0.20
Single-family areas	0.30-0.50	Heavy soil, flat, 2%	0.13-0.17
Multi units, detached	0.40-0.60	Heavy soil, ave., 2-7%	0.18-0.22
Multi units, Attached	0.60-0.75	Heavy soil, steep, 7%	0.25-0.35
Suburban	0.25-0.40		0.30-0.60
Industrial:		Agricultural land:	0.20-0.50
Light areas	0.50-0.80	Bare packed soil	
Heavy areas	0.60-0.90	Smooth	0.30-0.60
Parks, cemeteries	0.10-0.25	Rough	0.20-0.50
Playgrounds	0.20-0.35	Cultivated rows	0.20-0.40
Railroad yard areas	0.20-0.40	Heavy soil no crop	0.10-0.25
Unimproved areas	0.10-0.30	Heavy soil with crop	0.15-0.45
Streets:		Sandy soil no crop	0.05-0.25
Asphalt	0.70-0.95	Sandy soil with crop	0.05-0.25
Concrete	0.80-0.95	Pasture	0.10-0.25
Brick	0.70-0.85	Heavy soil	0.15-0.45
Drives and walks	0.75-0.85	Sandy soil	0.05-0.25
Roofs	0.75-0.85	Woodlands	0.05-0.25

NOTE: The designer must use judgement to select the appropriate C value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest C values.

Source: American Society of Civil Engineers

APPENDIX D: *Frequency Estimates from NOAA*
for
Camden County Courthouse





PF tabular | PF graphical | Supplementary information | Print Page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.434 (0.392-0.479)	0.509 (0.460-0.562)	0.584 (0.527-0.645)	0.663 (0.597-0.732)	0.748 (0.670-0.825)	0.819 (0.733-0.902)	0.887 (0.790-0.976)	0.954 (0.845-1.05)	1.04 (0.910-1.14)	1.11 (0.970-1.23)
10-min	0.693 (0.626-0.765)	0.814 (0.736-0.899)	0.935 (0.845-1.03)	1.06 (0.954-1.17)	1.19 (1.07-1.31)	1.31 (1.17-1.44)	1.41 (1.26-1.55)	1.51 (1.34-1.66)	1.64 (1.44-1.81)	1.75 (1.53-1.93)
15-min	0.866 (0.783-0.956)	1.02 (0.925-1.13)	1.18 (1.07-1.31)	1.34 (1.21-1.48)	1.51 (1.35-1.67)	1.65 (1.48-1.82)	1.78 (1.59-1.96)	1.91 (1.69-2.10)	2.06 (1.81-2.27)	2.20 (1.92-2.43)
30-min	1.19 (1.07-1.31)	1.41 (1.28-1.56)	1.68 (1.52-1.86)	1.94 (1.75-2.14)	2.24 (2.01-2.47)	2.49 (2.23-2.74)	2.73 (2.43-3.00)	2.97 (2.63-3.27)	3.28 (2.88-3.62)	3.56 (3.10-3.93)
60-min	1.48 (1.34-1.63)	1.77 (1.60-1.96)	2.16 (1.95-2.38)	2.53 (2.28-2.79)	2.98 (2.67-3.29)	3.37 (3.02-3.71)	3.76 (3.35-4.14)	4.17 (3.69-4.58)	4.71 (4.14-5.19)	5.20 (4.53-5.73)
2-hr	1.73 (1.55-1.93)	2.09 (1.87-2.32)	2.58 (2.32-2.88)	3.09 (2.76-3.43)	3.72 (3.31-4.13)	4.29 (3.80-4.76)	4.86 (4.28-5.40)	5.47 (4.80-6.07)	6.32 (5.49-7.02)	7.08 (6.10-7.86)
3-hr	1.86 (1.67-2.07)	2.23 (2.01-2.45)	2.77 (2.49-3.10)	3.34 (2.99-3.72)	4.07 (3.63-4.53)	4.74 (4.20-5.27)	5.44 (4.79-6.03)	6.20 (5.42-6.85)	7.27 (6.28-8.04)	8.24 (7.06-9.13)
6-hr	2.21 (2.00-2.46)	2.66 (2.40-2.96)	3.31 (2.98-3.69)	3.99 (3.58-4.43)	4.87 (4.35-5.40)	5.70 (5.06-6.30)	6.56 (5.79-7.23)	7.50 (6.56-8.24)	8.83 (7.63-9.71)	10.1 (8.59-11.1)
12-hr	2.60 (2.35-2.89)	3.12 (2.82-3.48)	3.90 (3.51-4.34)	4.73 (4.24-5.26)	5.83 (5.18-6.44)	6.85 (6.06-7.57)	7.94 (6.95-8.75)	9.14 (7.92-10.1)	10.9 (9.27-11.9)	12.5 (10.5-13.7)
24-hr	3.07 (2.83-3.35)	3.73 (3.44-4.08)	4.82 (4.43-5.27)	5.73 (5.26-6.25)	7.09 (6.45-7.71)	8.25 (7.45-8.96)	9.52 (8.52-10.3)	10.9 (9.66-11.9)	13.0 (11.3-14.2)	14.8 (12.7-16.2)
2-day	3.55 (3.26-3.86)	4.29 (3.96-4.68)	5.51 (5.06-6.00)	6.55 (6.00-7.13)	8.13 (7.38-8.81)	9.48 (8.54-10.3)	11.0 (9.80-11.9)	12.7 (11.1-13.8)	15.2 (13.1-16.6)	17.4 (14.8-19.1)
3-day	3.78 (3.49-4.10)	4.57 (4.23-4.96)	5.84 (5.40-6.33)	6.91 (6.36-7.48)	8.49 (7.76-9.18)	9.84 (8.93-10.6)	11.3 (10.2-12.2)	12.9 (11.5-14.0)	15.4 (13.4-16.8)	17.6 (15.1-19.3)
4-day	4.01 (3.73-4.33)	4.85 (4.51-5.25)	6.17 (5.73-6.66)	7.26 (6.72-7.83)	8.85 (8.14-9.54)	10.2 (9.32-11.0)	11.6 (10.5-12.5)	13.2 (11.8-14.3)	15.5 (13.7-16.9)	17.7 (15.4-19.4)
7-day	4.68 (4.38-5.03)	5.65 (5.29-6.07)	7.09 (6.61-7.60)	8.28 (7.71-8.87)	9.99 (9.26-10.7)	11.4 (10.5-12.2)	13.0 (11.8-13.9)	14.6 (13.2-15.7)	17.0 (15.1-18.3)	18.9 (16.6-20.6)
10-day	5.29 (4.98-5.64)	6.34 (5.96-6.76)	7.85 (7.37-8.37)	9.10 (8.53-9.69)	10.9 (10.2-11.6)	12.4 (11.5-13.2)	14.0 (12.8-14.9)	15.6 (14.2-16.7)	18.1 (16.2-19.5)	20.0 (17.7-21.7)
20-day	7.19 (6.80-7.61)	8.56 (8.10-9.07)	10.4 (9.83-11.0)	11.9 (11.2-12.6)	14.1 (13.2-14.9)	15.8 (14.7-16.8)	17.7 (16.3-18.8)	19.6 (18.0-20.9)	22.4 (20.2-24.0)	24.6 (21.9-26.5)
30-day	8.86 (8.39-9.37)	10.5 (9.97-11.1)	12.7 (12.0-13.4)	14.4 (13.6-15.2)	16.7 (15.7-17.7)	18.6 (17.4-19.7)	20.5 (19.1-21.8)	22.5 (20.8-24.0)	25.2 (23.0-27.0)	27.3 (24.7-29.4)
45-day	11.0 (10.4-11.7)	13.0 (12.3-13.8)	15.5 (14.7-16.5)	17.6 (16.6-18.7)	20.6 (19.3-21.8)	23.0 (21.5-24.3)	25.5 (23.6-27.0)	28.1 (25.8-29.9)	31.7 (28.8-33.8)	34.6 (31.1-37.2)
60-day	13.2 (12.5-13.9)	15.6 (14.7-16.4)	18.4 (17.4-19.4)	20.6 (19.5-21.8)	23.7 (22.3-25.1)	26.2 (24.5-27.7)	28.7 (26.7-30.4)	31.2 (28.9-33.1)	34.6 (31.7-36.9)	37.2 (33.9-39.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Estimates from the table in csv format: precipitation frequency estimates | Submit

Steel Formula coefficients for Times of Concentration 5 – 120 minutes

Year	a	b
2	132.32	16.85
10	191.70	19.57

Where:

I = a / (b+Tc)

NOAA Web Site for North Carolina:

http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nc

APPENDIX E: *BMP Inspection Checklist*

Routine self inspection of your BMP is the best way to catch potential problems before they become a liability. The following is a guide to get you started. Answering YES to any of these questions indicates a need for corrective action or consultation with a professional inspector. We encourage you to copy this checklist and maintain a record of your inspections.

