STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

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September 23, 2013

Mr. Mike Randall
Stormwater Permitting Unit
NC Division of Energy, Mineral and Land Resources
1617 Mail Service Center
Raleigh, NC 27699-1617

Subject: Report of Findings for the Southeast White Oak River Bacteria TMDL in compliance with NPDES permit NCS000250 Part III Section C.7

Dear Mr. Randall:

Please find attached NCDOT's Report of Findings in response to the TMDL for Fecal Coliform for Embayments in Southeast White Oak River and in fulfillment of the requirements in Part III Section C.7 of our NPDES permit (NCS000250). This report describes the results of our Assessment and Monitoring Plan implementation activities, including field evaluations and stormwater control measure retrofit feasibility studies.

If you have questions, or need additional information, please feel free to contact me at 919-707-6737.

Sincerely,

Andrew McDaniel, PE
NCDOT Highway Stormwater Program Manager

cc: Art McMillan, NCDOT
Ken Pace, NCDOT

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Report of Findings
Southeast White Oak River TMDL

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List of Acronyms

AMP	Assessment and Monitoring Plan
BMP	Best Management Practice
CBRA	Coastal Barrier Resources Act
CN	Curve Number
CWA	Clean Water Act
GIS	Geographic Information Systems
I&M	Inspection and Maintenance
LA	Load Allocation
LSPC	Loading Simulation Program in C++
LULC	Land Use and Land Cover
MOS	Margin of Safety
MPN	Most Probable Number
NC	North Carolina
NCDENR	North Carolina Department of Environment and Natural Resources
NCDOT	North Carolina Department of Transportation
NCDWQ	North Carolina Division of Water Quality
NCDWR	North Carolina Division of Water Resources
NCNHP	North Carolina Natural Heritage Program
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PDE	Permanent Drainage Easement
RoF	Report of Findings
ROW	Right-of-Way
SCM	Stormwater Control Measure
SCMS	Stormwater Control Management System
Tc	Time of Concentration
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Wasteload Allocation

Executive Summary

In 2009, the North Carolina Department of Environment and Natural Resources (NCDENR), Division of Water Quality (NCDWQ) prepared TMDLs to address fecal coliform bacteria impairment in three waterbodies located within the White Oak River Basin: Boathouse Creek, Dubling Creek, and a portion of the estuary known as Hills Bay embayment (NCDENR, 2009a). Two of these TMDLs identified the North Carolina Department of Transportation (NCDOT) as a contributor to impairment and assigned NCDOT a unique wasteload allocation. As required by NCDOT's National Pollutant Discharge Elimination System (NPDES) permit, NCDOT prepared and submitted to NCDWQ an Assessment and Monitoring Plan (AMP) which described NCDOT's strategy for field assessing assets and identifying load reduction opportunities in the Boathouse Creek and Hills Bay watersheds (NCDOT, 2011). This report, referred to as the Report of Findings (RoF), describes the results of NCDOT's AMP implementation activities, including field exercises and stormwater control measure (SCM, also referred to as best management practices or BMPs) retrofit feasibility studies. Furthermore, this report fulfills NCDOT's NPDES requirement to prepare a RoF within six months of completing AMP activities.

Between 2011-2013, NCDOT completed a range of watershed assessment activities to identify potential sources of bacteria in the NCDOT right-of-way (ROW) and evaluate potential SCM retrofit opportunities. This work included a field inventory of NCDOT's stormwater conveyance system, bacteria source assessment, illicit discharge evaluation, and SCM feasibility study at four locations within the Hills Bay and Boathouse Creek watersheds. The feasibility study resulted in a determination that one of the four study sites was viable as a retrofit location at this time. This location (See Figure 7), referred to as "Site #2" in this report, is located in the Boathouse Creek watershed and includes a drainage area of 23.1 acres that is comprised of both NCDOT and non-NCDOT land use and land cover (LULC) types. The Site #2 project includes a proposed infiltration basin located within an NCDOT permanent drainage easement along NC-24 (Cedar Point Boulevard) in Cedar Point, NC. Existing loads entering the Site #2 infiltration basin and associated bacteria load reductions were calculated using the United States Environmental Protection Agency's (USEPA's) National Stormwater Calculator and HydroCAD® stormwater modeling software. Results of this analysis are presented in Table E1.

Table E1. NCDOT's existing load, WLA, and anticipated load reductions achieved after implementing the Site #2 infiltration basin SCM in the Boathouse Creek watershed.

	Fecal Coliforms - Boathouse Creek Watershed
NCDOT existing load from TMDL (counts/day)	3.54E+10
NCDOT WLA from TMDL (counts/day)	9.91E+09
Site #2 drainage area existing load (counts/day)	3.54E+10
Site #2 infiltration basin volume reduction (%)	82.2%
Bacteria load reduction from Site #2 infiltration basin (counts/day)	2.91E+10
NCDOT adjusted existing load with Site #2 infiltration basin (counts/day)	6.30E+09

1 Introduction

North Carolina's 2002 303(d) Impaired Waters List identified portions of the White Oak watershed (Carteret County, NC) as impaired due to violations of the fecal coliform bacteria water quality standards (NCDENR, 2003). In April 2009, the United States Environmental Protection Agency (USEPA) approved TMDLs for three waterbodies in this watershed; Boathouse Creek, Dubling Creek, and a portion of the White Oak River known as Hills Bay under a report titled "Total Maximum Daily Loads of Fecal Coliform for Embayments in Southeast White Oak River" (NCDENR, 2009a). The TMDL identified NCDOT as a significant contributor to impairment in Boathouse Creek and Hills Bay embayment and assigned NCDOT wasteload allocations (WLAs) for these waterbodies.

Part III, Section C of the NCDOT's National Pollutant Discharge Elimination System (NPDES) permit requires the Department to implement a program in the drainage areas of those TMDLs which name the NCDOT as a significant contributor of the pollutant of concern and assigns the NCDOT a WLA explicit from other point sources. Under this requirement, NCDOT is responsible for developing an Assessment and Monitoring Plan (AMP) that describes a strategy for evaluating pollutant contributions from NCDOT areas in the impaired watershed. After implementing the AMP, NCDOT must submit a Report of Findings (RoF) that describes the activities needed, such as structural and nonstructural BMPs, to bring NCDOT into compliance with the WLA and a schedule for implementing those BMPs. The process and timeline for these requirements is illustrated in Figure 1.

In September 2011, NCDOT submitted an AMP to NCDWQ outlining NCDOT's plan for addressing impairment in Boathouse Creek and Hills Bay embayment (NCDOT, 2011). The AMP included a proposed stormwater infrastructure inventory, field survey and geotechnical analysis at three priority areas and watershed-wide assessments of illicit discharges in the NCDOT right-of-way (ROW), sources of fecal coliform bacteria draining to the NCDOT ROW, and existing NCDOT structural BMPs.

This document describes the findings of those activities undertaken by NCDOT to evaluate it's pollutant contribution within the Boathouse Creek and Hills Bay watersheds (Section 3.0). This document also evaluates stormwater controls creditable towards the Department's wasteload allocation (Section 4.0) and provides a schedule for implementing those controls (Section 5.0). This document builds on the conclusions and recommendations of the TMDL and defines a cost-effective plan that reduces pollutant contributions from NCDOT areas in the watershed in accordance with NCDOT's assigned WLAs.

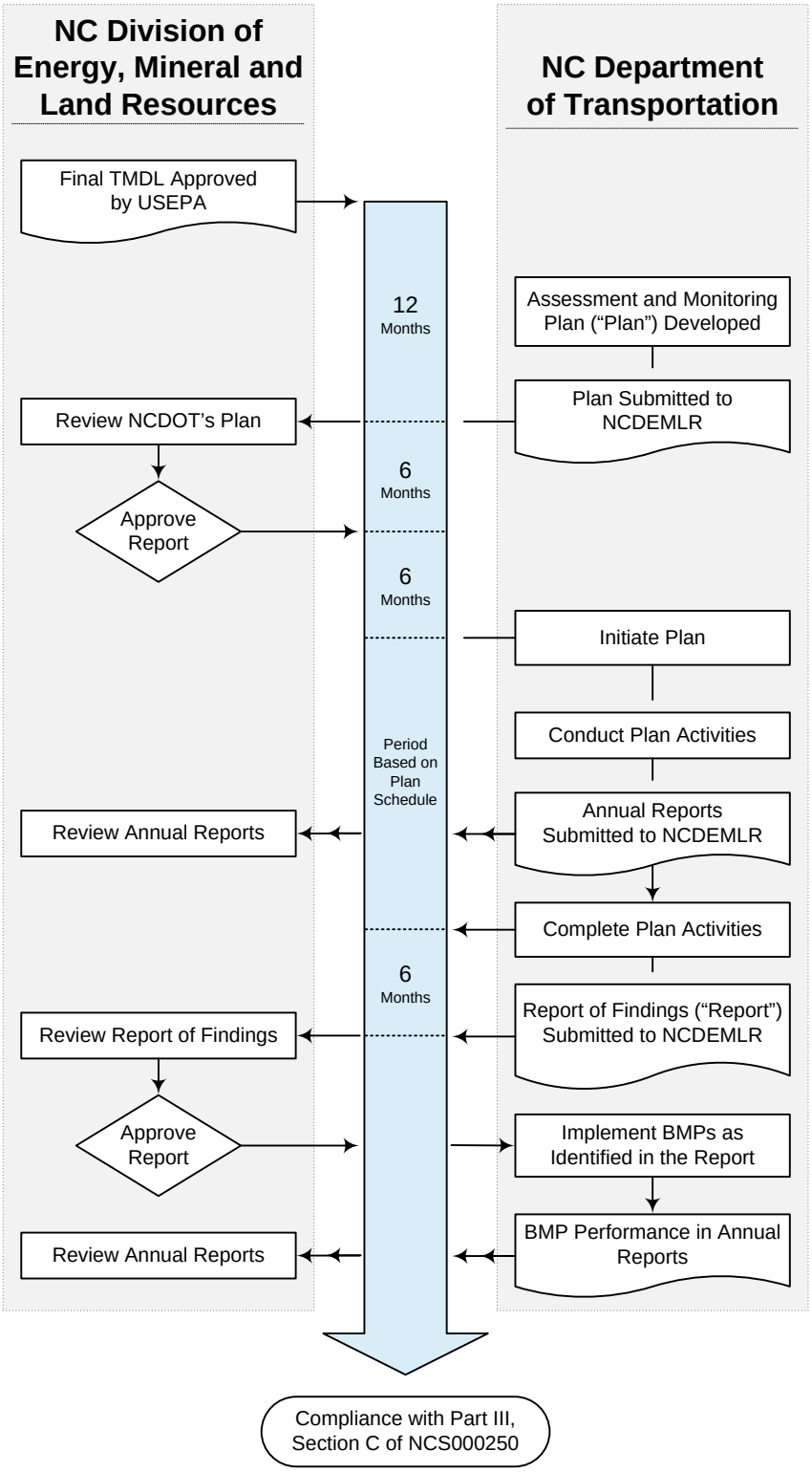

Figure 1. Timeline for TMDL-related requirements (Part III, Section C of NCDOT's NPDES permit).

2 Southeast White Oak River Bacteria TMDL

The Southeast White Oak River TMDL was developed for three impaired waterbodies: Boathouse Creek, 20-31; Dubling Creek, 20-30; and a portion of the White Oak River known as Hills Bay embayment, 20-(18)c4 (Figure 2). These impaired waterbodies were placed on the 2002 North Carolina 303(d) Imparied Waters List due to shellfish harvesting restrictions imposed by the Division of Marine Fisheries.

Fecal coliform bacteria loading from these impaired watersheds and the bacteria concentration within the waterbodies were determined using a linked Loading Simulation Program in C++ (LSPC) watershed model and Tidal Prism Model. The TMDL and subsequent allocations were based on the 90th percentile of the existing load conditions (Table 1). Because NCDOT was the only NPDES permitted entity in the watershed, the entire WLA was allocated to the Department.

Table 1. TMDL allocation summary – bacterial counts per day (NCDENR, 2009a).

Waterbody	Existing	WLA	LA	MOS[1]	Required Reduction[2]	TMDL
Boathouse Creek (20-31)	6.17×10^{11}	9.91×10^{9}	1.75×10^{11}	2.41×10^{10}	66%	2.09×10^{11}
Dubling Creek (20-30)	1.77×10^{11}	0.00	1.53×10^{11}	5.00×10^{9}	11%	1.58×10^{11}
White Oak River[3] 20-(18)c4	2.88×10^{10}	6.60×10^{8}	1.24×10^{10}	1.44×10^{9}	50%	1.45×10^{10}

[1] According to the TMDL report the margin of safety is equivalent to 11.6% of the target concentration in all embayments and based on an MPN target of 38 instead of 43. The MOS load in the table represents the difference between the total loading using that target.

[2] According to the TMDL report the reduction required includes the margin of safety; however, the actual reduction required should not count the margin of safety, and the overall reductions required would be 70%, 14%, and 55%, respectively.

[3] Referred to as the "Hills Bay embayment" in the TMDL and this report.

The TMDL document represented NCDOT as having an area of 27.9 acres within the Boathouse Creek watershed, 0.1 acres within the Dubling Creek watershed, and 7.6 acres within the Hills Bay watershed, corresponding to 5.1%, 0.04%, and 5.0% of each respective watershed. The TMDL further identified NCDOT as a significant contributor of fecal coliform bacteria to the Boathouse Creek and Hills Bay watersheds.

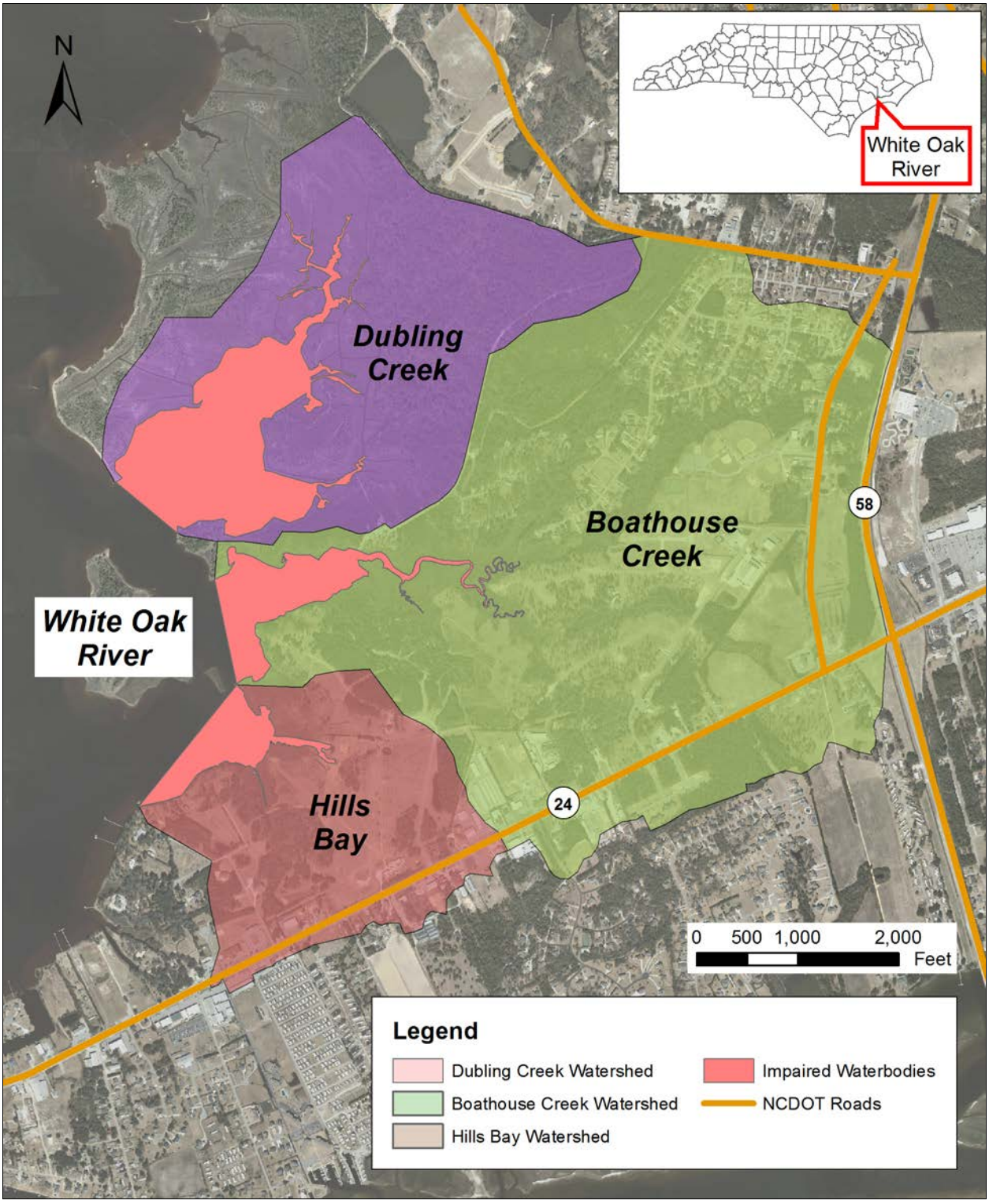

Figure 2. Map of the Southeast White Oak River TMDL watersheds.

3 Watershed and Priority Area Investigations

Between 2011-2013, NCDOT completed a number of field and technical evaluations in the Southeast White Oak River watershed, including activities defined in the AMP (NCDOT, 2011) and additional investigations that were identified during the course of implementing the AMP. These activities are summarized in the following list and subsections.

1) Summarized the locations of implicit stormwater outfalls that have the potential of discharging fecal coliform bacteria to Boathouse Creek and Hills Bay (Section 3.1)

2) Inspected NCDOT ROW to identify potential illicit discharges into the NCDOT conveyance system and performed a fecal coliform source assessment within the NCDOT ROW and on lands draining into the NCDOT conveyance system (Section 3.2)

3) Performed an inventory of existing NCDOT structural BMPs within the TMDL area (Section 3.3)

4) Evaluated drainage area and land use and land cover (LULC) assignments (Section 3.4)

5) Performed detailed studies at four priority areas to assess the viability of implementing load reduction measures at these locations. The findings from these studies are summarized in Section 3.5 and Appendix A (Call Sign Engineers, 2012).

6) Collaborated with NCDOT Division staff through field exercises, training and oral presentations.

3.1 Implicit Stormwater Outfalls

Per Part III Section C.3 of the Department's NPDES permit:

> *"NCDOT's Program shall summarize the locations of NCDOT outfalls that are identified in its implicit Stormwater Outfall Inventory that have the potential to discharge the TMDL pollutant of concern into the impaired segments, to their tributaries, and to segments and tributaries within the watershed contributing to the impaired segments."*

An implicit stormwater outfall is defined as the intersection of a NCDOT-maintained road segment with a stream reach/waterbody as identified through a GIS based desktop analysis. For this analysis, the best available stream line data (1:24,000-scale hydrography) and NCDOT road centerline dataset were intersected using ArcGIS® 10.1. NCDOT conducted this analysis and did not identify any implicit stormwater outfalls within the Boathouse Creek or Hills Bay watersheds; however, the detailed studies described in Section 3.5 did reveal the presence of one NCDOT outfall at Site #3.

3.2 Illicit Discharges and Source Assessment

NCDOT conducted a field investigation to identify illicit discharges to the NCDOT stormwater drainage system. This investigation involved inspection of NCDOT ROW and drainage system network during wet

and dry conditions. Additionally, NCDOT conducted a fecal coliform source assessment within the ROW and on lands draining into the NCDOT stormwater drainage system, where appropriate. These investigations resulted in the finding of no illicit discharges and no additional sources of fecal coliform bacteria from land owners adjacent to NCDOT which were not already identified in the TMDL report.

3.3 Existing Stormwater Controls

NCDOT conducted a review of existing stormwater controls within the TMDL area. NC-58, Old NC-58 (SR 1113), and VFW Road (SR 1114) manage and convey stormwater runoff via vegetated swales having mild longitudinal slopes. Portions of VFW Road do not have a defined conveyance system and runoff flows into adjacent properties in a low velocity, diffuse manner. A series of infiltration basins are located on the NC-24 causeway near the White Oak River, but these basins were determined to be outside of the TMDL watershed area. The majority of NC-24 is curb and gutter. Additional information about the stormwater conveyance system along NC-25 is provided in Section 3.5.

3.4 Drainage Area and Land Use/Land Cover Assessment

The TMDL reports land use/land cover areas (LULC) within the three watersheds and associated acreages for each LULC. During field activities and desktop mapping reviews of the Boathouse Creek and Hills Bay watersheds, NCDOT identified and made improvements to the watershed boundaries. These adjustments are illustrated in Figure 3.

NCDOT maintains roads within the Hills Bay and Boathouse Creek watersheds and as such, steps were taken to evaluate the LULCs associated with those areas that were added or removed in these two watersheds. The areas affected by these changes were assigned LULCs according to the information provided in Table B-1, Appendix B, of the TMDL Document (NCDENR, 2009a). The most notable adjustment to the Boathouse Creek watershed boundary was the removal of approximately 12 acres of residential and NCDOT road area from the northeastern limits of the watershed because this area was found to drain away from the Boathouse Creek watershed. The most notable finding in the Hills Bay watershed was that approximately 12.3 acres of previously-excluded urban areas, located south of NC Highway 24, were estimated to be within the Hills Bay watershed. Table 2 and Table 3 summarize the changes in areas by LULC in Hills Bay and Boathouse Creek watersheds, respectively. Figure 3 and Figure 4 illustrate the watershed boundary adjustments and associated LULC, respectively.