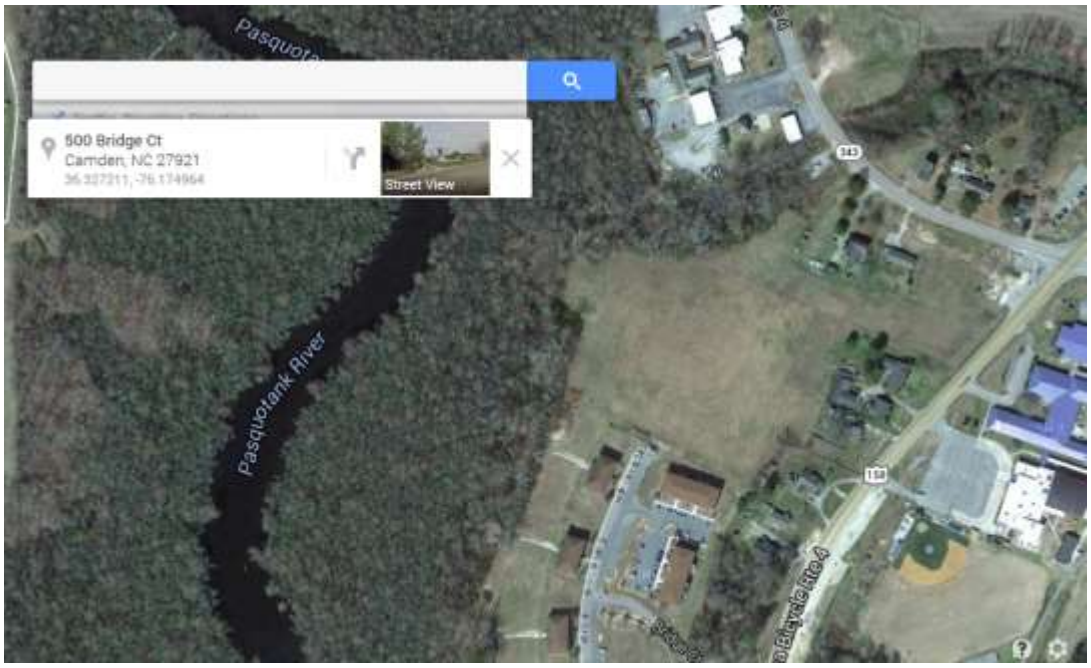
	Yes	No
Does the facility show signs of settling, cracking, bulging, misalignment or other structural deterioration?	❑	❑
Do the embankments, emergency spillways, side slopes or inlet/outlet structures show signs of erosion?	❑	❑
Is the outlet pipe damaged or not functioning properly?	❑	❑
Do the impoundment and inlet areas show erosion, low spots or lack of stabilization?	❑	❑
Is woody vegetation that may interfere with the facility's performance present on the banks?	❑	❑
Is there evidence of animal burrows?	❑	❑
Are contributing areas unstabilized with evidence of erosion?	❑	❑
Do vegetated areas need mowing or is there a build up of clippings that could clog the facility?	❑	❑
Does the depth of sediment pose a threat to storage volume?	❑	❑
Is there standing water in appropriate areas?	❑	❑
Is there standing water in inappropriate areas?	❑	❑

Is there accumulation of trash or debris?	❑	❑
Is there evidence of encroachment or improper use of the impounded areas?	❑	❑
Are there signs of vandalism?	❑	❑
Do any safety devices such as fences, gates or locks need repair?	❑	❑
Is there excessive algae or dominance of one type of vegetation?	❑	❑
Is there evidence of automotive fluids entering or clogging the facility?	❑	❑
Is there evidence of a fish kill?	❑	❑

APPENDIX F: *USDA Web Soil Survey Report*

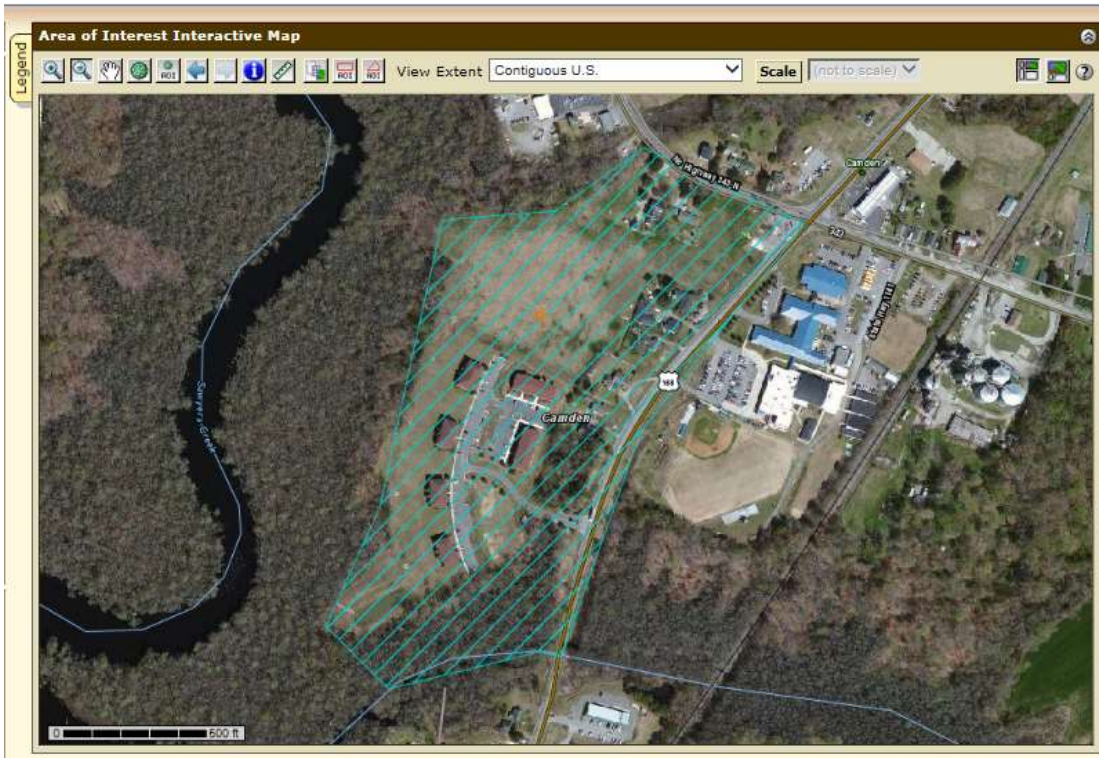
http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Obtain the project's location though Google Maps or other means.