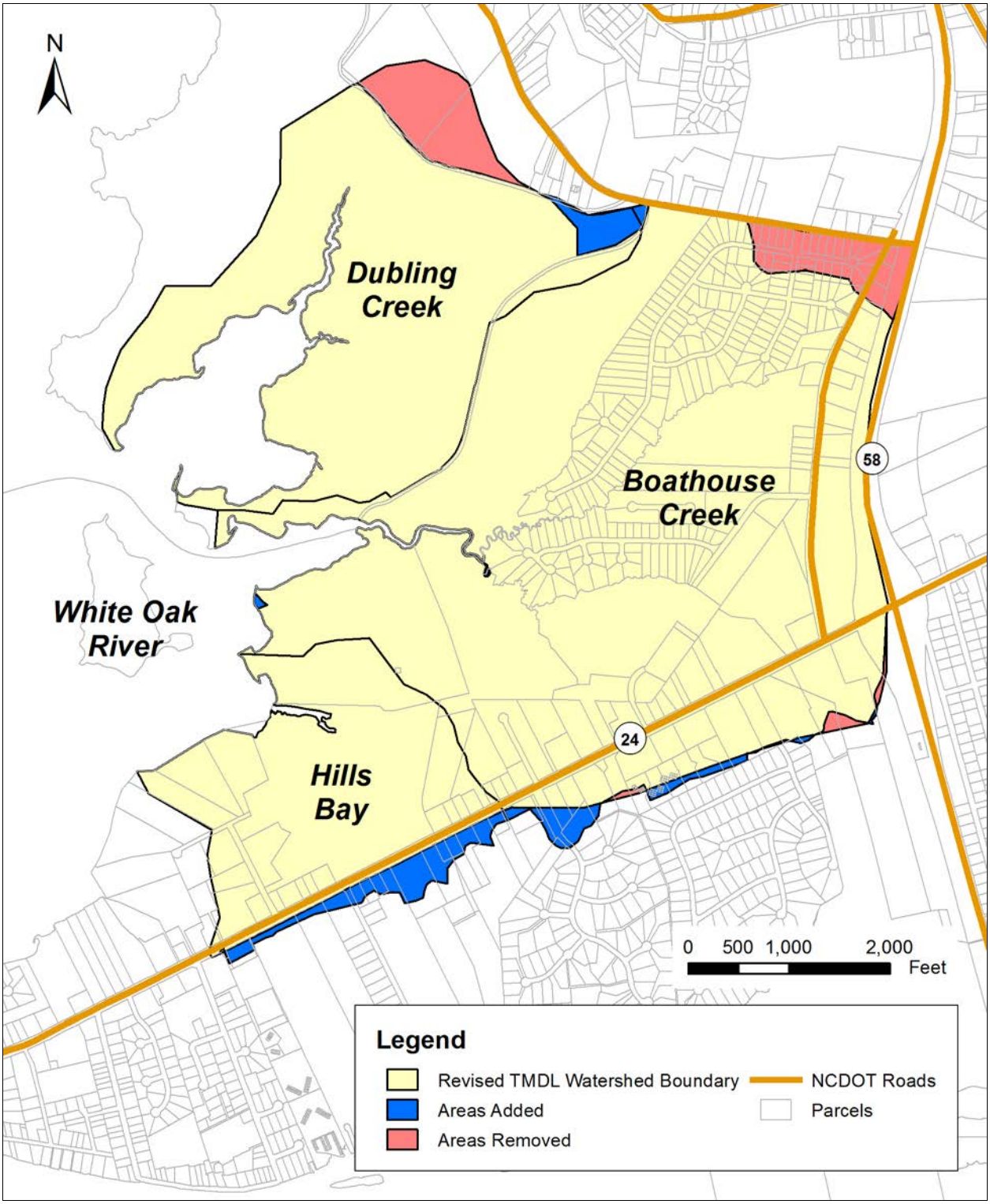

Figure 3. Map illustrating watershed boundary changes.

Table 2. LULC drainage areas as defined in the TMDL and revised based on field assessments in the Hills Bay watershed.

LULC category	Area defined in the TMDL report (acres)	Area adjustment per new watershed boundary (acres)	Adjusted area (acres)
Wetland	11.54	0.00	11.54
Pasture	67.82	0.00	67.82
Forest	37.76	0.00	37.76
Urban	26.55	12.34	38.89
NCDOT	7.55	-0.03	7.52
Total	**151.22**	**12.31**	**163.53**

Table 3. LULC drainage areas as defined in the TMDL and revised based on field assessments in the Boathouse Creek watershed.

LULC category	Area defined in the TMDL report (acres)	Area adjustment per new watershed boundary (acres)	Adjusted area (acres)
Wetland	61.74	0.00	61.74
Pasture	55.18	1.13	56.31
Forest	206.53	1.57	208.10
Urban	196.72	-12.06	184.66
NCDOT	27.9	-3.20	24.70
Total	**548.07**	**-12.56**	**535.51**

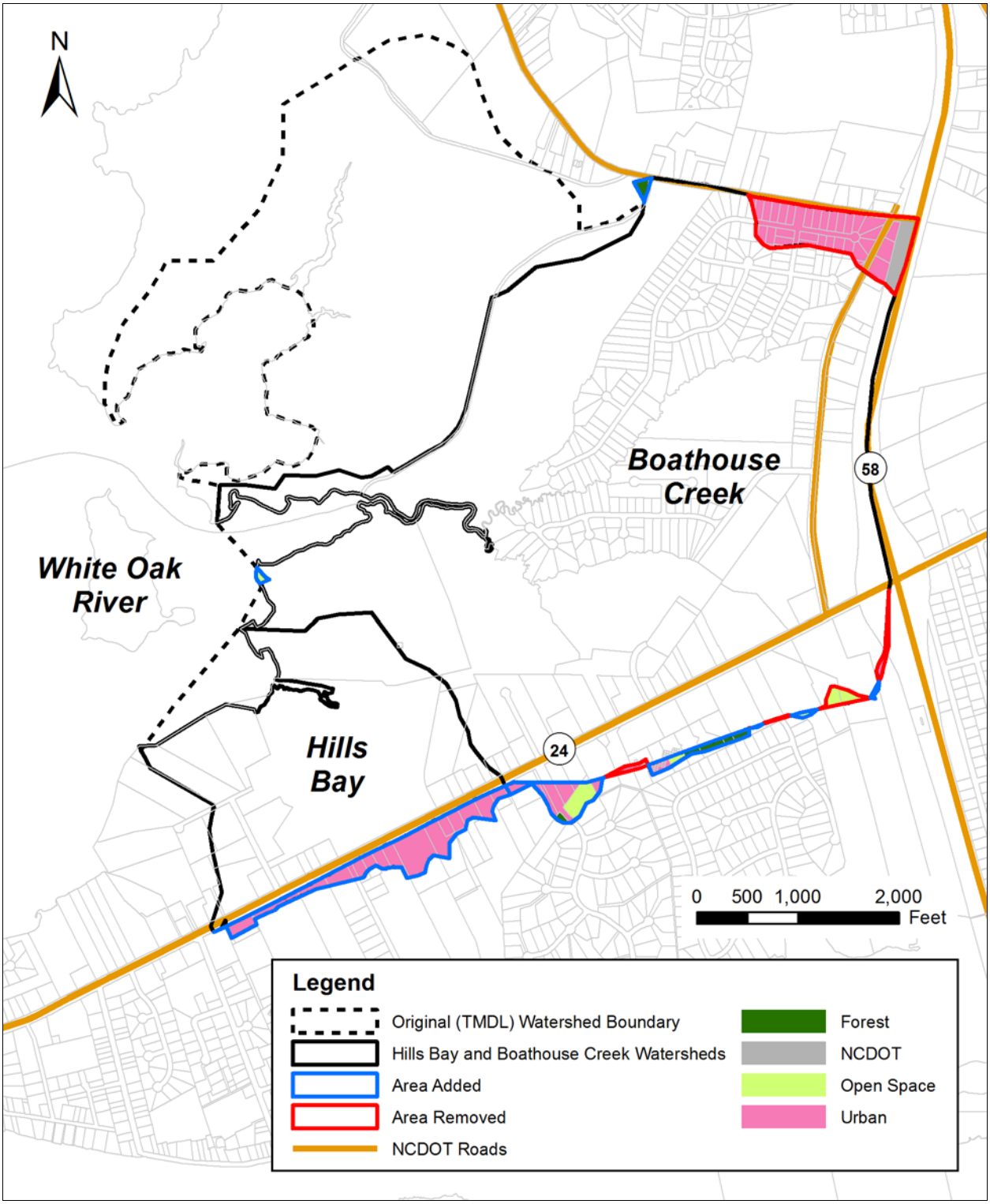

Figure 4. LULC associated with areas added and a removed as a result of revised watershed boundaries for Boathouse Creek and Hills Bay.

3.5 Priority Area Field Investigations

NCDOT performed detailed studies at four locations within the Hills Bay and Boathouse Creek watersheds through a contract with Call Sign Engineers (Call Sign Engineers, 2012). The objective of these studies was to collect additional data, not available in the TMDL report, to support the assessment of potential load reduction measures at these locations. Efforts included locating and mapping stormwater drainage features, identifying potential conflicts with existing utilities, estimating space and property requirements, identifying human and natural environment concerns, preparing preliminary cost estimates, determining constructability, and estimating load reductions. The locations for the four sites (illustrated in Figure 5) are listed below and described in the following subsections.

- Site #1 – NC-24 and Bluff Road
- Site #2 – NC-24 between Commercial Court and Lois Lane
- Site #3 – NC-24 west of Old NC-58
- Site #4 – Eastbound Shoulder of VFW Road

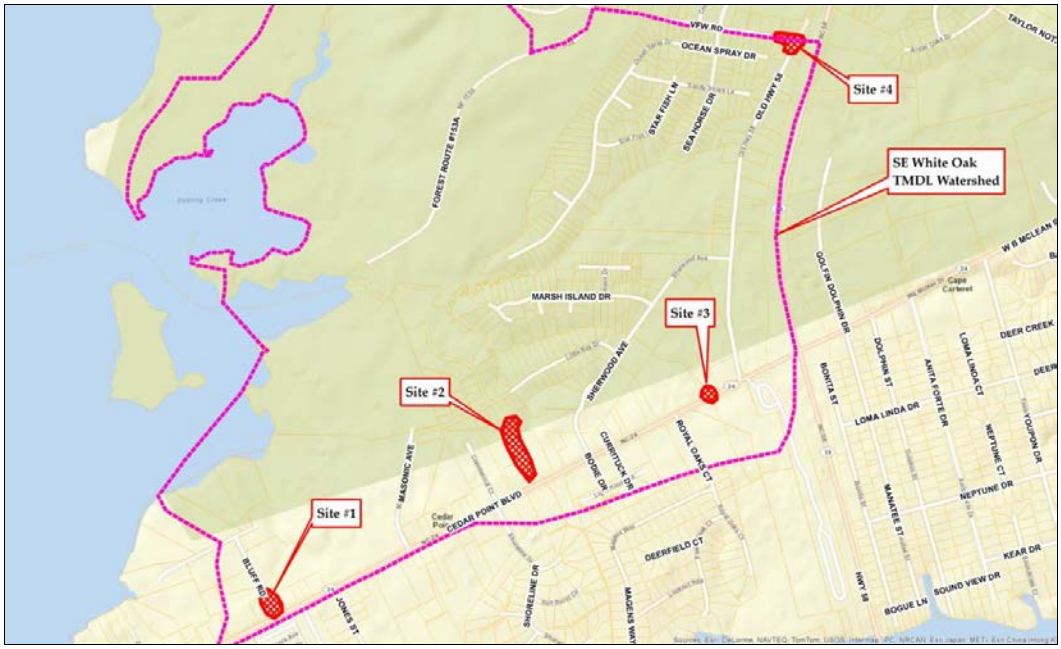

Figure 5. Map illustrating priority areas in which NCDOT performed field surveys (Source: Call Sign Engineers, 2012).

3.5.1 Site #1 – NC-24 and Bluff Road

Site #1 is located near the corner of NC-24 (Cedar Point Blvd) and Bluff Road which is a Town owned local access road (Figure 6). The area draining to this site is 20.5 acres, with 66.5% impervious cover. The drainage system outlet at Site #1 discharges from NCDOT's permanent drainage easement (PDE) into an undeveloped wooded area. No outfall is present at Site #1. Future development within the drainage area is anticipated to be minimal. An SCM retrofit was evaluated at a location measuring 275 x 30 ft. within the NCDOT PDE. A temporary construction easement and lane closure would likely be required

from the Town of Cedar Point along a portion of Bluff Road. The longitudinal slope is approximately 1.0%. The soils were identified as Arapahoe and Seabrook, very poorly drained and moderately well drained soils, respectively.

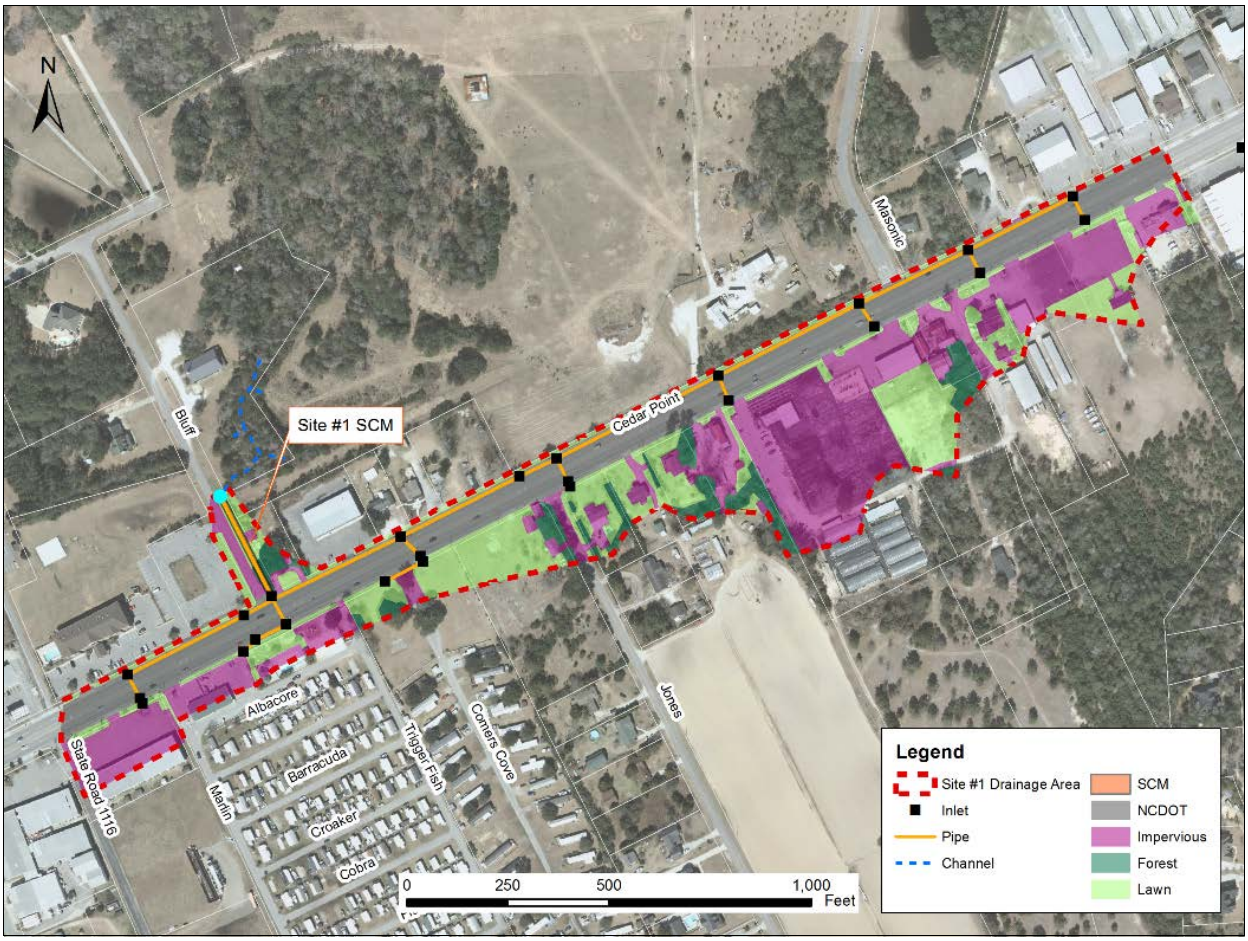

Figure 6. Site #1 (NC-24 and Bluff Road) drainage area, stormwater conveyance system and LULC.

No natural environment or cultural/human environment constraints were identified at this site. Nor were any streams field identified or represented on a United States Geological Survey (USGS) map or the Carteret County Soil Survey map within the site. Within a one mile radius of the site no federally threatened or endangered species were inventoried in the NC Natural Heritage Program (NCNHP) GIS database. Finally, the site is not located within a designated Coastal Barrier Resources Act (CBRA) area.

An underground storage and infiltration SCM was evaluated because of the relatively high fecal coliform removal ability (NCDENR, 2009b). Other options were considered but eliminated due to safety and aesthetic concerns related to the site's close proximity to the town street and adjoining property owners. Existing utilities were identified as being present within the site. At a minimum, a 6 inch water main and 2 inch water lateral would need to be relocated. Preliminary designs for two SCM alternatives were evaluated. The first alternative was an online configuration where all stormwater is routed through the underground infiltration device. This alternative was eliminated due to intensive maintenance

requirements necessary to ensure water would never back up and flood NC-24, a vital hurricane evacuation route. The second option was an offline configuration which bypassed higher flows and lessened maintenance and safety concerns. Site constraints limited the BMP's capacity to approximately 0.1 inches of runoff. Estimated construction cost for this second option is approximately $100,000. Due to the high construction costs, challenges associated with the conflicting water main, and limited treatment, this option was considered infeasible for the time being.

3.5.2 Site #2 – NC-24 between Commercial Court and Lois Lane

Site #2 is located off of NC-24 (Cedar Point Blvd), between Commercial Court and Lois Lane (Figure 7). The original drainage area of this site was reported to be 18.8 acres, with 47.3% impervious cover (Call Sign Engineers, 2012). Subsequent assessments determined that the area surrounding and draining to the proposed BMP location is part of the Site #2 drainage area. Therefore, the drainage area was revised to be 23.1 acres, with 47.2% impervious cover. Open areas allow for the potential of future development within the drainage area. The proposed SCM would be located within an NCDOT PDE measuring 650 x 35 ft. A temporary construction easement is not anticipated to be required. The longitudinal slope is approximately 1.5%. The soil was identified as Wando, a well-drained soil.

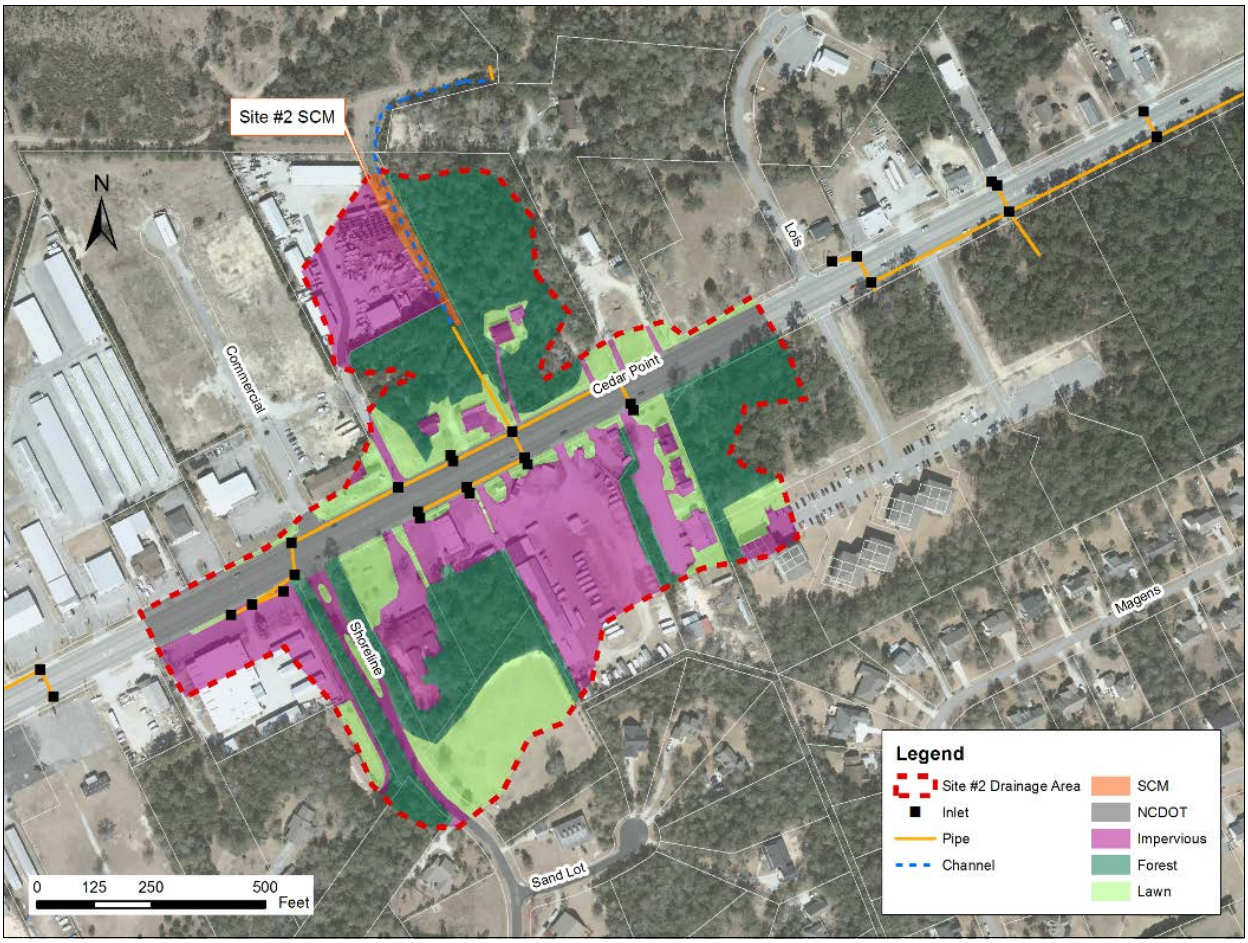

Figure 7. Site #2 (NC-24 between Commercial Court and Lois Lane) drainage area, stormwater conveyance system and LULC.

No stream was field identified or represented on a USGS topographic map or Carteret County Soil Survey map within the site. Within a one mile radius of the site no federally threatened or endangered species have been inventoried in the NCNHP GIS database. The site is not located within a designated CBRA area.

The proposed SCM is a linear infiltration basin impounding captured runoff via a concrete weir. Existing utilities are not anticipated to impact design or construction. A preliminary design has been completed with an estimated construction cost of $46,400.

3.5.3 Site #3 – NC-24 west of Old NC-58

Site #3 is located alongside NC-24 (Cedar Point Blvd), west of Old NC-58 (Figure 8). The area draining to this site is 36.3 acres, with 19.0% impervious cover. There is a relatively large amount of open area within the drainage area with potential for development in the future. The proposed SCM would be partially located within a narrow NCDOT 100-ft. ROW. A temporary construction easement for additional access or staging areas would be required from the Town of Cedar Point. The longitudinal slope is approximately less than or equal to 0.5%. The soil was identified as Arapahoe, a very poorly drained soil.

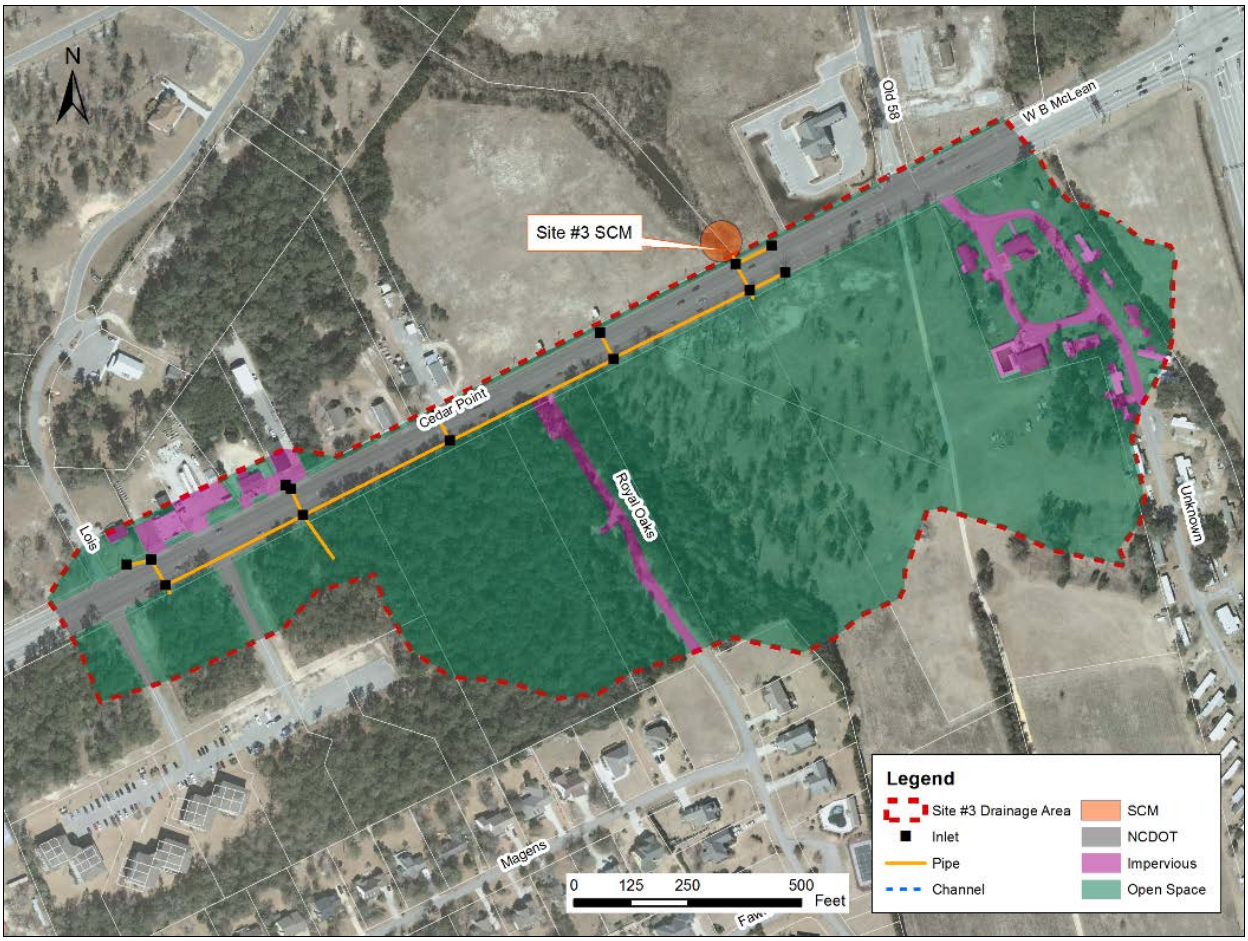

Figure 8. Site #3 (NC-24 west of Old NC-58) drainage area, stormwater conveyance system and LULC.

No stream was represented on a USGS topographic map or the Carteret County Soil Survey map within the site. However, Site #3 appeared to be very near the headwaters of Boathouse Creek and may impact jurisdictional waters or wetlands. NCDOT's stormwater conveyance system shown in Figure 8 outlets at Site #3. This outlet is believed to qualify as an outfall given it's proximity to the headwaters of Boathouse Creek. Within a one-mile radius of the site no federally threatened or endangered species have been inventoried in the NCNHP GIS database. The site is not located within a designated CBRA area.

Existing utilities within the ROW would need to be relocated include an 8 in. water main, along with telephone and cable lines. An SCM for Site #3 would require additional area beyond the NCDOT ROW and/or an innovative approach, and may impact jurisdictional waters. Tree box filter SCMs along NC-24 may avoid these issues but would only filter runoff originating from the travel lanes. The bacteria source assessment revealed little evidence that fecal material is being deposited on the travel lanes. Rather, it is most likely that sources of fecal coliform reside off the NCDOT ROW and would not be removed via tree box filters. Due to these factors and site constraints a preliminary SCM plan was not completed for this site.

3.5.4 Site #4 –Eastbound Shoulder of VFW Road

Site #4 is located within the NCDOT ROW near the intersection of Old Highway 58 and VFW Road (Figure 9). This site was originally within the Southeast White Oak River TMDL watershed boundary; however, field investigation determined that this site does not drain into the TMDL watershed. Therefore, no further assessment was performed for this site.

Figure 9. Site #4 (Eastbound Shoulder of VFW Road) SCM location and watershed boundary.

4 Wasteload Allocation Compliance Measures

NCDOT was assigned a WLA for fecal coliform of 6.60E+08 counts/day for Hills Bay and a WLA of 9.91E+09 counts/day for Boathouse Creek. As described in Section 3.0, only one of the four potential retrofit locations that were evaluated by NCDOT was found to be a viable option. This location, referred to as "Site #2", includes a permanent drainage easement that is located between Commercial Court and Lois Lane on NC 24 in the Boathouse Creek watershed (Figure 7). The anticipated stormwater retrofit at Site #2 is an infiltration basin that will be constructed by installing a weir within an existing open-channel conveyance (J-Ditch) that runs perpendicular to NC-24. The J-Ditch will receive runoff from NC-24 and other commercial and residential LULCs. A 13.5 foot wide broad crested weir is proposed to be installed within the ditch in order to impound an estimated runoff volume of 3,725 cubic feet. The drainage area controlled by the BMP is approximately 23.1 acres. For additional detail on existing site conditions, see *Stormwater Retrofit Site Assessment Report for Southeast White Oak TMDL Watershed* (Call Sign Engineers, 2012), provided in Appendix A of this report.

The remainder of this section describes the procedures used to estimate existing bacteria loads from the Site #2 drainage area and load reductions associated with the proposed J-Ditch infiltration basin.

4.1 Existing Load Assessment

Field assessments determined that the Site #2 drainage area is approximately 23.1 acres and that it includes a mix of NCDOT, urban, forest, and pasture/herbaceous LULCs. To calculate existing loads associated with the Site #2 drainage area, NCDOT used existing daily loading rates (counts/day) from the TMDL report and the revised watershed boundary to back-calculate unit area loading rates (counts/day/acre) for each LULC type. The unit area loading rates were then multiplied by the area (acres) associated with each LULC type in the Site #2 drainage area to calculate daily loads (counts/day) for each LULC and for the entire Site #2 drainage area. Because the Site #2 drainage area includes both NCDOT and non-NCDOT LULCs, steps were taken to calculate existing loads for all LULC types. Additional detail on this procedure follows.

The TMDL report documents bacteria accumulation rates for all LULC categories; however, the report only documents existing loads (also referred to as "delivered" loads) for two land use groups; NCDOT and all non-NCDOT LULCs (combined). Using the total accumulation rate reported for non-NCDOT LULCs (6.61E+12 counts/day) and the total existing load from non-NCDOT LULCs (5.82E+11 counts/day) in the Boathouse Creek watershed, the combined non-NCDOT LULCs existing load was found to be approximately 91.2% less than the combined non-NCDOT LULCs accumulation rates. This 91.2% decline between the total accumulation rate and existing delivered load for all non-NCDOT LULCs was assumed to represent the effects of fate and transport through the watershed and was used to estimate existing loads for each individual non-NCDOT LULC. This step involved multiplying the existing accumulation

rates for each non-NCDOT LULC by a factor of 8.8% (100% minus 91.2%)[1]. This approach assumes that decay rates are similar for non-NCDOT LULCs. The estimated existing loads (counts/day) for each LULC were then divided by associated LULC areas to determine LULC-specific unit area loading rates (counts/day/acre). These unit area loading rates were then used to calculate fecal coliform loads from the Site #2 BMP drainage area. Results of these calculations are summarized in Table 4 and Table 5.

Table 4. Delivered loading rate calculation for each LULC in the Boathouse Creek watershed.

LULC category	Existing Accumulation Rate (counts/day)[a]	Existing In-Stream Delivered Load (counts/day)[b]	Adjusted Area within the Watershed (acres)[c]	Existing (Delivered) Loading Rate (counts/day/acre)[d]
Wetland	7.35E+11	6.47E+10	61.74	1.05E+09
Pasture/Herbaceous	1.96E+11	1.72E+10	56.31	3.06E+08
Forest	1.51E+12	1.33E+11	208.10	6.38E+08
Urban	4.17E+12	3.67E+11	184.66	1.99E+09
NCDOT	2.19E+11	3.54E+10	24.70	1.43E+09
Total	**6.83E+12**	**6.17E+11**	**535.51**	

[a] Reported in the TMDL document

[b] For wetland, pasture/herbaceous, forest and urban LULC categories, the existing in-stream delivered loads are calculated by multiplying the existing accumulation rate (counts/day) by an adjustment factor of 8.8% (100% minus 91.2%). The TMDL reports NCDOT's existing in-stream delivered load as 3.54E+10 counts/day as shown in the table.

[c] Information contained in Table B-1, Appendix B, of the TMDL Document was used to define LULCs for areas added or removed from the watershed.

[d] Delivered loading rates were calculated by dividing the existing in-stream delivered load (counts/day) by the adjusted area (acres).

[1] In Boathouse Creek watershed accumulation rates are presented for non-NCDOT LULCs as follows: wetland (7.35E+11 counts/day), pasture/herbaceous (1.96E+11 counts/day), forest (1.51E+12 counts/day), and urban (4.17E+12 counts/day). The sum of these accumulation rates is 6.61E+12 counts/day. The total existing (delivered) load from these non-NCDOT LULCs is presented in the TMDL as 5.82E+11 counts/day. The 91.2% decline is calculated based on the following: ((6.61E+12 - 5.82E+11)/6.61E+12)*100% = 91.2%.

Table 5. LULC summary and existing bacterial loads for the Site #2 drainage area in the Boathouse Creek watershed.

LULC category	Area (acres)	Delivered Loading Rate (counts/day/acre)[a]	Delivered Load to Site #2 BMP (counts/day)[b]
Wetland	0.0	1.05E+09	0.00E+00
Pasture/Herbaceous	2.0	3.06E+08	6.07E+08
Forest	3.9	6.38E+08	2.48E+09
Urban	13.8	1.99E+09	2.74E+10
NCDOT	3.4	1.43E+09	4.97E+09
Total	**23.1**		**3.54E+10**

[a] Delivered loading rates, also presented in Table 4, were calculated by dividing the existing in-stream delivered load (counts/day) for the entire Boathouse Creek watershed by the revised area (acres) for each LULC in the watershed.

[b] Site #2 delivered loads were calculated from each LULC by multiplying the watershed-wide delivered loading rates (counts/day/acre) by their corresponding LULC areas (acres) within the Site #2 draining area (e.g. for NCDOT, the delivered loading rate of 1.43E+09 counts/day/acre was multiplied by 3.4 acres to result in a delivered load of 4.97E+09 counts/day)

4.2 Bacteria Load Reduction

The approach to estimating the bacteria load reduction for infiltration-type stormwater controls was based on the assumption that the annual fraction of runoff volume infiltrated by the control is adequately representative of bacteria load reduction. This assumption is supported by a research project sponsored by NCDOT that evaluated the performance of dune infiltration systems installed at Kure Beach, North Carolina (Price, et al., 2011). Monitoring of groundwater wells down gradient of these systems showed that concentrations of bacteria were very close to ambient levels, indicating treatment or dilution of the infiltrated volume. As such, for the estimate provided here, annual runoff volume reduction is considered to be analogous to bacteria load reduction. It should also be noted that this approach may be overly conservative, as control of the first flush of runoff, typically containing the highest pollutant concentrations, may not be under credited using the proposed calculation method.

To estimate annual runoff volume captured/infiltrated for each BMP, a series of single event rainfall-runoff simulations were conducted for a range of storms with different precipitation depths and the resulting fraction of runoff infiltrated for each event was applied to annual runoff contribution estimates for the corresponding precipitation depth interval. The single event rainfall-runoff simulations were performed using HydroCAD® stormwater modeling software Version 10.00. Inflow hydrographs were generated using the SCS runoff curve number and unit hydrograph method, assuming the SCS 24-hour Type III synthetic rainfall distribution. Runoff curve numbers (CN) were derived based on values provided in tables within the HydroCAD® software program. Based on existing site information provided in the Site Assessment Report (Call Sign Engineers, 2012), the soils at Site #2 were assumed to be categorized as Hydrologic Soil Group A. Because much of the impervious area in the BMP drainage areas

are directly connected to the outlet and because the CN values for pervious and impervious areas were very different, the pervious areas and the impervious areas were modeled as two discrete, yet composite drainage areas. Representative Time of Concentration (Tc) values were estimated for both the composite pervious area and the composite impervious area for each site. Tc values were estimated using methods provided in *Technical Release-55, Urban Hydrology for Small Watersheds* (NRCS, 1986). Calculation worksheets for Tc values are provided in Appendix B. Watershed characteristics are summarized in Table 6.

Table 6. Site #2 Watershed Characteristics Summary.

LULC category	Area (acre)	Runoff Curve Number (CN)	Time of Concentration (Tc) (minutes)
Impervious Area	10.9	98	10
Pervious Area	12.2	46[a]	27
Woods/Forest	7.7	49[b]	--
Grass/Lawn	4.5	45[c]	--
Total Area	**23.1**		

Notes:

[a] Composite CN value based on weighted average of CN values for Woods and Grass.

[b] Based on CN values provided in HydroCAD® for woods with poor coverage and hydrologic soil group A.

[c] Based on CN values provided in HydroCAD® for grass cover 50% to 75% and hydrologic soil group A.

Pond and reach routing were accomplished using the storage indication method in the HydroCAD® model. Exfiltration/infiltration in the storage areas was simulated using the conductivity method in the HydroCAD® model, which uses the Darcy's law equation to estimate an infiltration velocity based on a user supplied hydraulic conductivity value and a derived hydraulic gradient (calculated by the model using the water surface in the storage area and the groundwater elevation). Two field tests were conducted at Site #2 to determine the seasonal high water table elevation and hydraulic conductivity (Appendix C). These tests resulted in hydraulic conductivity rates of 17.3 inches per hour and 16.3 inches per hour. The hydraulic conductivity value used for the model, 16.8 inches per hour, was based on an average of two field infiltration tests. The single event rainfall-runoff simulations were performed for a series of storm events with precipitation depths ranging from 0.2 inches to 3.53 inches. Summary reports for the HydroCAD® simulations for Site #2 and for all storm events considered are provided in Appendix D. Figure 10 shows the infiltration performance of the BMP at Site #2 based on the results of the single event rainfall-runoff simulations.

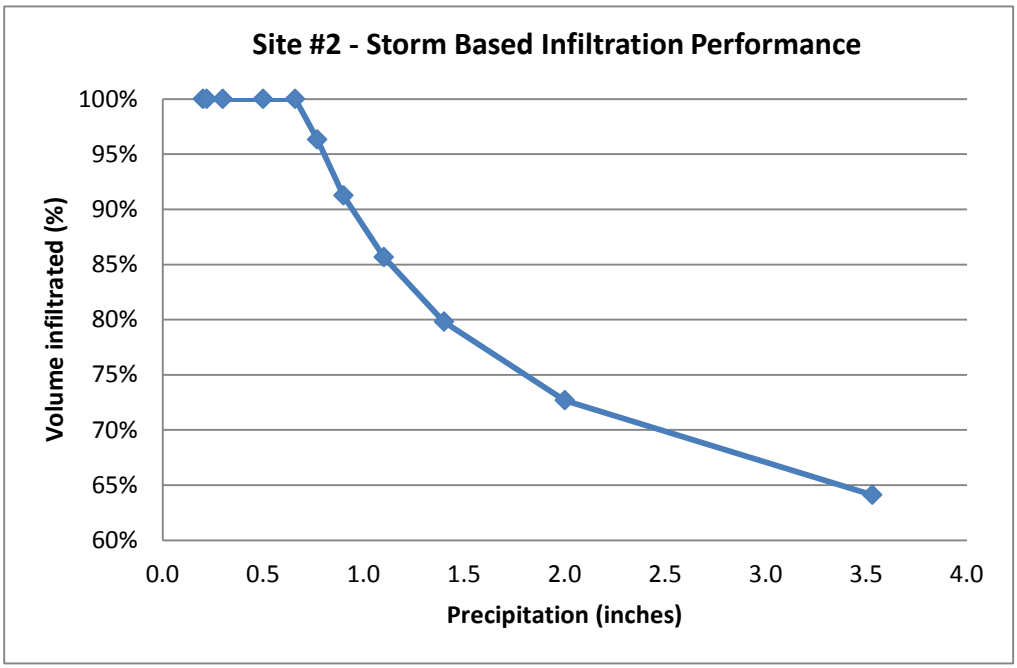

Figure 10. Site #2 - Single Event Storm Infiltration Performance of BMP

The annual runoff contributions by precipitation depth interval were estimated using the USEPA's National Stormwater Calculator (http://www.epa.gov/nrmrl/wswrd/wq/models/swc/). EPA's National Stormwater Calculator is a desktop application that provides estimates of annual precipitation and frequency of runoff throughout the United States. Site specific information were entered into the Calculator, including site location, land cover, soil drainage, and topography. Precipitation and evaporation data used in the model were taken from monitoring station MOREHEAD CITY 2 WNW, which was provided by the Calculator. Results of the Calculator for runoff contribution by rainfall interval are provided in Figure 11. Full summary reports from the Calculator are provided in Appendix E.

Using the results of the HydroCAD® simulations and National Stormwater Calculator, the annual runoff volume captured (in percent) was estimated. For each precipitation depth interval, the percent of the total runoff volume infiltrated for each storm event considered (from HydroCAD® simulations) was applied to the percent of annual runoff contribution (from National Stormwater Calculator) to arrive at the percent of annual runoff captured (for each precipitation depth interval). The annual runoff captured expressed as a percent of the total runoff volume for each precipitation depth interval are summed to estimate a percent of total annual runoff infiltrated by the SCM. A summary of the calculations for the annual estimated runoff volume captured are presented in Appendix F. Using this methodology, the percent of total annual runoff infiltrated by the proposed SCM at Site #2 was estimated to be 82.2%.

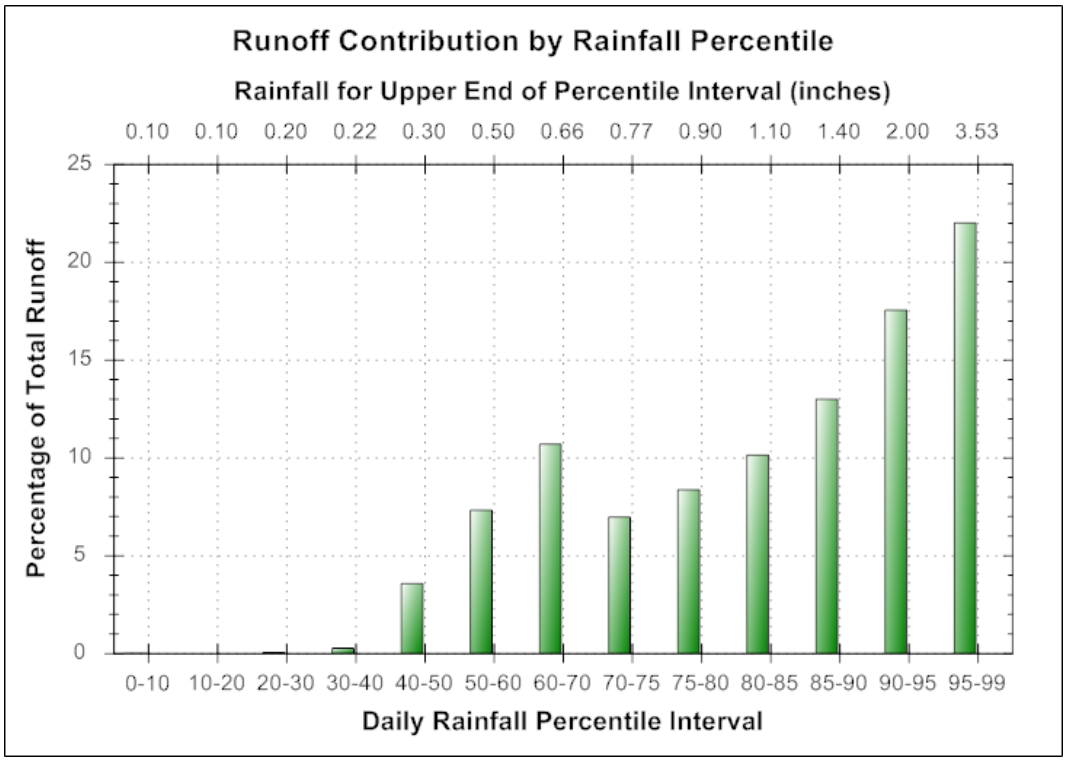

Figure 11. Site #2 Runoff contribution by rainfall interval from National Stormwater Calculator.