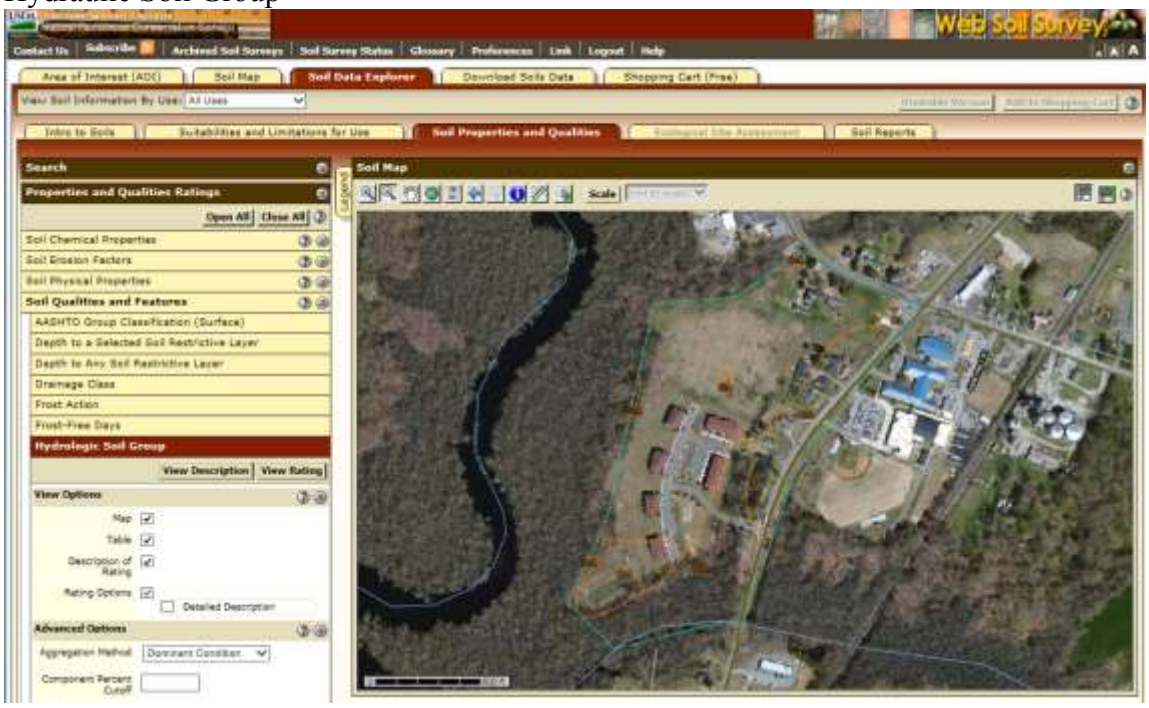


Latitude and Longitude: 36.327211, -76.174964

Area of Interest:



Hydraulic Soil Group



Rating

Warning: Soil Ratings Map may not be valid at this scale.

You have zoomed in beyond the scale at which the soil map for this area is intended to be used. Mapping of soils is done at a particular scale. The soil surveys that comprise your AOI were mapped at 1:24,000. The design of map units and the level of detail shown in the resulting soil map are dependent on that map scale.

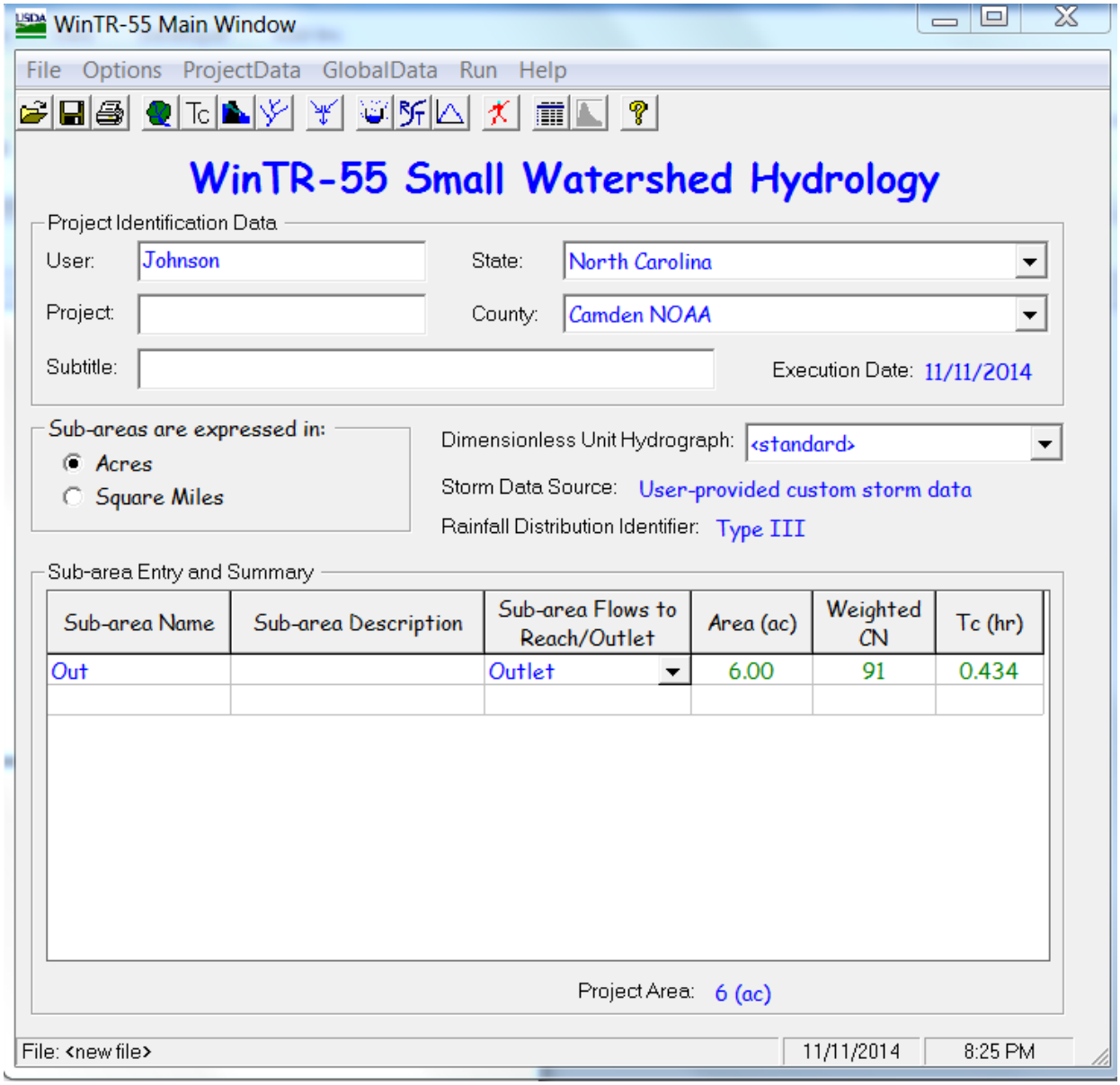
Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