Using the existing loads established in the previous section and the estimates for annual runoff volume reduction, the bacteria load can be estimated. Table 7 summarizes the potential bacteria load reduction for Site #2.

Table 7. Bacteria Load Reduction from BMP implementation at Site #2.

	Fecal Coliforms - Boathouse Creek Watershed
NCDOT existing load from TMDL (counts/day)	3.54E+10
NCDOT WLA from TMDL (counts/day)	9.91E+09
Site #2 drainage area existing load (counts/day)	3.54E+10
Site #2 infiltration basin volume reduction (%)	82.2%
Bacteria load reduction from Site #2 infiltration basin (counts/day)	2.91E+10
Adjusted NCDOT existing load with Site #2 infiltration basin (counts/day)	6.30E+09

5 Implementation and Reporting

Construction of the Site #2 infiltration basin is anticipated to begin in late 2013 or early 2014 and be completed by September 2014. The Site #2 basin will be routinely inspected and maintained so that it continues to function as designed. NCDOT implements an Inspection and Maintenance (I&M) program to address NPDES permit requirements for maintaining SCM assets. This program includes dedicated personnel responsible for the functionality of NCDOT's Stormwater Control Management System (SCMS) website, an SCM I&M Manual, training, program auditing, and cross-training between design engineers, construction, and maintenance staff to increase SCM I&M awareness within NCDOT. NCDOT's schedule for implementing the Site #2 basin and reporting on maintenance and effectiveness to the North Carolina Division of Energy, Mineral and Land Resources (NCDEMLR) is presented in Table 8.

While no viable BMP options have been identified for reducing bacteria loads from NCDOT ROW in the Hills Bay watershed, NCDOT will continue to investigate and evaluate opportunities for future projects in this watershed. Future annual reports will document steps taken to reassess bacteria load reducing opportunities in the Hills Bay watershed (Table 8).

Table 8. NCDOT implementation and reporting schedule for compliance with the Boathouse Creek and Hills Bay TMDLs.

Report of Findings Implementation Activity	Completion Date
Report of Findings submitted to NCDEMLR	September 13, 2013
Construction of J-Ditch Infiltration Basin at Site #2	September 2014
Reassessment of potential bacteria controls in the Hills Bay watershed	2014 Annual Report[a]
BMP maintenance and effectiveness reporting	2014 Annual Report[a]

[a] In conjunction with NCDOT's NPDES annual reporting.

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Appendix A

Stormwater Retrofit Site Assessment Report
Southeast White Oak TMDL Watershed

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Stormwater Retrofit Site Assessment Report

Southeast White Oak TMDL Watershed

December 13, 2012

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Appendix 1 – Site #1 Supporting Documentation

Appendix 2 – Site #2 Supporting Documentation

Appendix 3 – Site #3 Supporting Documentation

Appendix 4 – Site #4 Supporting Documentation

Appendix 5 – SCM Performance Curves

1. Executive Summary

1.1 Purpose of Assessment Report

In April 2009, the NCDOT was identified by the NC Division of Water Quality (DWQ) as a significant contributor of fecal coliform bacteria within the Southeast White Oak TMDL Watershed (Town of Cedar Point, Carteret County). To comply with its NPDES permit, NCDOT drafted an Assessment and Monitoring Plan that outlined a set of actions to further assess NCDOT's contribution of fecal coliform bacteria to the watershed, which was approved by DWQ in September 2011. NCDOT stated in the Assessment and Monitoring Plan that it would assess the feasibility of installing retrofit stormwater control measures (SCM) at three different locations within the watershed. An additional site was later added to be studied, resulting in four total sites to be assessed.

Figure 1.1. Project Vicinity Map

The purpose of this Assessment Report is to evaluate the feasibility of constructing a retrofit stormwater control at each of the four sites, as well as document the procedures used during the evaluation process. Figure 1.2 below shows the general locations of the four sites.

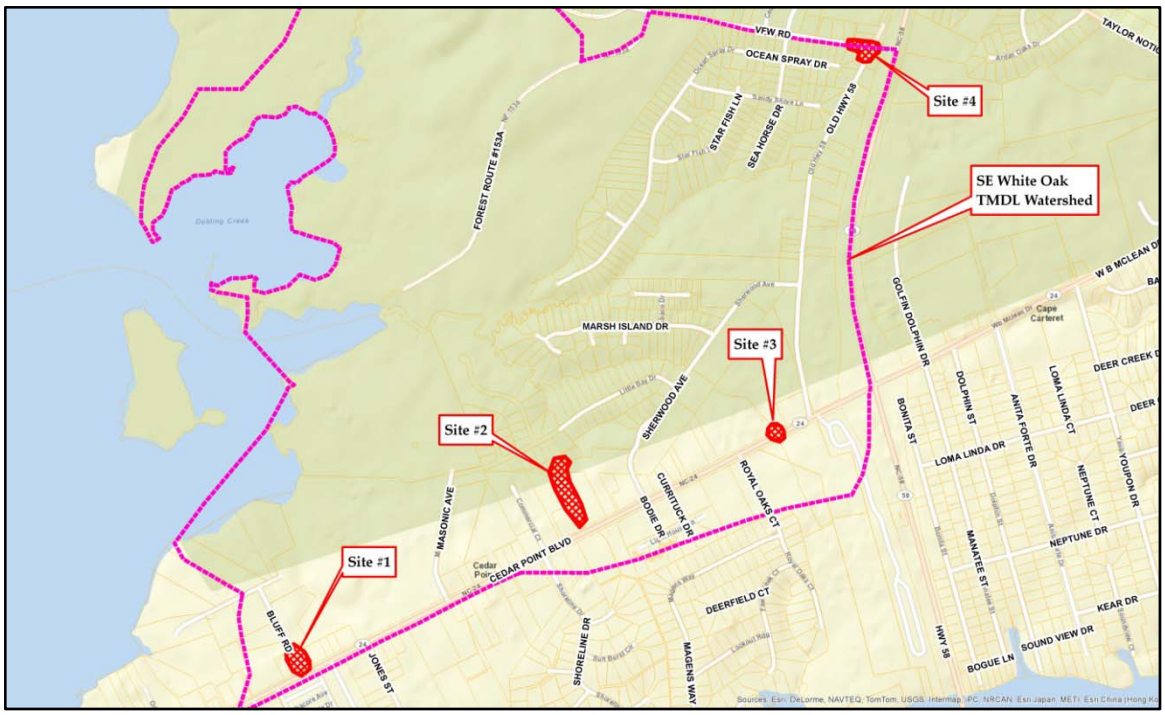

Figure 1.2. Project Site Vicinity Map

1.2 General Description of Assessment Tasks Performed

Each site was evaluated to determine the feasibility of constructing a retrofit stormwater control measure within the NCDOT rights-of-way, easement boundaries, and if applicable, on adjacent properties. Potential fatal flaws and constraints that may influence the implementation of a final design for each site were considered. Two of the four sites were determined to be viable retrofit candidates, and as part of this report, a conceptual/preliminary design was created for Sites #1 and #2. The general steps and tasks that were performed at each of the four sites are as follows:

- Compiling available GIS data. Sources of GIS data included Carteret County, NCDOT, and NC One Map; including such information as aerials, soils, LiDAR, utilities, and parcel lines.
- Compile available NCDOT data. This included construction drawings and design plans for past work that has been done by NCDOT within the vicinity of each site (NCDOT project R-2015AA and AB). The right-of-way and easement information was also obtained from the local NCDOT right-of-way agent.
- Incorporate available NCDOT GIS data. The NCDOT Highway Stormwater Program had used GPS to locate drainage inlets, pipes, and performed measure downs. This information was used in the report.
- Create Base Mapping. The above information was used to create base maps.
- Create Drainage Area Map. The drainage area for each site was estimated using the drainage patterns and base mapping.
- Project Site Visits. Each of the four project sites were visited in order to assess the drainage patterns that were estimated in the previous steps (visual assessments of the

human environment potentially impacted by the construction and maintenance of an SCM and other potential constraints from surrounding land features).

- Categorical Exclusion (CE). The sites were assessed for items from the CE checklist process that could potentially limit project approval.
- Utilities. The location of utilities was estimated by visual inspection, from examining old NCDOT plans, and available data that was obtained from the Town of Cedar Point.
- Assessment of Constructability. The assessment included a review of probable project construction methods and permanent access, potential staging areas, and other constraints that may impact constructability.
- Assessment of potential retrofit SCM types. When applicable, conceptual SCM designs were assessed based on the constraints and conditions observed in the above steps. This includes the engineer's opinion of probable construction cost and estimated water quality treatment for each conceptual design.

1.3 Summary of Findings

As stated in the previous section, only Sites #1 and #2 were determined to be viable retrofit candidates. As a result, preliminary designs and opinions of construction cost were not developed for Sites #3 and #4; the reasons for not further assessing these sites is discussed in greater detail in Sections 4 and 5 of this report.

During the development of this report it was determined that there were two viable design options for Site #1. Option #1 assesses a traditional underground infiltration system with a pre-treatment/forebay device. Option #2 is considered to be a lower maintenance alternative that includes a flow splitter box. Different design options were not investigated for Site #2, but two pollutant removal alternatives were incorporated when assessing the Site's potential as a stormwater retrofit site. As Table 1.3.2 shows, Site #2 offers a much higher retrofit site value when considered as an infiltration basin rather than an extended dry-detention basin. A soils investigation by a soil scientist should be performed on Site #2 prior to making a final site determination.

The major factors that were considered while assessing the retrofit value for the sites were fecal coliform bacteria removal ability, the potential removal of total suspended solids (TSS), and runoff volume reduction. For informational purposes, total phosphorus (TP) removal was also assessed. As previously mentioned, NC DWQ identified NCDOT as a contributor of fecal coliform bacteria, which is the primary driving force for this Assessment Report. However, resources and studies on fecal coliform bacteria relative to stormwater runoff and removal efficiencies for various stormwater control measures are limited. NC DWQ generally does not use numeric values when discussing fecal coliform bacteria removal. Their BMP Manual states that infiltration devices have high removal ability and extended dry-detention basins have medium removal ability (NCDENR, 2009). Another Stormwater Manual from Beaufort County, SC states that infiltration devices are expected to have the highest removal efficiencies at 80% to 90%, and that extended dry-detention basins provide a moderate level of removal efficiency at around 30% (Beaufort, 2012). Due to the limited amount of information on fecal coliform bacteria in stormwater, other more well documented stormwater pollutants were included when assessing the site's retrofit value. A Stormwater BMP

Performance Analysis study prepared for the US Environmental Protection Agency (EPA) by Tetra Tech, Inc. was used to estimate the pollutant removals for each site option and alternative. The study looks at pollutant removal efficiencies for various stormwater control measures relative to depth of runoff treated; the pollutants assessed are TSS, TP, and runoff volume reduction (USEPA, 2010). The performance curve methodology presented by Tetra Tech is especially helpful in this Assessment Report, because due to the limited available retrofit area for each site, the depth of runoff treated is a fraction of the actual first flush depth. Most stormwater removal efficiencies are estimated by assuming that the stormwater device captures the entire first flush runoff depth. Table 1.3.1 on the following page outlines the stormwater control device characteristics for Sites #1 and #2, as well as their estimated pollutant removal efficiencies.

Table 1.3.2 on the following page outlines the estimated pollutant removals for each stormwater control device at Sites #1 and #2 relative to the opinion of probable construction cost. Not only were the relative costs assessed for the entire contributing drainage basin, but they were also broken out for only the runoff produced from the NCDOT right-of-way area within the basin. This assessment does not include a long term cost estimate for device operation and maintenance, but this should be considered during the final design phase. If it is determined by a soil scientist at Site #2 that the soils will infiltrate and the seasonal high water table has sufficient depth, then constructing a linear infiltration basin at Site #2 is the most viable retrofit option. The second most viable option is Option #2 at Site #1, which incorporates the use of a splitter box in order to minimize operation and maintenance costs. The biggest challenge with this option will be designing an effective splitter box configuration that will capture the lower flows, but still allow the higher flows and maintenance issues to be maintained in the existing storm system.

It is recommended that a detailed soils investigation be done by a soil scientist at Sites #1 and #2 prior to entering into the scoping process for the final design phase.

Table 1.3.1 - Estimated SCM Performance

	Proposed SCM	Total DA [ac]	(1) Runoff Treated [in]	NCDOT R/W Area [ac]	(1) NCDOT R/W Runoff Treated [in]	(2) Fecal Removal Ability	(3) Percent Removal TSS - Total DA	(3) Percent Removal TSS - NCDOT R/W	(3) Percent Removal TP - Total DA	(3) Percent Removal TP - NCDOT R/W	(3) Percent R.O. Volume Reduction - Total DA	(3) Percent R.O. Volume Reduction - NCDOT
Site #1 - Option #1	Underground Infiltration	20.5	0.15	6.0	0.3	High	63.5%	87.0%	43.5%	68.0%	44.5%	66.5%
Site #1 - Option #2	Underground Infiltration w/flow splitter	20.5	0.1	6.0	0.2	High	50.0%	77.0%	32.0%	55.0%	34.0%	55.0%
Site #2 - Dry Basin	Dry Detention Basin	18.8	0.2	2.9	0.6	Medium	24.5%	35.0%	4.5%	7.0%	--	--
Site #2 - Infiltration Basin	Detention Basin w/infiltration	18.8	0.2	2.9	0.6	High	75.5%	90.0%	50.0%	71.0%	33.0%	54.0%

Note 1: Estimated Runoff Treated from NCDOT Toolbox WQv equation (NCDOT, 2008)

Note 2: Estimated fecal removal ability for device type (NCDENR, 2009)

Note 3: Estimated Pollutant Removal and Runoff Volume Reduction from BMP Performance Curves (USEPA, 2010)

Table 1.3.2 - Estimated SCM Performance in Relation to Cost

	Proposed SCM	Probable Const. Cost	Percent R.O. Volume Reduction - Total DA	Percent R.O. Volume Reduction - NCDOT	Cost per lb TSS Removed - Total DA	Cost per lb TSS Removed - NCDOT R/W	Cost per lb TP Removed - Total DA	Cost per lb TP Removed - NCDOT R/W	Cost per % of Volume Reduction - Total DA	Cost per % of Volume Reduction - NCDOT R/W
Site #1 - Option #1	Underground Infiltration	$87,120	44.5%	66.5%	$5.99	$14.93	$5,886.49	$12,811.76	$1,957.75	$1,310.08
Site #1 - Option #2	Underground Infiltration w/flow splitter	$57,233	34.0%	55.0%	$5.00	$11.08	$5,250.73	$10,406.0	$1,683.32	$1,040.60
Site #2 - Dry Basin	Dry Detention Basin	$46,400	--	--	$9.01	$41.50	$33,142.86	$154,666.7	--	--
Site #2 - Infiltration Basin	Detention Basin w/infiltration	$46,400	33.0%	54.0%	$2.92	$15.91	$2,974.36	$13,647.1	$1,406.06	$859.26

2. Site #1 – NC-24 and Bluff Road

2.1 Project Site Vicinity Map

Figure 2.1 shows the approximate site limits outlined in red. The project site is located within a NCDOT permanent drainage easement (PDE) along Bluff Road in Cedar Point, NC near the intersection of NC-24 (Cedar Point Boulevard) and Bluff Road. The existing site conditions are shown on Sheet 1 in Appendix 1.

Figure 2.1. Site #1 Vicinity Map

2.2 Contributing Drainage Area

The size and boundary of the drainage area that contributes runoff to Site #1 is shown on the Drainage Area Map in Appendix 1. The drainage area drains a portion of the NC-24 corridor within the Town of Cedar Point; the runoff is mostly conveyed through a closed storm drainage system. The downstream end of the project site limits captures a drainage area of approximately 20.5 acres and has an estimated impervious cover of 66.5%. The estimated time of concentration for the drainage basin is around 10 minutes.

2.3 Land Use and Development Trends

The land use and current impervious cover estimates were determined using Carteret County GIS data and 2010 digital aerial photos (see Drainage Area Map in Appendix 1). The contributing drainage area has a relatively high percentage of impervious cover and could be considered to be in a near full built-out condition. It is anticipated that the potential impacts on Site #1 from current and future development will be minimal.

2.4 Existing Site Conditions

2.4.1 Geology and Soils

The Carteret County Soil Survey (Soil Survey, 2012) identifies two soil types within Site #1.

Soil Mapping Unit	Mapping Unit	Drainage Class	Hydric Status
Arapahoe fine sandy loam	Ap	Very Poorly Drained	Hydric
Seabrook fine sandy loam	Se	Moderately Well Drained	Partially Hydric

Table 2.4.1. Soils within Site #1

Arapahoe fine sandy loam is nearly level, and is considered to be very poorly drained, hydric soil. The soil mapping unit is considered to be hydric. It is found on broad flats and in depressions on low marine and stream terraces. Typically, the surface layer is black and very dark gray fine sandy loam to 23 inches, and the subsoil is dark grayish brown fine sandy loam to a depth of 36 inches. The underlying material is light brownish gray loamy sand and sand to a depth of 72 inches. Arapahoe can be prime farmland if it is drained.

Seabrook fine sandy loam is nearly level and moderately well drained. The soil mapping unit is considered to be partially hydric. It is found in slightly convex areas on stream and low marine terraces. Typically the surface layer is dark grayish brown fine sand to a depth of 8 inches. The subsoil extends to 80 inches and includes light yellowish brown fine sand in the upper part, very pale brown fine sand with light gray mottles in the middle, and light gray sand in the lower part.

Site #1 is located within the outer coastal plain physiographic region of North Carolina. This portion of Carteret County is mapped as "surficial deposits" by the NC Geological Survey (Rhodes, 1985). Surficial deposits are described as sand, clay, gravel, and peat deposited in marine and other environments. The NCDWR Ground-Water Bulletin No. 1 (LeGrand, 1960) describes the area as deposits of quaternary age, primarily sand with subordinate amounts of clay. It also states that shell rock and loose shells are more prevalent in the lower part of the formation. The Carteret County Land Use Plan (1996) has a similar summary: "The County is underlain by an eastward-thickening wedge of sedimentary deposits of Pleistocene age ranging from 2,000 feet thick in the northwest portions of the county to almost 7,000 feet thick beneath the easternmost sections of offshore strand. Because of the depth of the surficial sand/siliceous deposits, little is known of the composition of underlying deposits. Well logs indicate that shell fragments and calcareous material are consolidated into a limestone at a depth of less than 120 feet west of Morehead City and at increasing depths further eastward. Microfossils obtained from some well samples indicate that the uppermost consolidated limestone is probably part of the Yorktown formation."

2.4.2 Topography

The existing topography of Site #1 as shown on Figure 2.1 is relatively flat, and the elevations across the site range from approximately 14 to 18 feet. The longitudinal slope along the working area is approximately 1.0%. It is not anticipated that the site topography will cause working constraints.

The preliminary assessment shows that the existing drainage system on the site should provide adequate elevation change to propagate positive drainage for a retrofit stormwater control measure.

2.4.3 Natural and Human Environment

Summary

The preliminary review of Site #1 did not find any likely environmental constraints that would prevent implementation of a stormwater retrofit project. This conclusion was reached by using the information provided in the following subsections.

Threatened & Endangered Species

A review of the NC Natural Heritage Program GIS database (NCNHP, 2012) showed no recorded federally threatened or endangered species within 1 mile of the project site. In addition, the list of threatened and endangered species for Carteret County was obtained from the US Fish and Wildlife Service (USFWS Region 4, 2012) and reviewed for its potential relevance to the site.

Federally Listed Species in Carteret County

Common Name	**Scientific name**	**Federal Status**	**Record Status**
American alligator	*Alligator mississippiensis*	T (S/A)	Current
Green sea turtle	*Chelonia mydas*	T	Current
Hawksbill (=carey) sea turtle	*Eretmochelys imbricata*	E	Historic
Kemp's (=Atlantic) ridley sea turtle	*Lepidochelys kempii*	E	Current
Leatherback sea turtle	*Dermochelys coriacea*	E	Current
Loggerhead sea turtle	*Caretta caretta*	T	Current
Piping plover	*Charadrius melodus*	T	Current
Red-cockaded woodpecker	*Picoides borealis*	E	Current
Roseate tern	*Sterna dougallii dougallii*	T	Current
Shortnose sturgeon	*Acipenser brevirostrum*	E	Current
West Indian manatee	*Trichechus manatus*	E	Current
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	E	Current
Seabeach amaranth	*Amaranthus pumilus*	T	Current

Based on existing GIS data and aerial photography, it appears that Site #1 could contain suitable habitat for rough-leaved loosestrife. A detailed site survey should be conducted if the site is selected for design.

Carteret County has designated critical habitat for the wintering piping plover. The critical habitat maps from the US Fish and Wildlife Service (USFWS, 2012) were reviewed, and it appears that only the designated critical habitat area NC-6 is located within Carteret County. This designated critical habitat area is located along the Outer Banks stretching west of Ocracoke Inlet and is not near Site #1.

Water Resources

Carteret County is one of North Carolina's twenty designated coastal counties and is subject to the Coastal Area Management Act (CAMA). The study area is located within the White Oak River basin [U.S. Geological Survey (USGS) Hydrologic Unit 03020301]. No stream is shown within Site #1 on either the USGS map or the Carteret County Soil Survey map (USDA, 1987). It appears from aerial photography that Site #1 drains into an unnamed tributary of the White Oak River approximately 1,000 feet downslope. This section of the White Oak River is listed as a high quality water (SA-HQW) by the DWQ (NCDWQ, 2011). Anadromous fish spawning area maps from NC Marine Fisheries (NCMF, 2007) were reviewed and portions of the White Oak River were found to be designated anadromous fish spawning areas. However, all designated spawning areas were a considerable distance upstream of the Site. This section of the White Oak River is also designated Essential Fish Habitat (EFH) by the National Marine Fisheries Service. The Coastal Barrier Resources Act (CBRA) maps were reviewed (NMFS, 2012), and Site #1 was not found to be located within a designated CBRA area. There are no water supply watersheds within 1 mile downstream of the study area. No jurisdictional stream or wetland feature is anticipated within Site #1 based on available data, but a site review to confirm this should be conducted if the site is selected for design.

Historic Places

The NC State Historic Preservation Office (NCSHPO) list of National Register of Historic Places for Carteret and Onslow Counties (NCSHPO, 2012) were reviewed to determine if any listed sites were in the vicinity of Site #1. No listed sites were found to be near the site. No archaeological features of significance are anticipated within Site #1 due to the disturbed nature of the site, but a letter requesting confirmation should be provided to NCSHPO if the site is selected for design.

2.4.4 Right-of-Way and Easements

The project site is located within a NCDOT Permanent Drainage Easement (PDE) which is approximately 275-ft by 30-ft (NCDOT, 1999). It is anticipated that a retrofit stormwater control measure could be constructed within the limits of the PDE. A temporary construction easement was in place during the widening of NC-24 in 1999, but the temporary easements expired within thirty (30) days after completion of the project (T.I.P. R-2105AA). Bluff Road is within a 60-ft wide right-of-way that is owned by the Town of Cedar Point. It is anticipated that a new temporary construction easement would need to be acquired in order to access and construct a stormwater control measure within the PDE. Initial communications with the Town of Cedar Point's Town Administrator indicate that acquiring a temporary construction easement should not be a problem.

2.4.5 Property Ownership and Site Access

The site would be accessed from the NCDOT right-of-way along NC-24. Since Bluff Road is within a 60-ft Town of Cedar Point right-of-way, a new temporary construction easement would need to be acquired in order to gain complete site access.

2.4.6 Utilities

A 6-inch waterline is routed along the project site within the permanent drainage easement. There is a lateral service line that provides water to the Dunkin' Donuts that is across Bluff Road. It is anticipated that both the 6-inch waterline and service lateral would be impacted during the construction of a retrofit stormwater control measure. The waterlines will likely have to be relocated within the Town of Cedar Point right-of-way prior to installation of a stormwater control measure. During the design phase the water lines should be located both horizontally and vertically in order to make a more accurate assessment.

2.5 Preliminary SCM Retrofit Design

2.5.1 SCM Selection Process

Usually the largest constraint for a stormwater retrofit project is the limited amount of area available to locate the proposed stormwater control measure. The constraint of available land holds true at all four potential sites in this Assessment Report. Site #1 is located within a PDE that is approximately 275 feet long by 30 feet wide. Due to the narrow width and close proximity to the edge of Bluff Road, as well as a structure on the adjacent property, the depth and width of excavation is extremely limited. Beyond the physical constraints, the narrow width also offers a challenge due to the human environment. A permanent deep excavation adjacent to Bluff Road could provide transportation safety issues, and this would most likely not be appealing to the adjoining property owner. These site constraints make using a linear underground storage device the most favorable alternative. Furthermore, underground devices can be used effectively to facilitate infiltration, which is favorable in terms of water quality treatment and is considered to have high removal ability for fecal coliform bacteria in stormwater runoff. During the final design phase, the actual design depths and infiltration capability will be dictated by the findings of a detailed soils investigation completed by a soil scientist; the depth to the seasonal high water table will be an important design component. Underground storage devices are generally not the most cost effective treatment solutions, but sometimes site constraints dictate their use, which is the case at Site #1.

2.5.2 Hydrologic Trespass

It is not anticipated that hydraulic trespass will be an issue if a stormwater control measure is installed at Site #1. However, during the design phase an assessment of the impacts of a stormwater control measure to the drainage system along NC-24 should be examined. Hydraulic trespass should be considered during the design, and the final design invert elevations should be altered in order to avoid trespass issues.

2.5.3 Design Features

Two design options have been selected for Site #1. Both options incorporate an underground storage and infiltration system. Option #1 uses a double perforated 48-inch pipe underground storage system that replaces a 236 linear foot section of the existing storm drainage system (see Sheet No. 2, Appendix A). Option #2 uses a double perforated 36-inch pipe underground storage system

that uses a splitter box to divert flow from the existing storm drainage system (see Sheet No. 3, Appendix A). The use of a flow splitter configuration on Option #2 is considered as a lower maintenance alternative to Option #1. Option #1 will capture the entire flow from the contributing drainage area within the pre-treatment device resulting in a routine maintenance requirement. The flow splitter configuration will capture low, first flush flows, but will theoretically by-pass trash and sediment along with the higher flows. The exact design features of the flow splitter configuration will need to be worked out during the final design phase.

2.5.4 Estimated Treatment

The depth of runoff treated within the proposed stormwater control measure was estimated for both the entire contributing drainage area and for only the area within the NCDOT right-of-way. Approximately 6.0 acres (29%) of the 20.5-acre drainage area consists of impervious cover within the NCDOT right-of-way.

Option #1 – estimated depth treated for total drainage area = 0.15 inches

Option #1 – estimated depth treated for only NCDOT impervious area = 0.30 inches

Option #2 – estimated depth treated for total drainage area = 0.10 inches

Option #2 – estimated depth treated for only NCDOT impervious area = 0.20 inches

2.5.5 Preliminary Opinion of Construction Costs

A detailed breakdown of the preliminary opinion of construction cost for each design option is shown in Appendix 1.

Site #1 – Option #1 Construction Cost Opinion = $87,120

Site #1 – Option #2 Construction Cost Opinion = $57,233

2.6 Conclusions and Recommendations

2.6.1 Summary of Site Assessment Findings

Site #1 is viable as a potential stormwater retrofit location. The presence of an existing PDE provides adequate area to treat a portion of the runoff from the NCDOT right-of-way. The existing topography and elevations of the existing drainage system provide sufficient elevation change to facilitate positive drainage through a stormwater control measure. This elevation change and the relatively high overall site elevation in relationship to receiving waters makes Site #1 a feasible stormwater retrofit site, which often times is a rarity within the coastal environment.

2.6.2 *Overall Constructability*

The majority of urban stormwater retrofit projects offer unique construction challenges, and Site #1 is no different. Due to the relatively tight site constraints, and the presence of an existing 6-inch water main and 2-inch water lateral within the project limits, construction of a proposed stormwater retrofit could be challenging. The close proximity to Bluff Road and the structure on the adjoining property will need to be considered during the excavation process. The use of trench boxes may be necessary in order to minimize the excavation footprint, as well as to stabilize steeper slopes in the sandy soils. Also, some traffic control measures may need to be considered along Bluff Road during the construction process.

2.6.3 *Cost Relative to Median Retrofit Costs*

When directly compared to other retrofit stormwater measures, underground storage devices are generally more expensive to construct and are more difficult to maintain. However, when compared to other stormwater control measures that treat a similar volume of runoff within an urban coastal environment, it is estimated that the proposed retrofit Options #1 and #2 would be close to the median costs for other retrofits. Furthermore, it is anticipated that this cost comparison would be even closer when specifically comparing underground storage devices in a similar environment. Other than the need to relocate a water main and lateral, it is not anticipated that there would be many construction challenges that would raise the cost above the compared median retrofit costs of similar underground storage devices. Table 1.3.2 shows a comparison of construction cost relative to treatment and removal efficiency.

2.6.4 *Additional Study Required for Final Design*

Before proceeding to the final design scoping phase, a soils investigation should be performed by a soil scientist at the site. The soils investigation will show the depth to the seasonal high water table, and it will determine the soil infiltration rates. The parameters determined in the soil investigation will dictate the final design features.

If Site #1 is taken to the final design phase, it is recommended that, prior to construction, that a structural conditions report be performed on the adjacent structure on the adjoining property. The purpose of the brief structural report is to document the pre-construction condition of the existing structure. This will protect NCDOT from false structural damage claims being filed by the adjacent property owner. Due to the close proximity of the existing structure to the working area it is recommended that this step is included in the final design phase.

3. Site #2 – NC-24 between Commercial Court and Lois Lane

3.1 Project Site Vicinity Map

Figure 3.1 shows the approximate site limits outlined in red. The project site is located within a permanent drainage easement (PDE) along NC-24 (Cedar Point Boulevard) in Cedar Point, NC. The existing site conditions are shown on Sheet 1 in Appendix 2.

Figure 3.1. Site #2 Vicinity Map

3.2 Contributing Drainage Area

The size and boundary of the drainage area that contributes runoff to Site #2 is shown on the Drainage Area Map in Appendix 2. The drainage area drains a portion of the NC-24 corridor within the Town of Cedar Point; the runoff is mostly conveyed through a closed storm drainage system. The downstream end of the project site limits captures a drainage area of approximately 18.8 acres and has an estimated impervious cover of 47.3 %. The estimated time of concentration for the drainage basin is around 10 minutes.

3.3 Land Use and Development Trends

The land use and current impervious cover estimates were determined using Carteret County GIS data and 2010 digital aerial photos (see Drainage Area Map in Appendix 2). The contributing drainage area has a relatively high percentage of impervious cover, but there are some open space areas that could be developed in the future. Although it is anticipated that the potential impacts on Site #2 from current and future development within the contributing drainage area will be minimal, it should still be considered during the final design phase.

3.4 Existing Site Conditions

3.4.1 Geology and Soils

The Carteret County Soil Survey (Soil Survey, 2012) identifies one soil type within Site #2.

Soil Mapping Unit	Mapping Unit	Drainage Class	Hydric Status
Wando fine sand, 0 to 6% slopes	WaB	Well Drained	Partially Hydric

Table 3.4.1. Soils within Site #2

Wando fine sand, 0 to 6% slopes is on ridges on low marine and stream terraces is well drained. The soil mapping unit is considered to be partially hydric as some components of the mapping unit are hydric. Typically the surface layer is dark brown fine sand to a depth of 8 inches. The subsoil extends to 80 inches and includes strong brown, yellow, brownish yellow, and reddish yellow fine sand.

Site #2 is located within the outer coastal plain physiographic region of North Carolina. This portion of Carteret County is mapped as "surficial deposits" by the NC Geological Survey (Rhodes, 1985). Surficial deposits are described as sand, clay, gravel, and peat deposited in marine and other environments. The NCDWR Ground-Water Bulletin No. 1 (LeGrand, 1960) describes the area as deposits of quaternary age, primarily sand with subordinate amounts of clay. It also states that shell rock and loose shells are more prevalent in the lower part of the formation.

3.4.2 Topography

The existing topography of Site #2 as shown on Figure 3.1 is relatively flat. The elevations across the site range from approximately 18 to 24 feet. The longitudinal slope along the working area is approximately 1.5%. The site topography relative to the PDE limits will need to be considered during the final design; working constraints could arise with achieving stable slopes with cut depths that are deeper than 4 to 6-ft. The preliminary assessment shows that the existing drainage system on the site should provide adequate elevation change to propagate positive drainage for a retrofit stormwater control measure.

3.4.3 Natural and Human Environment

<u>Summary</u>
The preliminary review of Site #2 did find potential jurisdictional wetlands that need to be delineated and potentially permitted, but did not find any likely environmental constraints that would prevent implementation of a stormwater retrofit project at Site #2. This conclusion was reached by using the information provided in the following subsections.

<u>Threatened & Endangered Species</u>
A review of the NC Natural Heritage Program GIS database (NCNHP, 2012) showed no recorded federally threatened or endangered species within 1 mile of the project site. In addition, the list of

threatened and endangered species for Carteret County was obtained from the US Fish and Wildlife Service (USFWS Region 4, 2012) and reviewed for its potential relevance to the site.

Federally Listed Species in Carteret County

Common Name	Scientific name	Federal Status	Record Status
American alligator	*Alligator mississippiensis*	T (S/A)	Current
Green sea turtle	*Chelonia mydas*	T	Current
Hawksbill (=carey) sea turtle	*Eretmochelys imbricata*	E	Historic
Kemp's (=Atlantic) ridley sea turtle	*Lepidochelys kempii*	E	Current
Leatherback sea turtle	*Dermochelys coriacea*	E	Current
Loggerhead sea turtle	*Caretta caretta*	T	Current
Piping plover	*Charadrius melodus*	T	Current
Red-cockaded woodpecker	*Picoides borealis*	E	Current
Roseate tern	*Sterna dougallii dougallii*	T	Current
Shortnose sturgeon	*Acipenser brevirostrum*	E	Current
West Indian manatee	*Trichechus manatus*	E	Current
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	E	Current
Seabeach amaranth	*Amaranthus pumilus*	T	Current

Based on existing GIS data and aerial photography, it appears that Site #2 could contain suitable habitat for rough-leaved loosestrife. A site survey should be conducted if the site is selected for design.

Carteret County has designated critical habitat for the wintering piping plover. The critical habitat maps from the US Fish and Wildlife Service (USFWS, 2012) were reviewed, and it appears that only the designated critical habitat area NC-6 is located within Carteret County. This designated critical habitat area is located along the Outer Banks stretching west of Ocracoke Inlet and is not near Site #2.

Water Resources

Carteret County is one of North Carolina's twenty designated coastal counties and is subject to the Coastal Area Management Act (CAMA). The study area is located within the White Oak River basin [U.S. Geological Survey (USGS) Hydrologic Unit 03020301]. No stream is shown within Site #2 on either the USGS map or the Carteret County Soil Survey map (USDA, 1987). It appears from aerial photography that Site #2 drains into Boathouse Creek approximately 1,000 feet downslope. Boathouse Creek is listed as a high quality water (SA-HQW) by the DWQ (NCDWQ, 2011). Within 1 mile of Site #2, Boathouse Creek drains into the White Oak River. Anadromous fish spawning area maps from NC Marine Fisheries (NCMF, 2007) were reviewed and portions of the White Oak River were found to be designated anadromous fish spawning areas. However, all designated spawning areas were a considerable distance downstream of the Site and Boathouse Creek was not shown as an anadromous fish spawning area. This section of the White Oak River is also designated Essential Fish Habitat (EFH) by the National Marine Fisheries Service. The Coastal Barrier Resources Act (CBRA) maps were reviewed (NMFS, 2012), and Site #2 was not found to be located within a

designated CBRA area. There are no water supply watersheds within 1 mile downstream of the study area. The R-21055AA (NCDOT, 1999) plans indicate a spring potentially within the construction limits for Site #2. This area needs to be delineated before proceeding with design and will require permitting if a wetland is determined to exist and cannot be avoided. Based on mapping and aerial photography, the drainage channel does not appear to be a jurisdictional stream, but would be verified during the wetland delineation.

Historic Places

The NC State Historic Preservation Office (NCSHPO) list of National Register of Historic Places for Carteret and Onslow Counties (NCSHPO, 2012) were reviewed to determine if any listed sites were in the vicinity of Site #2. No listed sites were found to be near the site. No archaeological features of significance are anticipated within Site #2 due to the disturbed nature of the site, but a letter requesting confirmation should be provided to NCSHPO if the site is selected for design.

3.4.4 Right-of-Way and Easements

The project site is located within a NCDOT PDE, which is approximately 650 feet by 35 feet (NCDOT, 1999). It is anticipated that a retrofit stormwater control measure could be constructed within the limits of the PDE. A temporary construction easement was in place during the widening of NC-24 in 1999, but the temporary easements expired within thirty (30) days after completion of the project (T.I.P. R-2105AA). If an access path can be cleared on one side of the easement, then it is anticipated that a new temporary construction easement would not be required for construction. A detailed survey of the site should be completed during the final design phase in order to assure the feasibility of constructing and accessing the site without additional easements.

3.4.5 Property Ownership and Site Access

The site would be accessed from the NCDOT right-of-way along NC-24. Since the PDE connects to the NCDOT right-of-way, it is anticipated that additional easements will not be required. It appears from viewing aerial photography relative to the PDE that the adjacent landowner has a trailer or structure that encroaches into the project limits. The structure locations should be verified with survey during the final design phase and further communication with the property owner could be required.

3.4.6 Utilities

It is not anticipated that utilities will impact the design or construction of a retrofit stormwater control measure at Site #2. However, the location of utilities should be verified through survey during the final design phase.

3.5 Preliminary SCM Retrofit Design

3.5.1 SCM Selection Process

Site #2 is located within a PDE that is approximately 650 feet long by 35 feet wide. Due to the narrow working area, the depth and width of potential excavation is extremely limited. The depth relative to the PDE limits also is the constraining factor in having the ability to day-light the existing outfall pipe. The existing drainage ditch provides previously excavated storage area that can be used to impound stormwater runoff. Therefore, impounding stormwater by using a series of weir spillways within the ditch appears to be the most economical solution. This design approach also enables the footprint of disturbance and required working area to be minimized, which is important at Site #2 due to the impacts of the tight constraints on site access.

3.5.2 Hydrologic Trespass

It is not anticipated that hydraulic trespass will be an issue if a stormwater control measure is installed at Site #2. However, during the design phase an assessment of the impacts of a stormwater control measure to the drainage system along NC-24 and adjacent properties should be examined. Hydraulic trespass should be considered during the design, and the final design invert elevations should be altered in order to avoid trespass issues.

3.5.3 Design Features

The proposed retrofit design includes a series of weir check dams and a large forebay/maintenance area at the upstream end of the stormwater control measure (see Sheet No. 2, Appendix 2). It is possible that a detailed topographic survey during the final design phase will show that approximately the same amount of stormwater can be impounded with a single weir check dam instead of two in series. If the underlying soils do not infiltrate at an acceptable rate, then the weir structure(s) would be constructed with a drawdown orifice and the stormwater control measure would function as an extended dry-detention basin. Since access for continued operation and maintenance could be somewhat limited, a large forebay would be installed at the existing pipe outfall. It is anticipated that the forebay would capture the majority of debris and sediment, and would limit periodic maintenance to the forebay area rather than being required to traverse the entire length of the project limits.

3.5.4 Estimated Treatment

The depth of runoff treated within the proposed stormwater control measure was estimated for both the entire contributing drainage area and for only the area within the NCDOT right-of-way. Approximately 2.9 acres or 15% of the contributing 18.8 acre drainage area is impervious cover within the NCDOT right-of-way.

Estimated depth treated for total drainage area = 0.20 inches

Estimated depth treated for only NCDOT impervious area = 0.60 inches

3.5.5 Preliminary Opinion of Construction Costs

A detailed breakdown of the preliminary opinion of construction cost is shown in Appendix 2. It is anticipated that whether the proposed retrofit at Site #2 functions as an extended dry-detention or infiltration basin, the construction cost would be about the same.

Site #2 – Construction Cost Opinion = $46,400

3.6 Conclusions and Recommendations

3.6.1 Summary of Site Assessment Findings

Site #2 is viable as a potential stormwater retrofit location. The presence of an existing PDE provides adequate area to treat a portion of the runoff from the NCDOT right-of-way. The existing topography and elevations of the existing drainage system and ditch provide sufficient elevation change to facilitate positive drainage through a stormwater control measure. This elevation change and the relatively high overall site elevation in relationship to receiving waters, makes Site #2 a feasible stormwater retrofit site, which often times is a rarity within the coastal environment.

3.6.2 Overall Constructability

The construction of a proposed stormwater retrofit at Site #2 is feasible, but could offer challenges due to the relatively tight site constraints. The most difficult construction task will be traversing the narrow working area during the material delivery process, particularly supplying concrete and rip rap for the proposed weir structures. Also, in order for construction traffic to safety enter and exit NC 24 some traffic control measures may be needed during the construction process.

3.6.3 Cost Relative to Median Retrofit Costs

In comparison to other stormwater control measures that treat a similar volume of runoff within an urban coastal environment, it is estimated that the proposed retrofit at Site #2 would be close to the median costs for other retrofits. The use of cast-in-place concrete for the weir structures and the site access constraints could raise the cost above the compared median retrofit costs of similar extended dry-detention/infiltration basins. Table 1.3.2 shows a comparison of construction cost relative to treatment and removal efficiency.

3.6.4 Additional Study Required for Final Design

Before proceeding to the final design scoping phase, a soils investigation should be performed by a soil scientist at the site. The soils investigation will show the depth to the seasonal high water table, and it will determine the soil infiltration rates. The parameters determined in the soil investigation will dictate whether the final design is an extended dry-detention basin or linear infiltration basin.

The R-2105AA construction drawings indicate a spring potentially within the construction limits for Site #2. This area needs to be delineated during the soils investigation before proceeding to final design scoping. It will require permitting if a wetland is determined to exist and cannot be avoided. Based on mapping and aerial photography, the drainage channel does not appear to be a jurisdictional stream, but would need to be verified during this same soils investigation process.

There appears to be a trailer structure located within the limits of the permanent drainage easement. The exact location should be determined by survey during the final design phase. If the structure is located within the easement, then actions and/or negotiations will need to take place to have it relocated.

4. Site #3 – NC-24 west of Old NC-58

4.1 Project Site Vicinity Map

Figure 4.1 shows the approximate site limits outlined in red. The project site is located within the NCDOT right-of-way along NC-24 (Cedar Point Boulevard) in Cedar Point, NC. The existing site conditions are shown on Sheet 1 in Appendix 3.