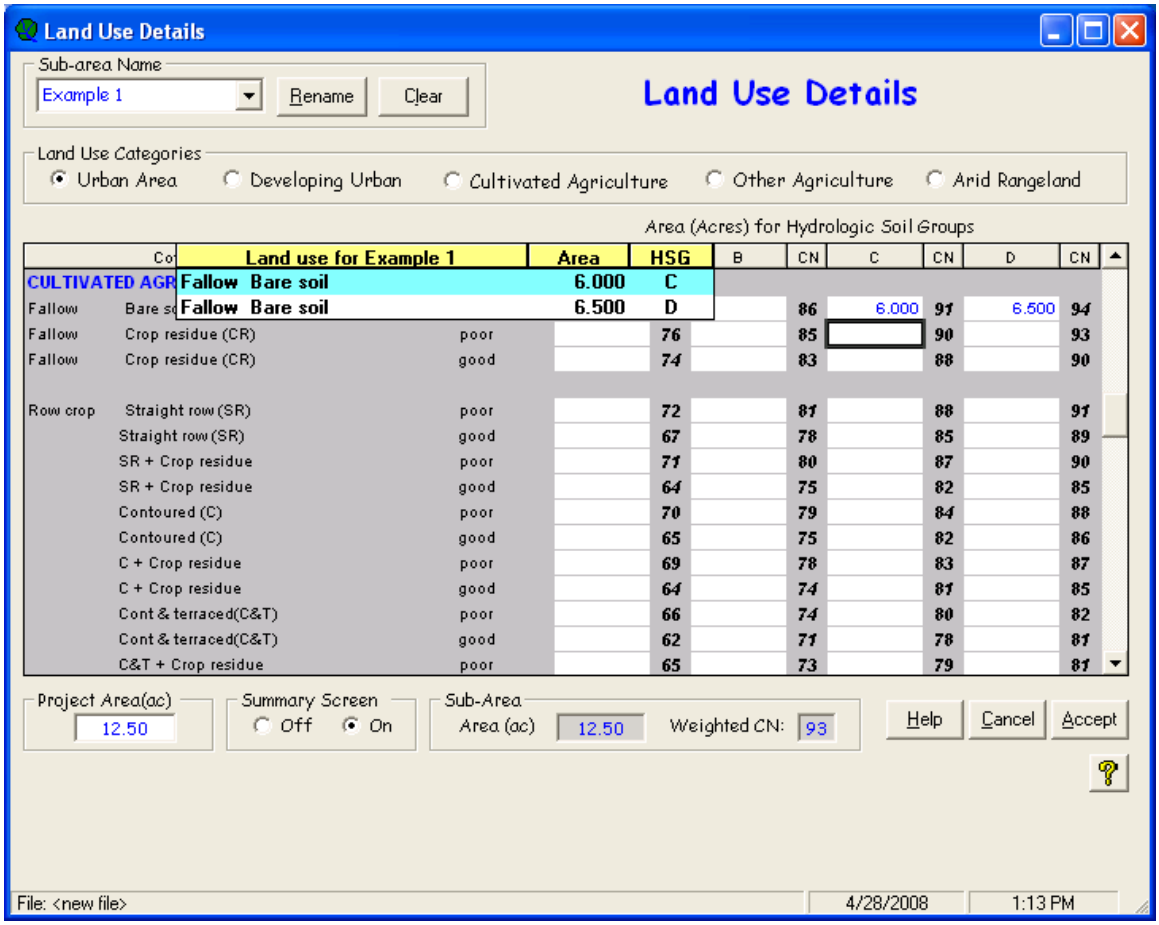
Tables — Hydrologic Soil Group — Summary By Map Unit

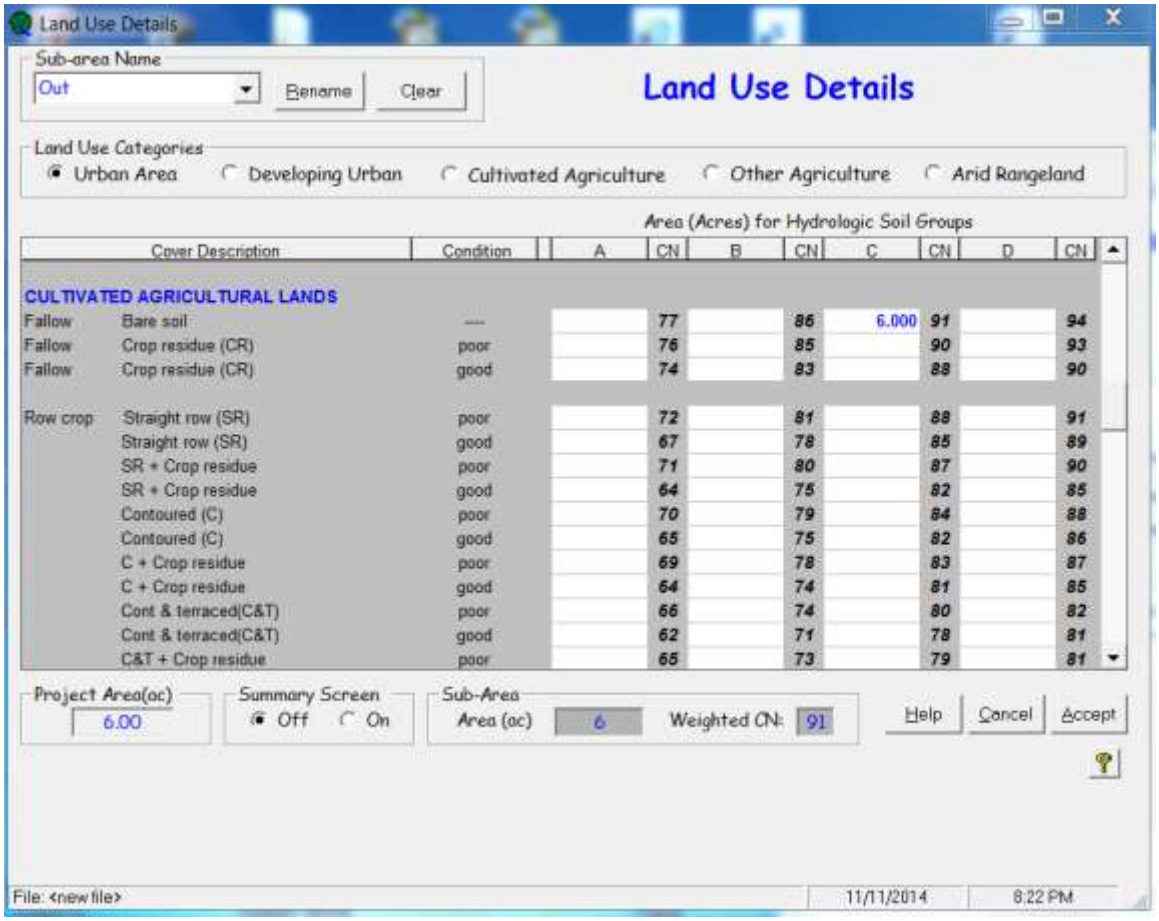
Summary by Map Unit — Camden County, North Carolina (NC029)

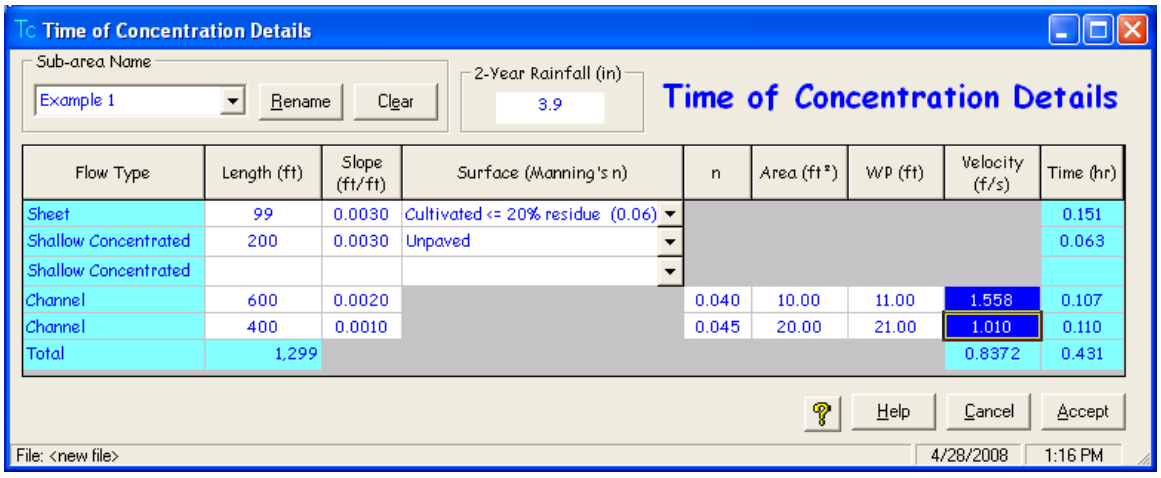
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
AaA	Altavista fine sandy loam, 0 to 2 percent slopes	C	7.7	21.2%
AtA	Augusta fine sandy loam, 0 to 2 percent slopes	B/D	0.5	1.5%
BoA	Bojac loamy sand, 0 to 3 percent slopes	A	0.1	0.3%
DoA	Dorovan muck, 0 to 1 percent slopes, frequently flooded	B/D	7.7	21.2%
StA	State fine sandy loam, 0 to 2 percent slopes	B	20.3	55.7%
Totals for Area of Interest			**36.4**	**100.0%**