Figure 4.1. Site #1 Vicinity Map

4.2 Contributing Drainage Area

The size and boundary of the drainage area that contributes runoff to Site #3 is shown on the Drainage Area Map in Appendix 3. The drainage area drains a portion of the NC-24 corridor within the Town of Cedar Point; the runoff is mostly conveyed through a closed storm drainage system. The downstream end of the project site limits captures a drainage area of approximately 36.3 acres and has an estimated impervious cover of 19.0 %.

4.3 Land Use and Development Trends

The land use and current impervious cover estimates were determined using Carteret County GIS data and 2010 digital aerial photos (see Drainage Area Map in Appendix 3). The contributing drainage area has a relatively low percentage of impervious cover; there is a substantial amount of open space areas that could be developed in the future. If a stormwater retrofit project is developed at Site #3, the impacts of future development within the drainage basin should definitely be considered in the design.

4.4 Existing Site Conditions

4.4.1 Geology and Soils

The Carteret County Soil Survey (Soil Survey, 2012) identifies one soil type within Site #3.

Soil Mapping Unit	Mapping Unit	Drainage Class	Hydric Status
Arapahoe fine sandy loam	Ap	Very Poorly Drained	Hydric

Table 4.4.1. Soils within Site #3

Arapahoe fine sandy loam is nearly level, is considered to be very poorly drained, hydric soil. It is found on broad flats and in depressions on low marine and stream terraces. Typically, the surface layer is black and very dark gray fine sandy loam to 23 inches, and the subsoil is dark grayish brown fine sandy loam to a depth of 36 inches. The underlying material is light brownish gray loamy sand and sand to a depth of 72 inches. Arapahoe can be prime farmland if it is drained.

Site #3 is located within the outer coastal plain physiographic region of North Carolina. This portion of Carteret County is mapped as "surficial deposits" by the NC Geological Survey (Rhodes, 1985). Surficial deposits are described as sand, clay, gravel, and peat deposited in marine and other environments. The NCDWR Ground-Water Bulletin No. 1 (LeGrand, 1960) describes the area as deposits of quaternary age, primarily sand with subordinate amounts of clay. It also states that shell rock and loose shells are more prevalent in the lower part of the formation.

4.4.2 Topography

The existing topography of Site #3 as shown on Figure 4.1 is relatively flat. Since the low point within the Site #3 project limits is a roadway sag point, the longitudinal slope along the working area is flat at approximately 0.5% or less.

4.4.3 Natural and Human Environment

<u>Summary</u>
The preliminary review of Site #3 found that potential jurisdictional features may prevent or require close coordination to avoid impacts to jurisdictional waters during construction of Site #3. No other likely environmental constraints were found that would prevent implementation of a stormwater retrofit project at Site #3. This conclusion was reached by using the information provided in the following subsections.

<u>Threatened & Endangered Species</u>
A review of the NC Natural Heritage Program GIS database (NCNHP, 2012) showed no recorded federally threatened or endangered species within 1 mile of the project site. In addition, the list of threatened and endangered species for Carteret County was obtained from the US Fish and Wildlife Service (USFWS Region 4, 2012) and reviewed for its potential relevance to the site.

Federally Listed Species in Carteret County

Common Name	Scientific name	Federal Status	Record Status
American alligator	*Alligator mississippiensis*	T (S/A)	Current
Green sea turtle	*Chelonia mydas*	T	Current
Hawksbill (=carey) sea turtle	*Eretmochelys imbricata*	E	Historic
Kemp's (=Atlantic) ridley sea turtle	*Lepidochelys kempii*	E	Current
Leatherback sea turtle	*Dermochelys coriacea*	E	Current
Loggerhead sea turtle	*Caretta caretta*	T	Current
Piping plover	*Charadrius melodus*	T	Current
Red-cockaded woodpecker	*Picoides borealis*	E	Current
Roseate tern	*Sterna dougallii dougallii*	T	Current
Shortnose sturgeon	*Acipenser brevirostrum*	E	Current
West Indian manatee	*Trichechus manatus*	E	Current
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	E	Current
Seabeach amaranth	*Amaranthus pumilus*	T	Current

Based on existing GIS data and aerial photography, it appears that Site #3 could contain suitable habitat for rough-leaved loosestrife. A site survey should be conducted if the site is selected for design.

Carteret County has designated critical habitat for the wintering piping plover. The critical habitat maps from the US Fish and Wildlife Service were reviewed (USFWS, 2012), and it appears that only the designated critical habitat area NC-6 is located within Carteret County. This designated critical habitat area is located along the Outer Banks stretching west of Ocracoke Inlet and is not near Site #3.

Water Resources

Carteret County is one of North Carolina's twenty designated coastal counties and is subject to the Coastal Area Management Act (CAMA). The study area is located within the White Oak River basin [U.S. Geological Survey (USGS) Hydrologic Unit 03020301]. No stream is shown within Site #3 on either the USGS map or the Carteret County Soil Survey map (USDA, 1987). It appears from aerial photography that Site #3 might be at or very near to the headwater of Boathouse Creek. Boathouse Creek is listed as a high quality water (SA-HQW) by the DWQ (NCDWQ, 2011). Within 1 mile of Site #3, Boathouse Creek drains into the White Oak River. Anadromous fish spawning area maps from NC Marine Fisheries (NCMF, 2007) were reviewed and portions of the White Oak River were found to be designated anadromous fish spawning areas. However, all designated spawning areas were a considerable distance upstream of the Site and Boathouse Creek was not shown as an anadromous fish spawning area. This section of the White Oak River is also designated Essential Fish Habitat (EFH) by the National Marine Fisheries Service. The Coastal Barrier Resources Act (CBRA) maps were reviewed (NMFS, 2012), and Site #3 was not found to be located within a designated CBRA area. There are no water supply watersheds within 1 mile downstream of the study area. Site #3 may impact jurisdictional waters or wetlands based on available data and

depending on the limits of construction. A site assessment/delineation to confirm this should be conducted if the site is selected for design.

Historic Places

The NC State Historic Preservation Office (NCSHPO) list of National Register of Historic Places for Carteret and Onslow Counties were reviewed (NCSHPO, 2012) to determine if any listed sites were in the vicinity of Site #3. No listed sites were found to be near the site. No archaeological features of significance are anticipated within Site #3 due to the disturbed nature of the site, but a letter requesting confirmation should be provided to NCSHPO if the site is selected for design.

4.4.4 Right-of-Way and Easements

The project site is located within the 100 feet wide NCDOT right-of-way that contains NC-24. There are no additional easements or right-of-way within the vicinity of the project site.

4.4.5 Property Ownership and Site Access

The site would be accessed from the NCDOT right-of-way along NC-24. If additional access and/or staging areas are required, then temporary construction easements would need to be acquired.

4.4.6 Utilities

Within the Site #3 project limits there is an 8-inch plastic water main located on the north side of NC-24 within the right-of-way, and there are also telephone and cable lines within the right-of-way. If excavation is done between the edge of NC-24 and the right-of-way limits, then these utilities will likely have to be relocated. The location of utilities should be verified through survey during the final design phase.

4.5 Preliminary SCM Retrofit Design

4.5.1 SCM Selection Process

The proposed area for Site #3 is confined to the working area between the edge of NC-24 and its 100 feet wide right-of-way limits. The site assessment shows that a stormwater control measure near the drainage area outfall would not only require additional easement area, but could potentially impact jurisdictional waters. One potential solution would be to use Filtera boxes or something similar along NC-24 to achieve some treatment. However, this solution would be expensive relative to the amount of stormwater runoff that would receive treatment, and treatment boxes in close proximity to NC-24 could cause safety concerns.

4.5.2 Hydrologic Trespass

A proposed stormwater retrofit at Site #3 would be located linearly within the NC-24 right-of-way, and would likely be directly connected to the existing drainage system. During the design phase an assessment of the impacts of a stormwater control measure to the drainage system along NC-24 and

adjacent properties should be examined, and the final design invert elevations should be altered in order to avoid trespass issues.

4.5.3 Design Features

In order to design a stormwater retrofit within the vicinity of Site #3, it would require an innovative design that would not be cost effective in comparison to Sites #1 and #2. Therefore, further investigation into a preliminary design plan was not completed for this Study.

4.5.4 Estimated Treatment

A preliminary design was not completed for this site, therefore treatment was not estimated.

4.5.5 Preliminary Opinion of Construction Costs

A preliminary design was not completed for this site; therefore a preliminary opinion of construction cost was not done.

4.6 Conclusions and Recommendations

4.6.1 Summary of Site Assessment Findings

In order to design a stormwater retrofit within the vicinity of Stie #3, it would require an innovative design that would not be cost effective in comparison to Sites #1 and #2. Therefore, further investigation into a preliminary design plan was not completed for this Study.

4.6.2 Additional Study Required for Final Design

It is recommended that no additional study should be done a Site #3 at this time.

5. Site #4 – Along Eastbound Shoulder of VFW Road

5.1 Project Site Vicinity Map

Figure 4.1 shows the approximate site limits outlined in red. The project site is located within the NCDOT right-of-way near the intersection of Old Highway 58 and VFW Road in Cedar Point, NC. The existing site conditions are shown in Appendix 4.

Figure 5.1. Site #4 Vicinity Map

5.2 Contributing Drainage Area

The Site Drainage Area Map in Appendix 4 shows the drainage patterns at Site #4. It was determined through field reconnaissance that Site #4 actually does not drain into the Southeast White Oak River TMDL watershed; it drains into an adjacent White Oak Sub-basin.

5.3 Conclusions and Recommendations

Site #4 was originally selected by NCDOT as a potential stormwater control measure retrofit site to help improve water quality within the Southeast White Oak River TMDL watershed. It was determined early during the development of this Assessment Report that Site #4 did not drain into the Southeast White Oak River TMDL watershed. Therefore, no further assessment was done for the site, and the site should not be included as viable stormwater retrofit for the purposes of this Assessment Report.

6. References

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Site #2 – Sht. No. 15 and 18 – Sta 165+54 Lt.

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March 2010. Prepared for US-EPA – Region 1
Prepared by Tetra Tech, Inc.
http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf

Appendix 1 – Site #1

Site Photographs

Site Base Mapping

Site Drainage Area Map

Site Preliminary Design Plans and Profile (Options #1 and #2)

Preliminary Design – Opinion of Probable Construction Costs

Site #1 Photographs

Standing in PDE (looking u.s. towards NC-24)

Standing in PDE (looking d.s. towards oufall)

Standing on edge of Bluff Rd. (looking u.s. at NC-24)

8/17/99

REVISIONS

SITE #1 BASE MAPPING

PROJECT REFERENCE NO.	SHEET NO.
SITE #1	1

R/W SHEET NO.

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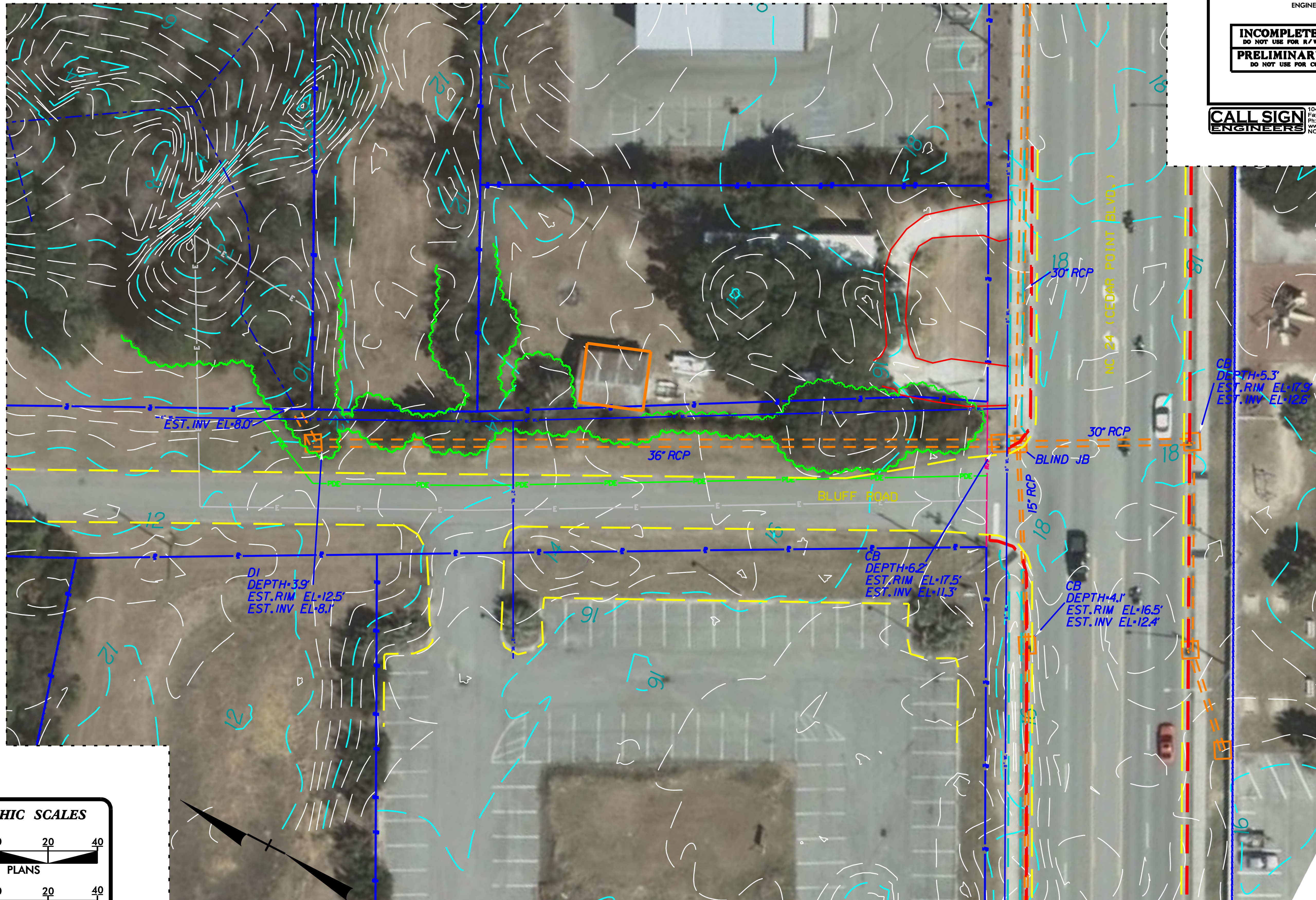

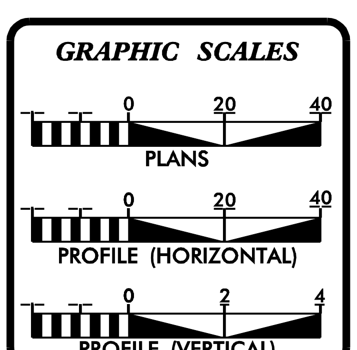

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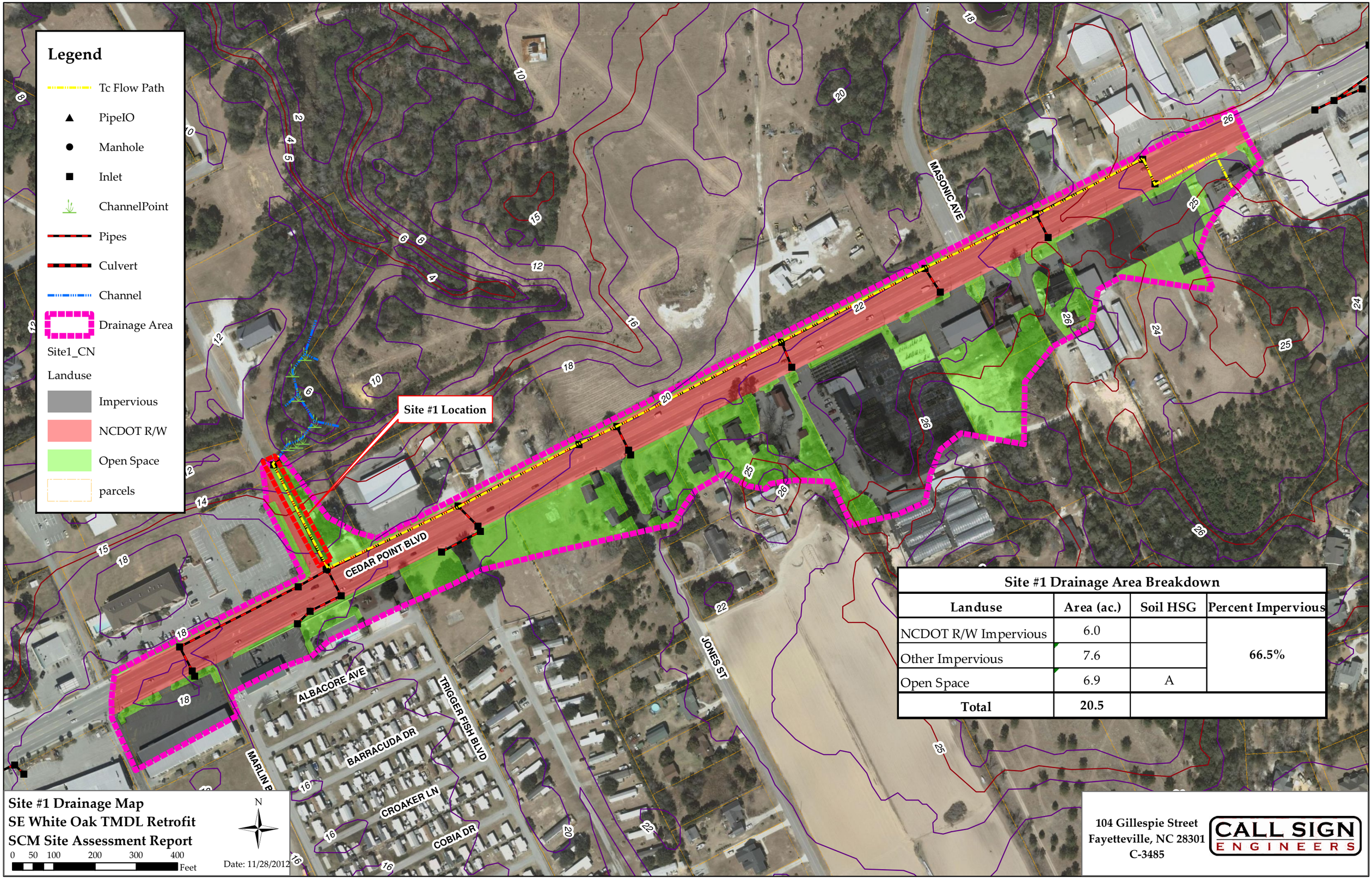


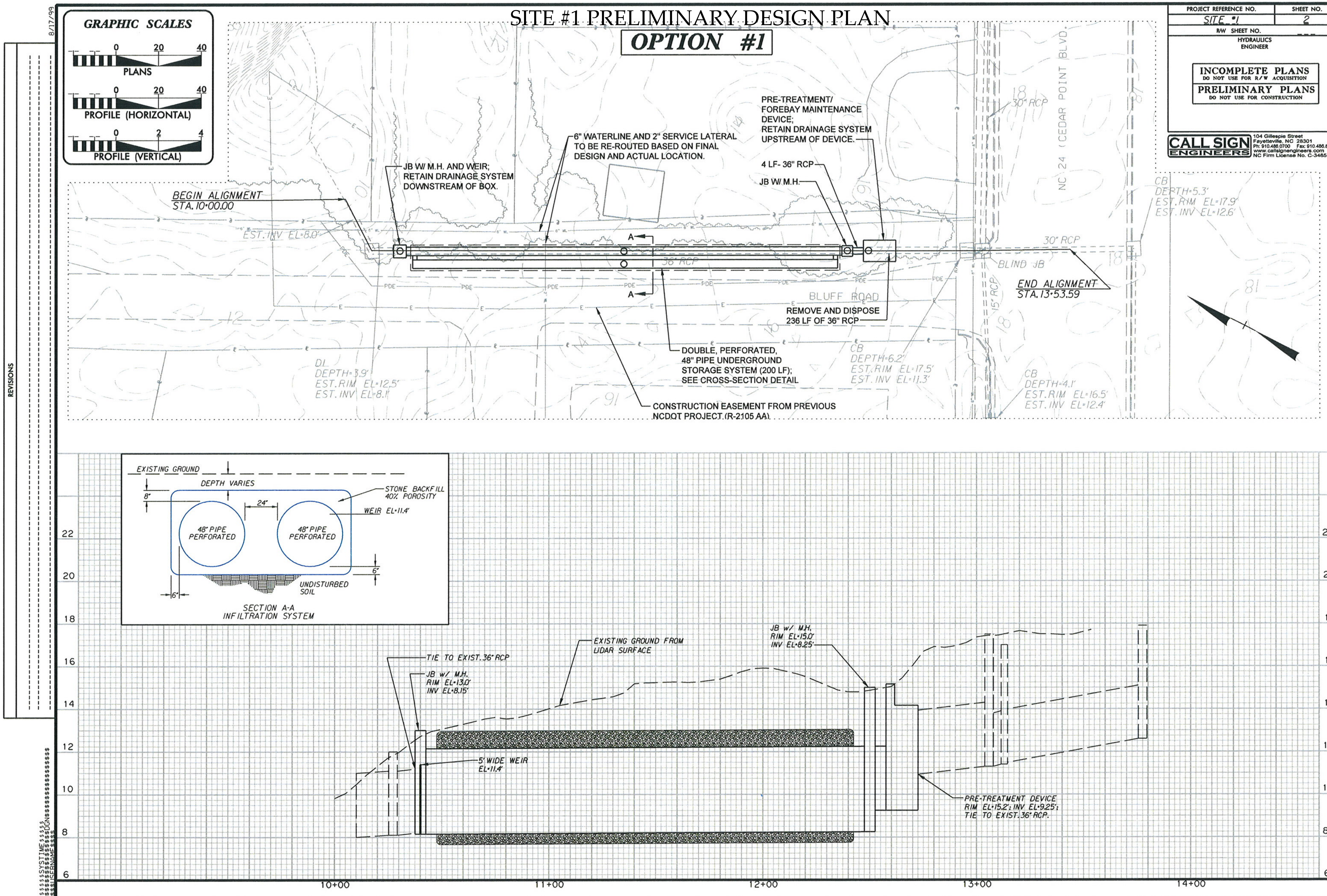
Site #1 Drainage Area Breakdown

Landuse	Area (ac.)	Soil HSG	Percent Impervious
NCDOT R/W Impervious	6.0		66.5%
Other Impervious	7.6		
Open Space	6.9	A	
Total	**20.5**		

Site #1 Drainage Map
SE White Oak TMDL Retrofit
SCM Site Assessment Report

SITE #1 PRELIMINARY DESIGN PLAN

OPTION #1



PROJECT REFERENCE NO.	SHEET NO.
SITE #1	2
R/W SHEET NO.	---

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SITE #1 PRELIMINARY DESIGN PLAN

OPTION #2

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SITE #1	3
R/W SHEET NO.	