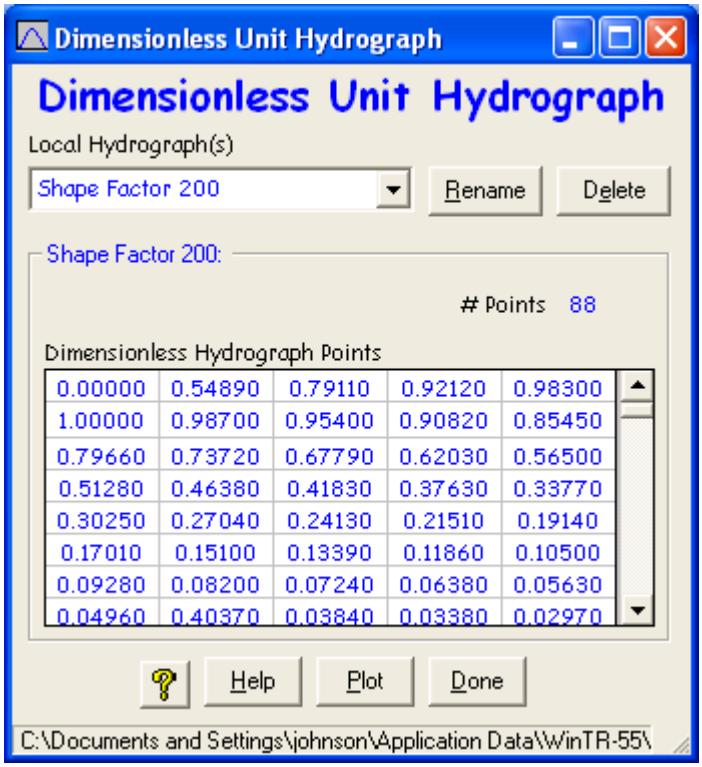
APPENDIX G: *WIN TR-55 Data Screens*




Land Use Details
Sub-area Name
Example 1
Rename
Clear
Land Use Details
Land Use Categories
Urban Area
Developing Urban
Cultivated Agriculture
Other Agriculture
Arid Rangeland
Area (Acres) for Hydrologic Soil Groups
Land use for Example 1
Area
HSG
B
CN
C
CN
D
CN
CULTIVATED AGR
Fallow Bare soil
6.000
C
Fallow Bare soil
6.500
D
Fallow Bare soil 86 6.000 91 6.500 94
Fallow Crop residue (CR) poor 76 85 90 93
Fallow Crop residue (CR) good 74 83 88 90
Row crop Straight row (SR) poor 72 81 88 91
Straight row (SR) good 67 78 85 89
SR + Crop residue poor 71 80 87 90
SR + Crop residue good 64 75 82 85
Contoured (C) poor 70 79 84 88
Contoured (C) good 65 75 82 86
C + Crop residue poor 69 78 83 87
C + Crop residue good 64 74 81 85
Cont & terraced(C&T) poor 66 74 80 82
Cont & terraced(C&T) good 62 71 78 81
C&T + Crop residue poor 65 73 79 81
Project Area(ac)
12.50
Summary Screen
Off
On
Sub-Area
Area (ac)
12.50
Weighted CN:
93
Help
Cancel
Accept
File: <new file>
4/28/2008
1:13 PM


Land Use Details
Sub-area Name
Out
Rename
Clear
Land Use Details
Land Use Categories
Urban Area
Developing Urban
Cultivated Agriculture
Other Agriculture
Arid Rangeland
Area (Acres) for Hydrologic Soil Groups
Cover Description
Condition
A
CN
B
CN
C
CN
D
CN
CULTIVATED AGRICULTURAL LANDS
Fallow Bare soil 77 86 6.000 91 94
Fallow Crop residue (CR) poor 76 85 90 93
Fallow Crop residue (CR) good 74 83 88 90
Row crop Straight row (SR) poor 72 81 88 91
Straight row (SR) good 67 78 85 89
SR + Crop residue poor 71 80 87 90
SR + Crop residue good 64 75 82 85
Contoured (C) poor 70 79 84 88
Contoured (C) good 65 75 82 86
C + Crop residue poor 69 78 83 87
C + Crop residue good 64 74 81 85
Cont & terraced(C&T) poor 66 74 80 82
Cont & terraced(C&T) good 62 71 78 81
C&T + Crop residue poor 65 73 79 81
Project Area(ac)
6.00
Summary Screen
Off
On
Sub-Area
Area (ac)
6
Weighted CN:
91
Help
Cancel
Accept
File: <new file>
11/11/2014
8:22 PM


Tc Time of Concentration Details
Sub-area Name
Example 1
Rename
Clear
2-Year Rainfall (in)
3.9
Time of Concentration Details
Flow Type | Length (ft) | Slope (ft/ft) | Surface (Manning's n) | n | Area (ft²) | WP (ft) | Velocity (f/s) | Time (hr)
Sheet | 99 | 0.0030 | Cultivated <= 20% residue (0.06) | | | | | 0.151
Shallow Concentrated | 200 | 0.0030 | Unpaved | | | | | 0.063
Shallow Concentrated | | | | | | | |
Channel | 600 | 0.0020 | | 0.040 | 10.00 | 11.00 | 1.556 | 0.107
Channel | 400 | 0.0010 | | 0.045 | 20.00 | 21.00 | 1.010 | 0.110
Total | 1,299 | | | | | | 0.8372 | 0.431
Help
Cancel
Accept
File: <new file>
4/28/2008
1:16 PM


Dimensionless Unit Hydrograph
Dimensionless Unit Hydrograph
Local Hydrograph(s)
Shape Factor 200
Rename
Delete
Shape Factor 200:
Points 88
Dimensionless Hydrograph Points
0.00000 0.54890 0.79110 0.92120 0.98300
1.00000 0.98700 0.95400 0.90820 0.85450
0.79660 0.73720 0.67790 0.62030 0.56500
0.51280 0.46380 0.41830 0.37630 0.33770
0.30250 0.27040 0.24130 0.21510 0.19140
0.17010 0.15100 0.13390 0.11860 0.10500
0.09280 0.08200 0.07240 0.06380 0.05630
0.04960 0.40370 0.03840 0.03380 0.02970
Help
Plot
Done
C:\Documents and Settings\johnson\Application Data\WinTR-55\

APPENDIX H: *Suggested Stormwater Drainage Study Outline*

Stormwater Drainage Report Outline

Introduction

A. Description of project
B. Description of adjacent areas
C. Description of existing drainage patterns
D. Description of existing major drainage structures
E. Existing Conditions Drainage Maps with supporting topo

Purpose

F. Description of proposed drainage improvements
G. Narrative of intended function
H. Proposed Conditions Drainage Map

Drainage Evaluation

I. Statement of basic assumptions
    1. Existing soil type, hydrologic soil group, and land use
    2. Storms considered in analysis and inches of rain in the design storm.
    3. Storm parameters, shape factor, antecedent moisture, depression storage, etc.
    4. Curve Number Calculations
    5. Time of Concentration Calculations
    6. Beginning point of analysis and tailwater elevation
    7. Evaluation of outfall adequacy
J. Description of Existing Conditions Analysis model
    1. Node descriptions, location, runoff and hydraulic characteristics
    2. Natural/existing attenuation characteristics
    3. Link type and hydraulic characteristics
    4. Node and Link Map
K. Results of Existing Conditions
L. Description of Proposed Conditions Analysis model
    1. Contrast and describe modifications to existing conditions model
    2. Node descriptions, location, runoff and hydraulic characteristics
    3. Link type and hydraulic characteristics
    4. Node and Link Map
M. Results of Proposed Conditions Model
    1. Analysis of Results
    2. Existing and proposed conditions comparison
    3. Recommended Improvements
    4. Statement of Final Evaluation by Design Professional
N. Appendix
    1. Hydraulic Grade Line Calculations of minor systems
    2. Entrance/Driveway Culvert Calculations