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REVISIONS

GRAPHIC SCALES
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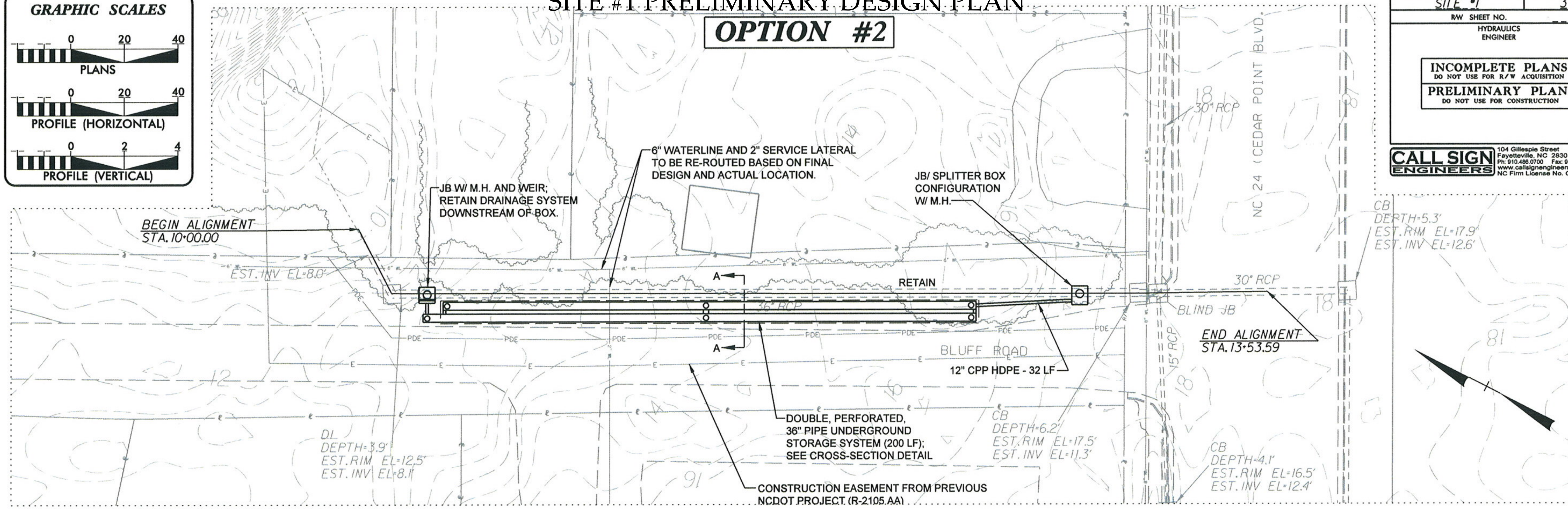
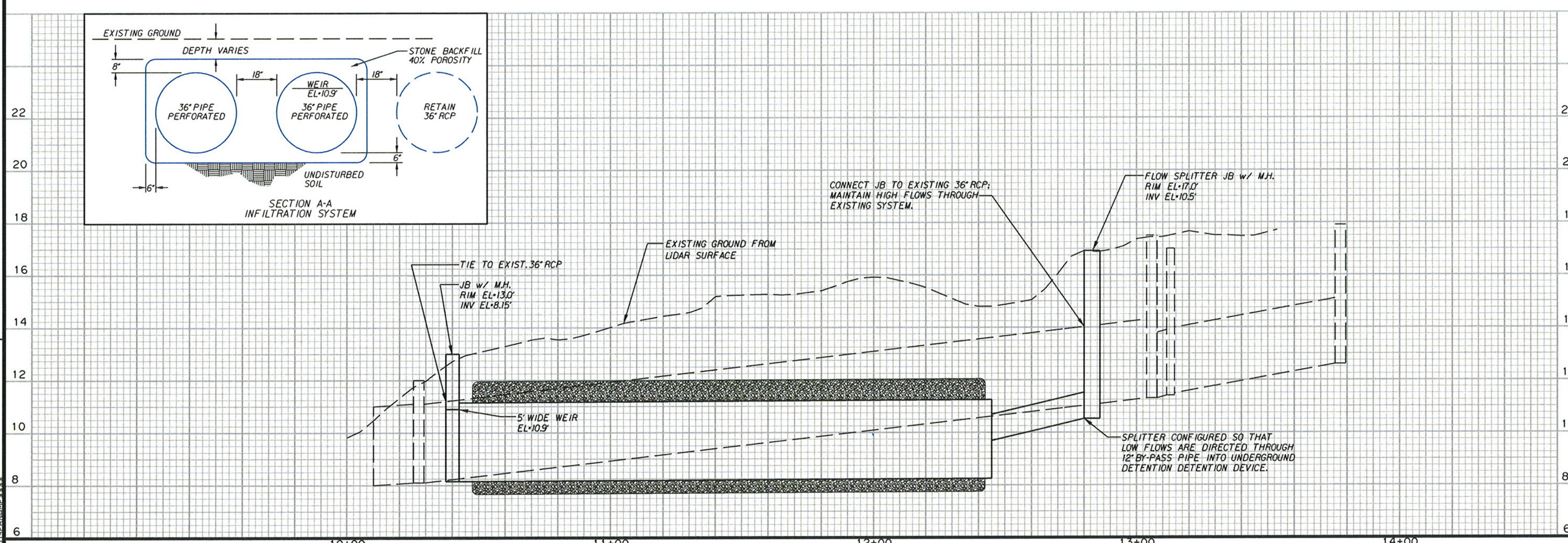
PROFILE (HORIZONTAL) 0 20 40
PROFILE (VERTICAL) 0 2 4





North Carolina Department of Transportation
Engineer's Opinion of Probable Construction Cost

TIP No.	**Site#1 - Option#1**	**Prelim.**	County:	**Carteret**
Route	SE White Oak Stormwater Retrofit Site Assesment			
From				**Estimate**
Typical Section				**$87,120**

Prepared By: C.H. Wadsworth, PE (Call Sign Engineers, PA) Date 10/10/2012
Requested By: Andrew McDaniel, PE (NCDOT Stormwater) Date 6/1/2012

Line Item	Sec No.	Description	Quantity	Unit	Price	Amount
1	Std. Specs.	Clearing and Grubbing	0.1	AC	$ 2,000.00	$ 200.00
2	Std. Specs.	Remove and Dispose 36" RCP	236	LF	$ 17.50	$ 4,130.00
3	Std. Specs.	48" RCP	4	LF	$ 55.00	$ 220.00
4	Std. Specs.	48" Perforated HDPE Infiltratinon System	400	LF	$ 65.00	$ 26,000.00
5	Std. Specs.	Drainage Struct. - Junction Box	2	EA	$ 2,250.00	$ 4,500.00
6	Std. Specs.	Manhole (Frame with Cover)	2	EA	$ 500.00	$ 1,000.00
7	Std. Specs.	Pre-treatment Device Structure	1.0	LS	$ 12,500.00	$ 12,500.00
8	Std. Specs.	Sediment Control Stone, Standard No. 5 or 57	320	Ton	$ 55.00	$ 17,600.00
9	Std. Specs.	Misc. Erosion & Sediment Control	1	LS	$ 250.00	$ 250.00
10	Std. Specs.	Seeding & Mulcing	0.1	AC	$ 2,500.00	$ 250.00
11	Std. Specs.	Relocate 6" Waterline	1	LS	$ 7,500.00	$ 7,500.00
12	Std. Specs.	Relocate 2" Water Lateral	1	LS	$ 1,250.00	$ 1,250.00
13	Std. Specs.	Mobilization	1	LS		$ 3,800.00

Lgth

Contract Cost	…….	……..	……..	$ 79,200.00
Cont. 10%	…….	……..	……..	$ 7,920.00
Construction Cost	…….	……..	……..	**$ 87,120.00**

North Carolina Department of Transportation
Engineer's Opinion of Probable Construction Cost

TIP No.	**Site#1 - Option#2**	**Prelim.**	County:	**Carteret**
Route	SE White Oak Stormwater Retrofit Site Assesment			
From				**Estimate**
Typical Section				**$57,233**

Prepared By: C.H. Wadsworth, PE (Call Sign Engineers, PA) Date 10/10/2012
Requested By: Andrew McDaniel, PE (NCDOT Stormwater) Date 6/1/2012

Line Item	Sec No.	Description	Quantity	Unit	Price	Amount
1	Std. Specs.	Clearing and Grubbing	0.1	AC	$ 2,000.00	$ 200.00
2	Std. Specs.	Remove and Dispose 36" RCP	12	LF	$ 22.50	$ 270.00
3	Std. Specs.	36" Perforated HDPE Infiltratinon System	400	LF	$ 50.00	$ 20,000.00
4	Std. Specs.	12" CPP HDPE	32	LF	$ 17.50	$ 560.00
5	Std. Specs.	Drainage Struct. - Junction Box	2	EA	$ 2,250.00	$ 4,500.00
6	Std. Specs.	Manhole (Frame with Cover)	2	EA	$ 500.00	$ 1,000.00
7	Std. Specs.	Sediment Control Stone, Standard No. 5 or 57	250	Ton	$ 55.00	$ 13,750.00
8	Std. Specs.	Misc. Erosion & Sediment Control	1	LS	$ 250.00	$ 250.00
9	Std. Specs.	Seeding & Mulcing	0.1	AC	$ 2,500.00	$ 250.00
10	Std. Specs.	Relocate 6" Waterline	1	LS	$ 7,500.00	$ 7,500.00
11	Std. Specs.	Relocate 2" Water Lateral	1	LS	$ 1,250.00	$ 1,250.00
12	Std. Specs.	Mobilization	1	LS		$ 2,500.00

Lgth

Contract Cost	…….	……..	……..	$ 52,030.00
Cont. 10%	…….	……..	……..	$ 5,203.00
Construction Cost	…….	……..	……..	**$ 57,233.00**

Appendix 2 – Site #2

Site Photographs

Site Base Mapping

Site Drainage Area Map

Site Preliminary Design Plans and Profile

Preliminary Design – Opinion of Probable Construction Costs

Site #2 Photographs

30-inch outfall pipe (looking d.s.)

30-inch outfall pipe (looking u.s.)

J-Ditch (looking d.s.)

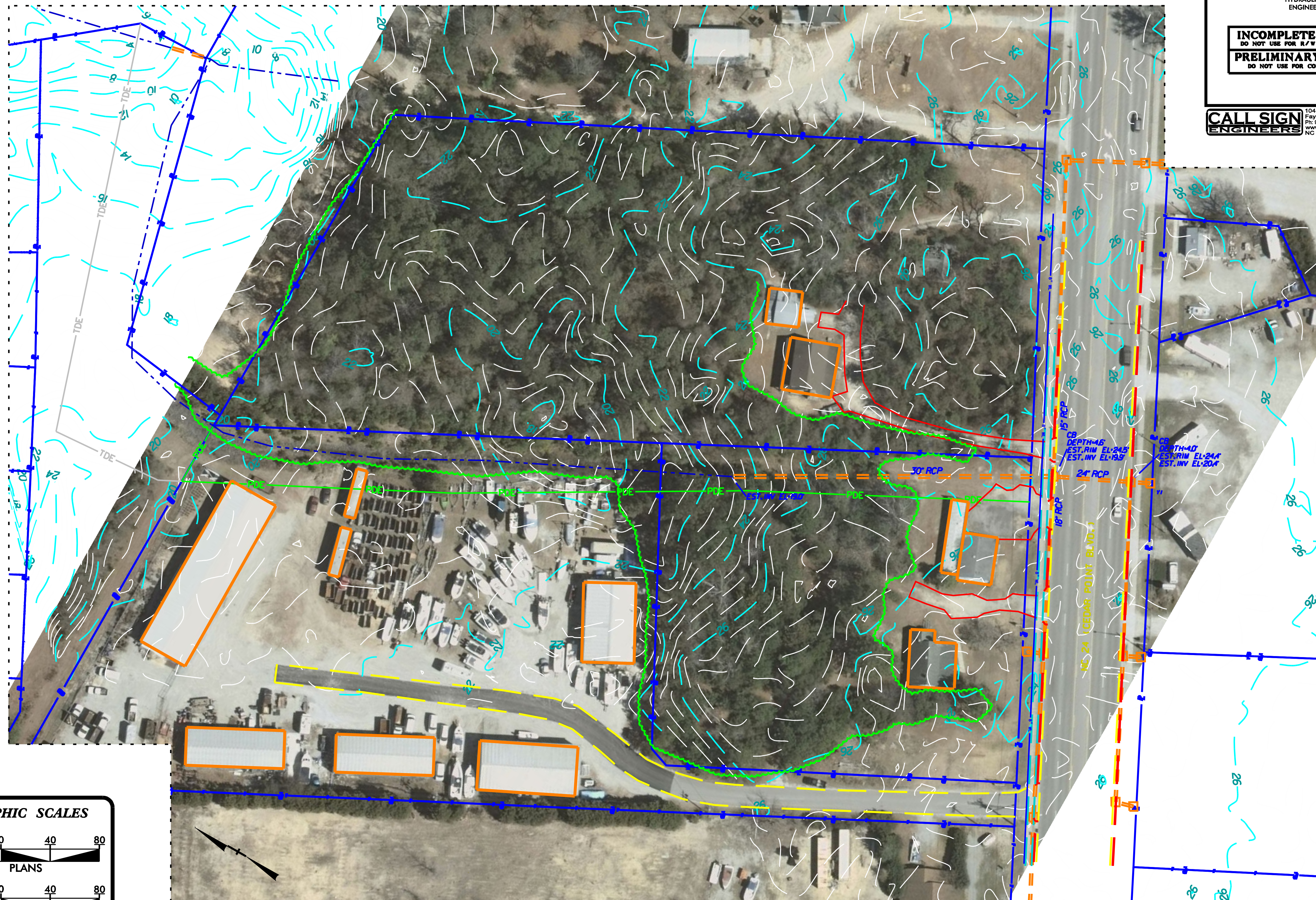
J-Ditch (looking u.s.)

Site #2 Access (looking d.s., from NC-24)

8/17/99

REVISIONS

SITE #2 BASE MAPPING



PROJECT REFERENCE NO.	SHEET NO.
SITE #2	1
R/W SHEET NO.	

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GRAPHIC SCALES

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PLANS

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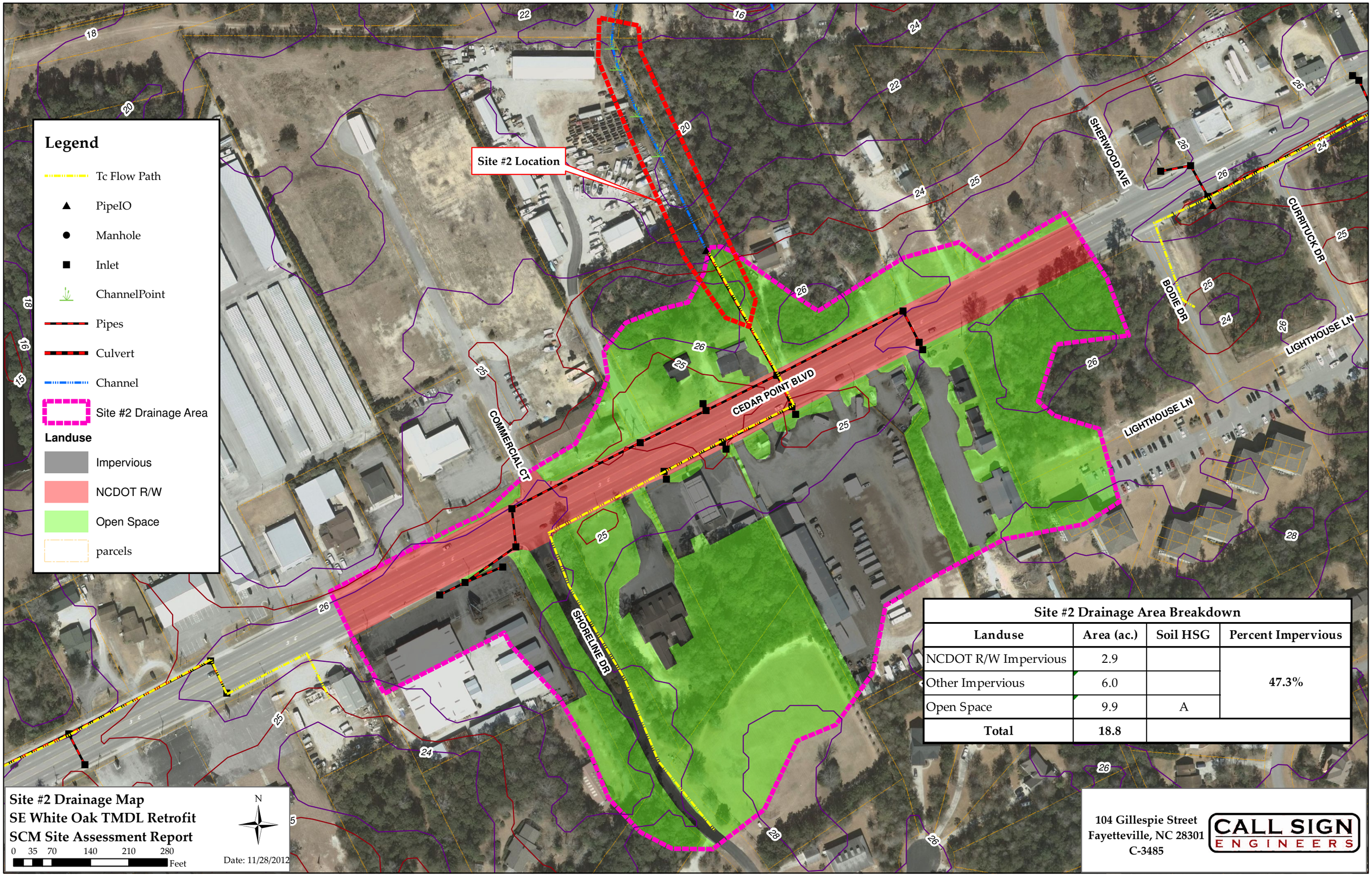
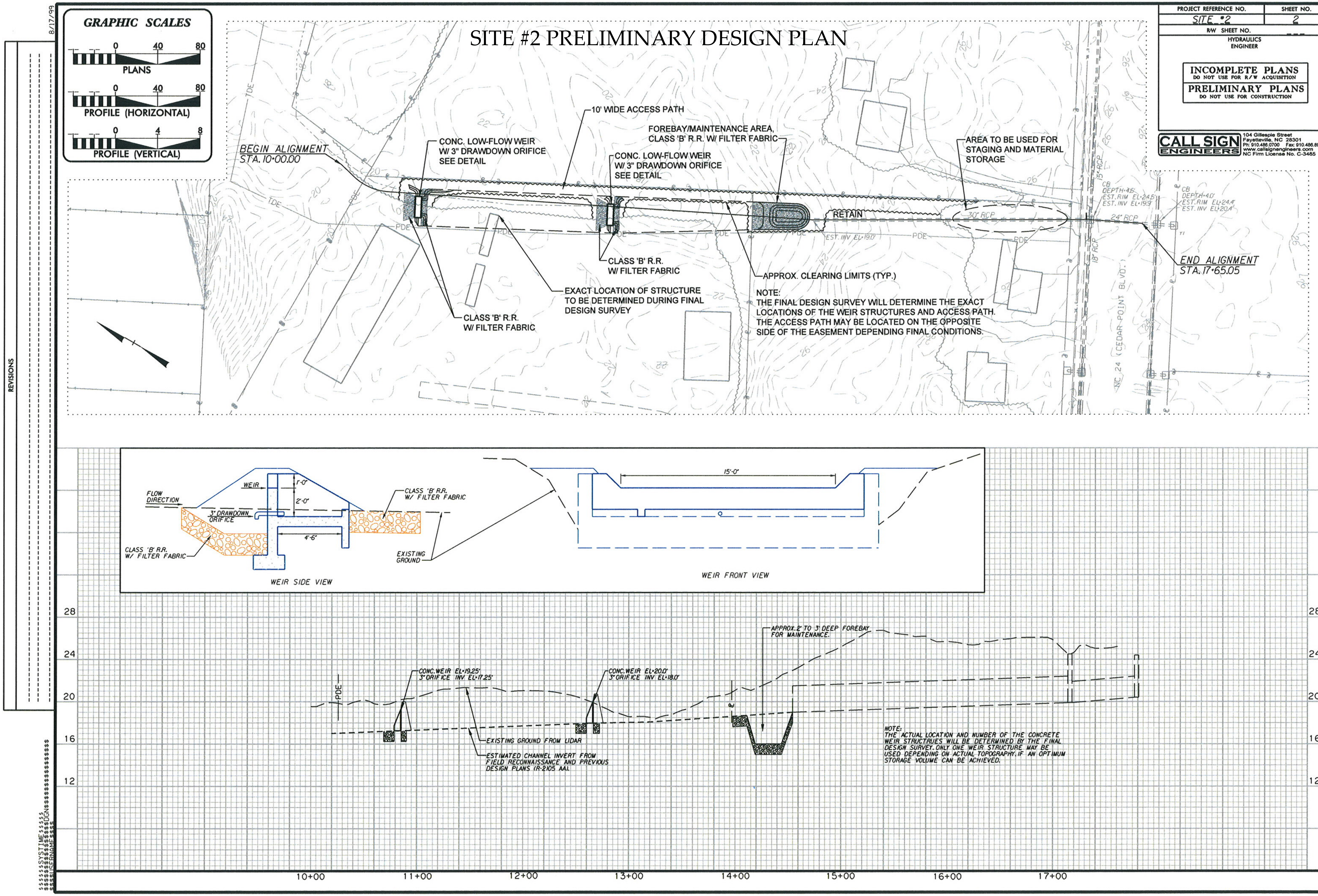