APPENDIX I:

Comparison of SCS and SWMM Green Ampt Runoff

SCS to SWMM Runoff

SCS	1 acre	SF = 200	10 year	5.6 inches	SF 200	Type III
	CN	75	80	85	90	
	Tc 10	1.97	2.31	2.64	2.94	
	Tc 20	1.44	1.69	1.92	2.15	
	Tc 30	1.314	1.34	1.54	1.72	
	Tc 40	0.94	1.11	1.28	1.43	

Runoff CN 75 — 1 acre — CN infiltration 10 year 5.6 inches slope 0.005

Width	% Impervious	25	30
600		1.99	2.14
500		1.90	2.06
400		1.79	1.95
350		1.73	1.89
300		1.66	1.83
250		1.58	1.75
100		1.24	1.4
50		1.00	1.13
25		0.78	0.86

Runoff CN 80 — 1 acre — CN infiltration 10 year 5.6 inches slope 0.005

Width	% Impervious	25	30
700		2.25	2.39
600		2.17	2.31
500		2.06	2.21
400		1.94	2.10
350		1.87	2.03
300		1.79	1.96
250		1.70	1.87
100		1.31	1.47
50		1.05	1.17
25		0.80	0.89

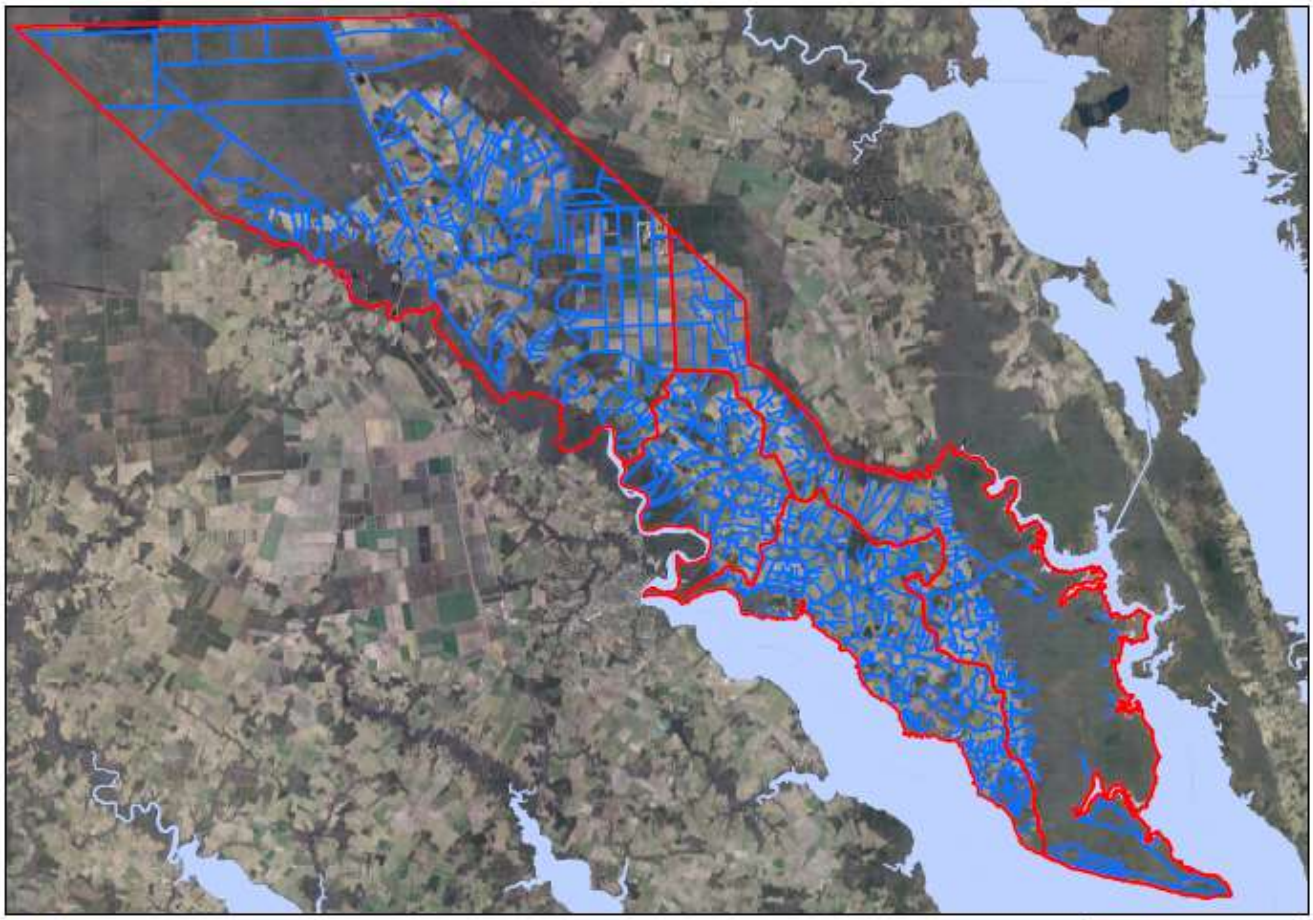
Runoff 1 acre CN infiltration 10 year 5.6 inches slope 0.005
CN 85

Width	% Impervious	25	30	35
700		2.45	2.57	2.69
600		2.35	2.48	2.61
500		2.24	2.38	2.52
400		2.10	2.26	2.40
350		2.03	2.18	2.34
300		1.94	2.10	2.26
250		1.84	2.00	2.16
100		1.39	1.55	1.69
50		1.10	1.22	1.33
25		0.83	0.91	0.99

Runoff 1 acre CN infiltration 10 year 5.6 inches slope 0.005
CN 90

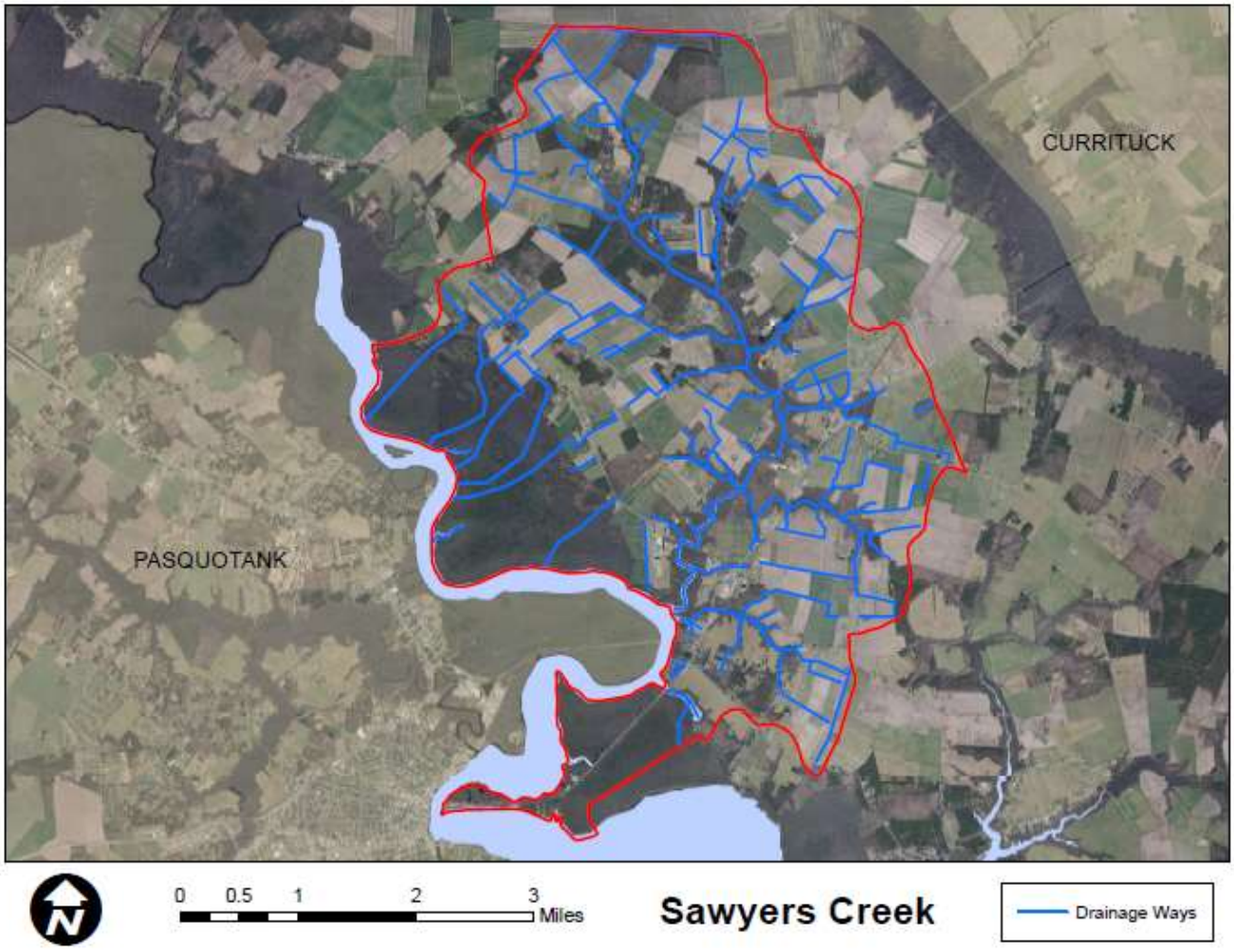
Width	% Impervious	40	50
700		2.96	3.17
600		2.89	3.11
500		2.80	3.04
400		2.69	2.92
350		2.62	2.89
300		2.54	2.82
250		2.45	2.73
100		1.92	2.17
50		1.49	1.68
25		1.06	1.21

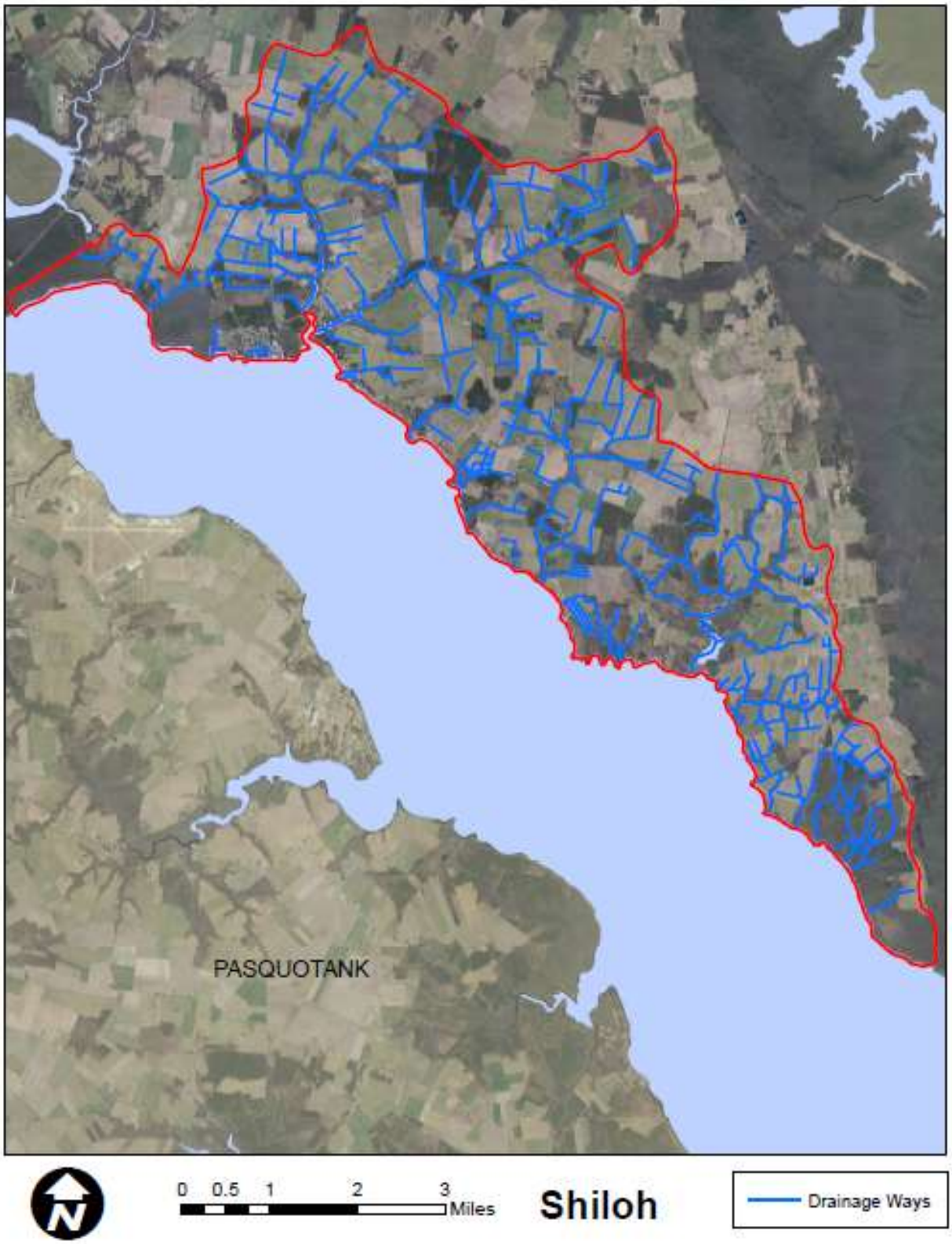
APPENDIX J: *County Maps*

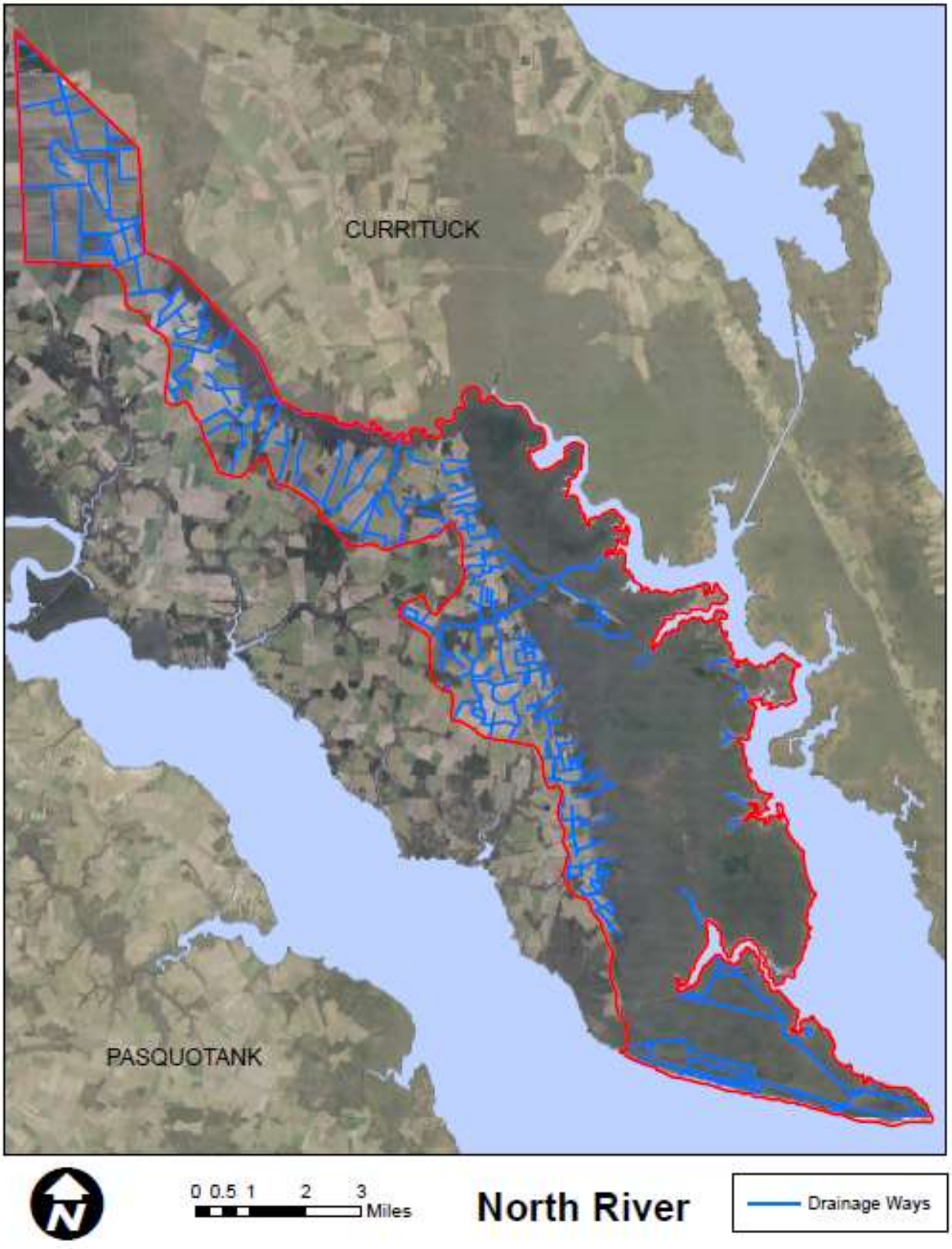


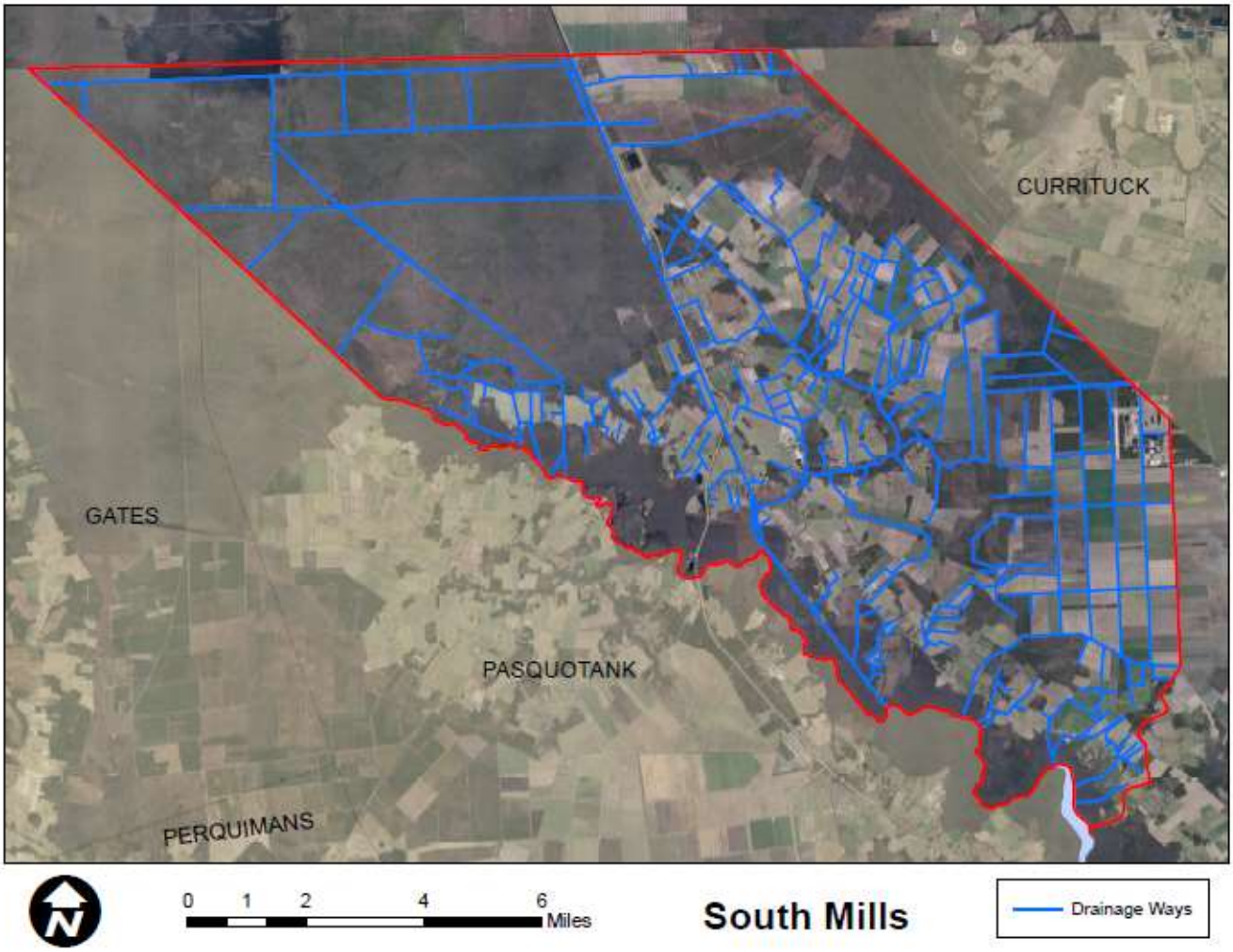
Camden County Watersheds and Drainage Ways

Watersheds
Drainage Ways


CURRITUCK
PASQUOTANK
0 0.5 1 2 3
Miles
Sawyers Creek
Drainage Ways


PASQUOTANK
0 0.5 1 2 3
Miles
Shiloh
Drainage Ways


CURRITUCK
PASQUOTANK
0 0.5 1 2 3
Miles
North River
Drainage Ways


CURRITUCK
GATES
PASQUOTANK
PERQUIMANS
0 1 2 4 6
Miles
South Mills
Drainage Ways

APPENDIX K: *References*

Ref. No.	Reference	WEB Address
1	Camden County Unified Development Ordinance	http://www.amlegal.com/nxt/gateway.dll/North%20Carolina/camdencounty_nc/camdencountynorthcarolinacodeofordinance?f=templates$fn=default.htm$3.0$vid=amlegal:camdenco_nc
2	Pasquotank County Drainage Manual	http://www.co.pasquotank.nc.us/Departments/planning/Drainage%20Manual%20FINAL%20FEB%2016%202009.pdf
3	Currituck County Stormwater Manual	http://co.currituck.nc.us/pdf/unified-development-ordinance/currituck-county-stormwater-manual-red-13sep01.pdf
4	NCDENR Division of Energy, Minerals, and Land Resources – Stormwater Permitting Program	http://portal.ncdenr.org/web/lr/stormwater
5	North Carolina Department of Environmental and Natural Resources (NCDENR) Division of Energy, Mineral and Land Resources Stormwater Best Management Practices Manual	http://portal.ncdenr.org/web/lr/bmp-manual
4	Erosion and Sediment Control Planning and Design Manual	http://portal.ncdenr.org/web/lr/erosion
5	NCDOT Guidelines for Drainage Studies and Hydraulic Design 2012	https://connect.ncdot.gov/resources/hydro/Pages/Guidelines-Drainage-Studies.aspx
6	NOAA ATLAS 14 POINT PRECIPITATION FREQUENCY ESTIMATES: NC	http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nc
7	WEB Soil Survey	http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
8	Win TR -55	http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1042901
9	EPA SWMM	http://www2.epa.gov/water-research/storm-water-management-model-swmm?

10	Curve Fitting by John C. Pezzullo for Storm Intensities	http://statpages.org/nonlin.html
11	FIRM Study (enter North Carolina, Camden and Camden – Search)	https://msc.fema.gov/portal/advanceSearch
12	County Drainage Maps	http://maps2.roktech.net/CamdenCountyNC_GoMaps/index.html#