Site #2 Drainage Area Breakdown

Landuse	Area (ac.)	Soil HSG	Percent Impervious
NCDOT R/W Impervious	2.9		47.3%
Other Impervious	6.0		
Open Space	9.9	A	
Total	**18.8**		

Site #2 Drainage Map
SE White Oak TMDL Retrofit
SCM Site Assessment Report

SITE #2 PRELIMINARY DESIGN PLAN



North Carolina Department of Transportation
Engineer's Opinion of Probable Construction Cost

TIP No.	**Site#2**	**Prelim.**	County:	**Carteret**
Route	SE White Oak Stormwater Retrofit Site Assesment			
From				**Estimate**
Typical Section				**$46,420**

Prepared By: C.H. Wadsworth, PE (Call Sign Engineers, PA) Date 10/10/2012
Requested By: Andrew McDaniel, PE (NCDOT Stormwater) Date 6/1/2012

Line Item	Sec No.	Description	Quantity	Unit	Price	Amount
1	Std. Specs.	Earthwork	1	LS	$ 2,500.00	$ 2,500.00
2	Std. Specs.	Clearing and Grubbing	0.2	AC	$ 7,500.00	$ 1,500.00
3	Std. Specs.	Concrete Weir #1	8	CY	$ 1,750.00	$ 14,000.00
4	Std. Specs.	Concrete Weir #2	8	CY	$ 1,750.00	$ 14,000.00
5	Std. Specs.	Plain Rip Rap, Class 'B'	90	Ton	$ 55.00	$ 4,950.00
6	Std. Specs.	Non-Woven, Type 2 Filter Fabric	230	SY	$ 5.00	$ 1,150.00
7	Std. Specs.	Misc. Erosion & Sediment Control	1	LS	$ 500.00	$ 500.00
8	Std. Specs.	Seeding & Mulcing	0.2	AC	$ 2,500.00	$ 500.00
9	Std. Specs.	Traffic Control	1	LS	$ 3,500.00	$ 3,500.00
10	Std. Specs.	Mobilization	1	LS		$ 2,100.00

Lgth

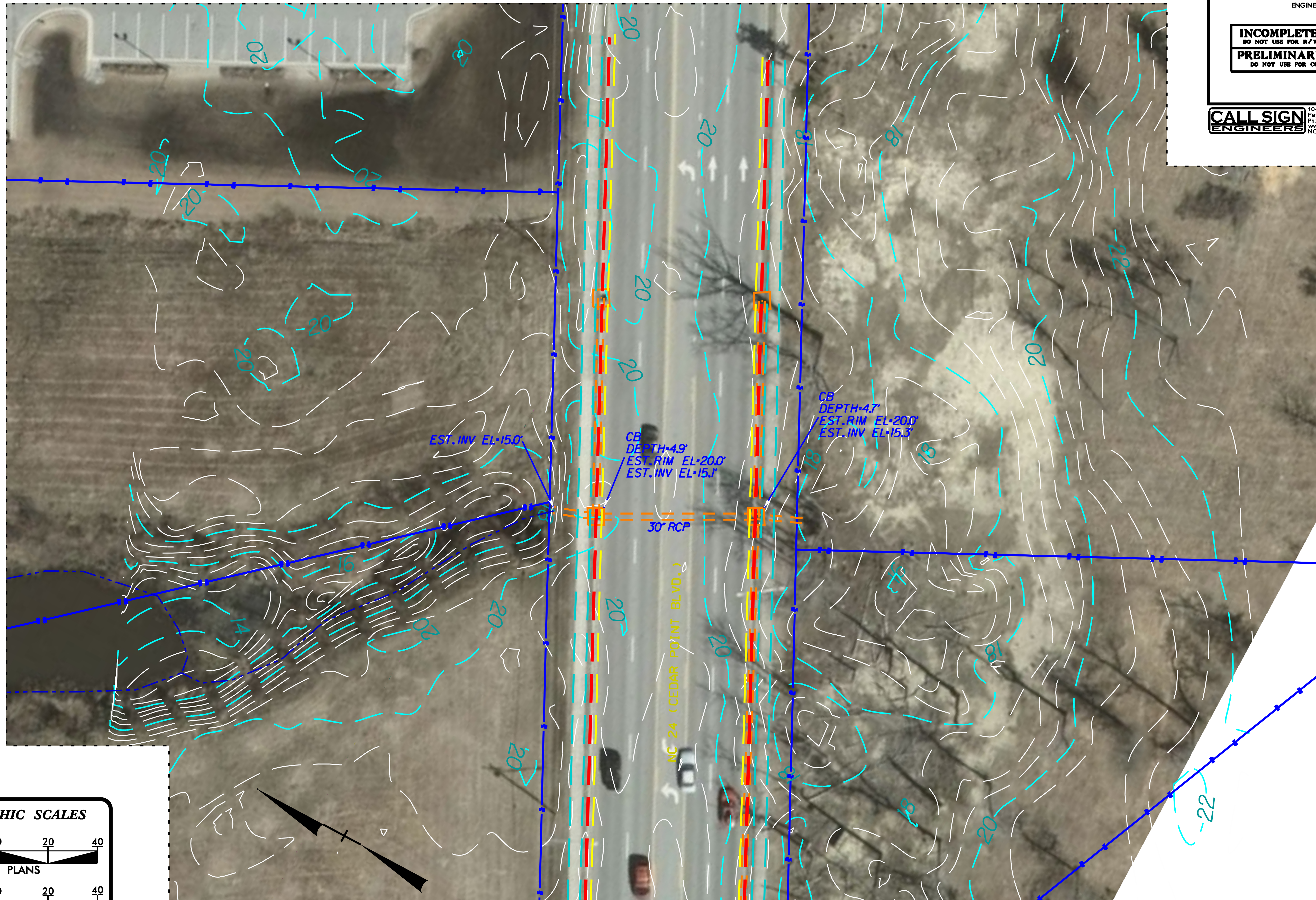
Contract Cost …….	……..	……..	$	42,200.00
Cont. 10% …….	……..	……..	$	4,220.00
Construction Cost …….	……..	……..	**$**	**46,420.00**

Appendix 3 – Site #3

Site Base Mapping

Site Drainage Area Map

SITE #3 BASE MAPPING



PROJECT REFERENCE NO.	SHEET NO.
SITE *	1
R/W SHEET NO.	

HYDRAULICS
ENGINEER

INCOMPLETE PLANS
DO NOT USE FOR R/W ACQUISITION

PRELIMINARY PLANS
DO NOT USE FOR CONSTRUCTION

CALL SIGN ENGINEERS
104 Gillespie Street
Fayetteville, NC 28301
Ph: 910.486.0700 Fax: 910.486.8900
www.callsignengineers.com
NC Firm License No. C-3485

REVISIONS

8/17/99

GRAPHIC SCALES

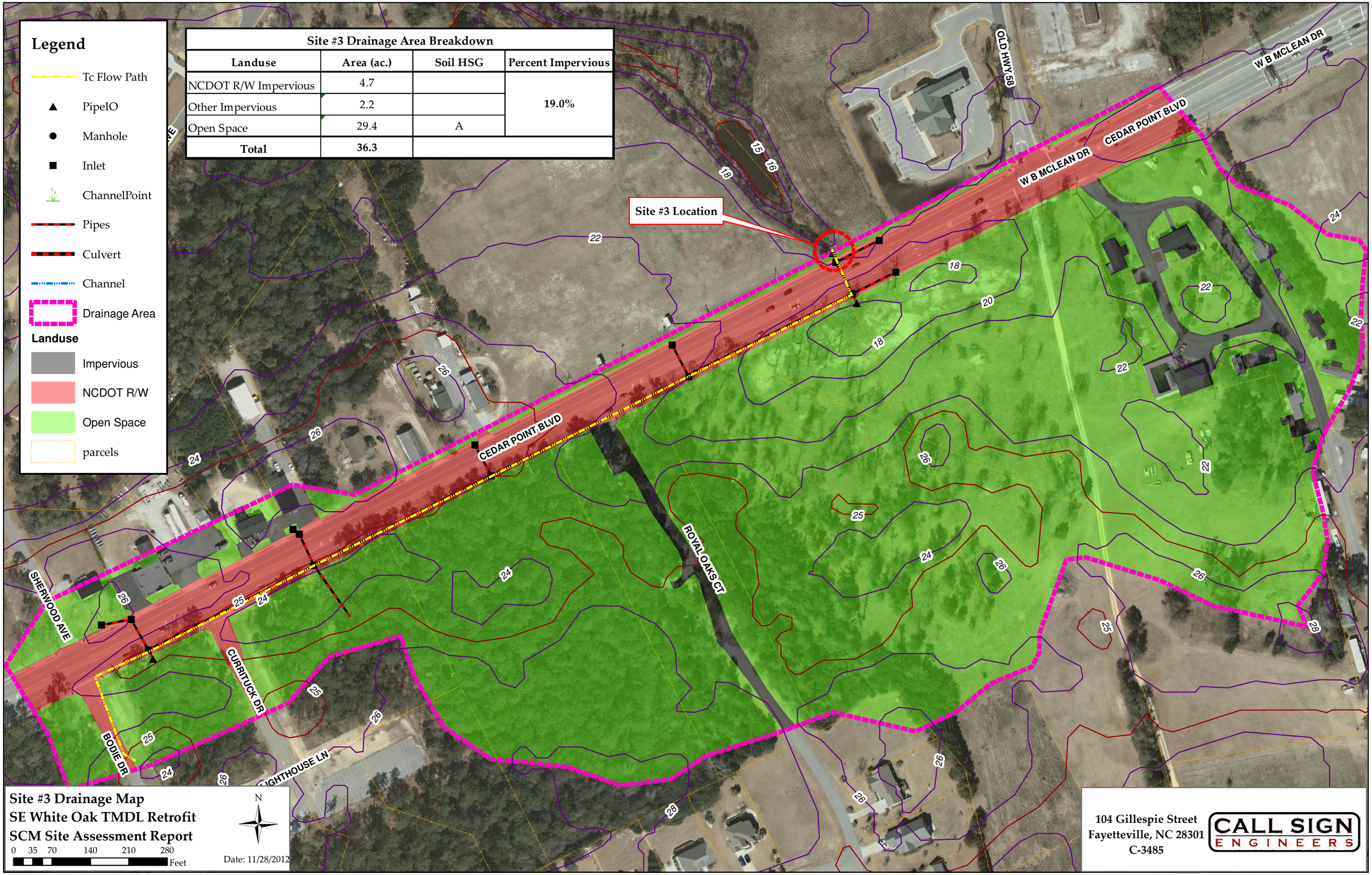
0 20 40
PLANS

0 20 40
PROFILE (HORIZONTAL)

0 2 4
PROFILE (VERTICAL)

$$$$$$SYSTIME$$$$$
$$$$$$$$$$$$$$$$DGN$$$$$$$$$$$$$$$
$$$$USERNAME$$$$

Site #3 Drainage Area Breakdown			
Landuse	Area (ac.)	Soil HSG	Percent Impervious
NCDOT R/W Impervious	4.7		19.0%
Other Impervious	2.2		
Open Space	29.4	A	
Total	36.3		



Site #3 Drainage Map
SE White Oak TMDL Retrofit
SCM Site Assessment Report

104 Gillespie Street
Fayetteville, NC 28301
C-3485

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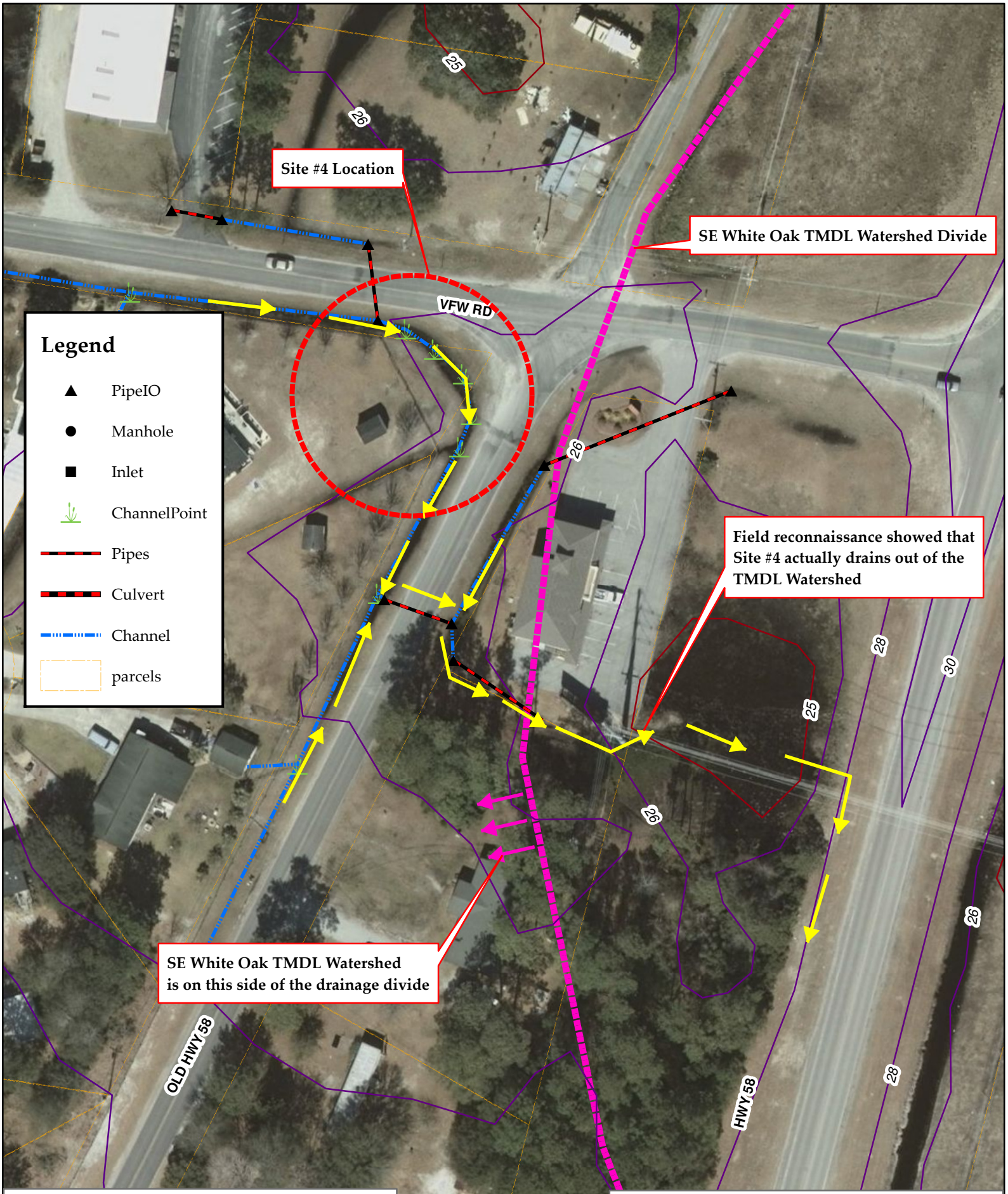
Appendix 4 – Site #4

Site Drainage Area Map



Site #4 Drainage Map
SE White Oak TMDL Retrofit
SCM Site Assessment Report

0 15 30 60 90 120 Feet

N

Date: 11/28/2012

104 Gillespie Street
Fayetteville, NC 28301
C-3485

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Appendix 5

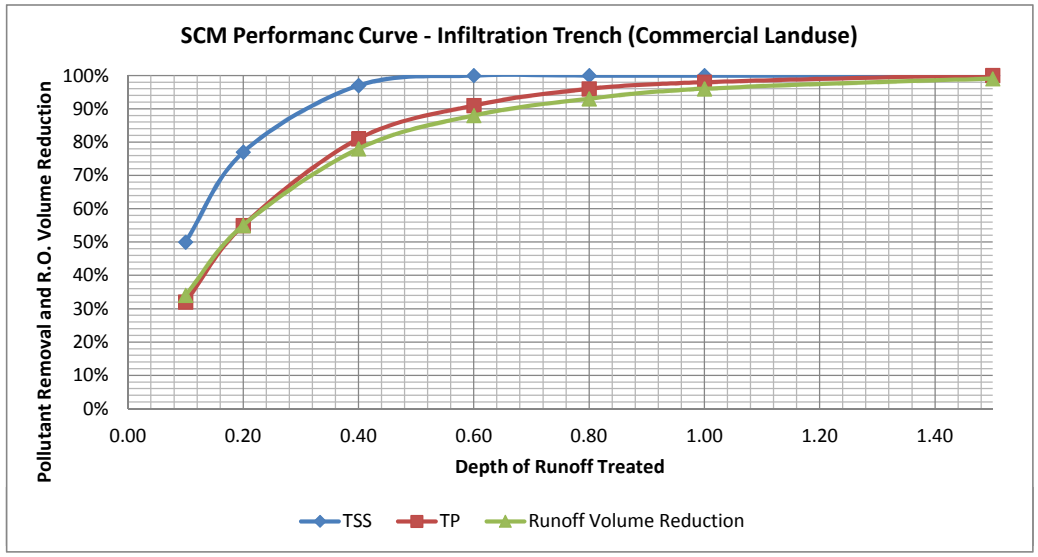
SCM Performance Curves
Developed from Tetra Tech Study (USEPA, 2010)

Runoff Volume Reduction	34%	55%	78%	88%	93%	96%	99%	100%

Annual Pollutant Loading Rates	TSS	TP
Pollutant Load (lbs/acre-yr)		
Commercial	1117.7	1.66

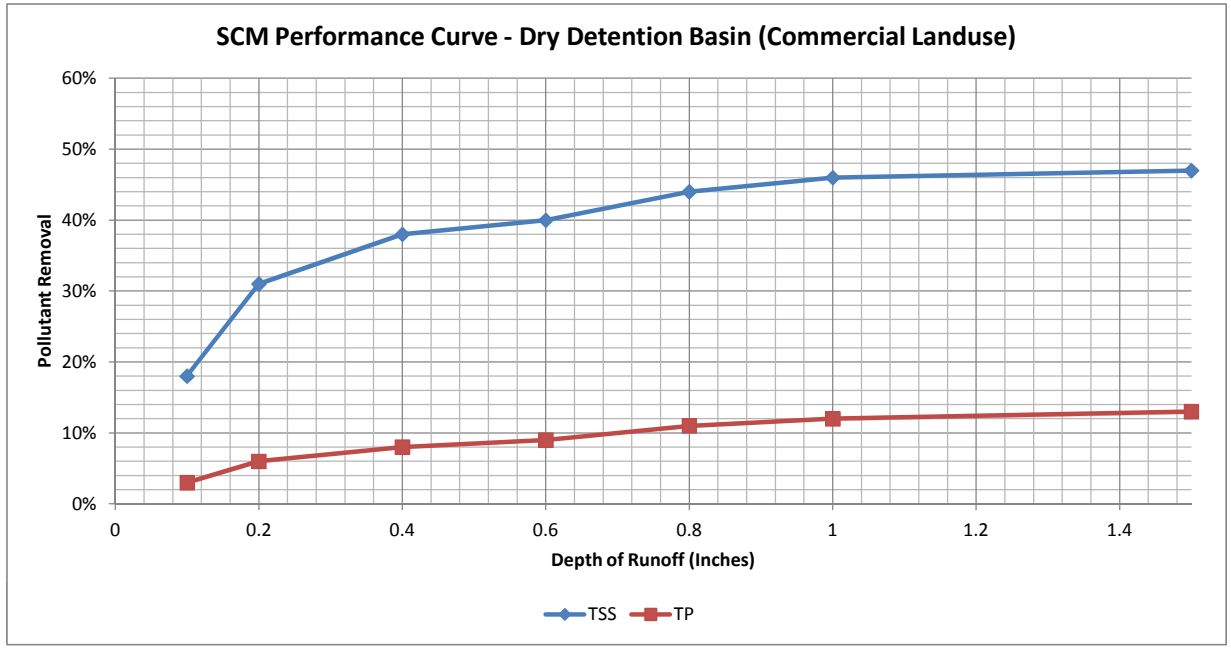
Soil Infiltration Rate 2.41 in/hr

For Site #1	Opt. #1	Opt. #2	
Total DA Runoff Treated=	0.15	0.1	in
Total DA=	20.5	20.5	ac
TSS Removal=	63.5%	50%	
TP Removal=	43.5%	32%	
Volume Reuction=	44.5%	34%	
Est. TSS Removed per year=	14550	11456	lbs
Est. TP Removed per year=	14.8	10.9	lbs
NCDOT R/W Runoff Treated=	0.3	0.2	in
NCDOT DA=	6	6	ac
TSS Removal=	87%	77%	
TP Removal=	68%	55%	
Volume Reuction=	66.5%	55%	
Est. TSS Removed per year=	5834	5164	lbs
Est. TP Removed per year=	6.8	5.5	lbs



	0.1	0.2	0.4	0.6	0.8	1	1.5	2
TSS	18%	31%	38%	40%	44%	46%	47%	49%
TP	3%	6%	8%	9%	11%	12%	13%	14%

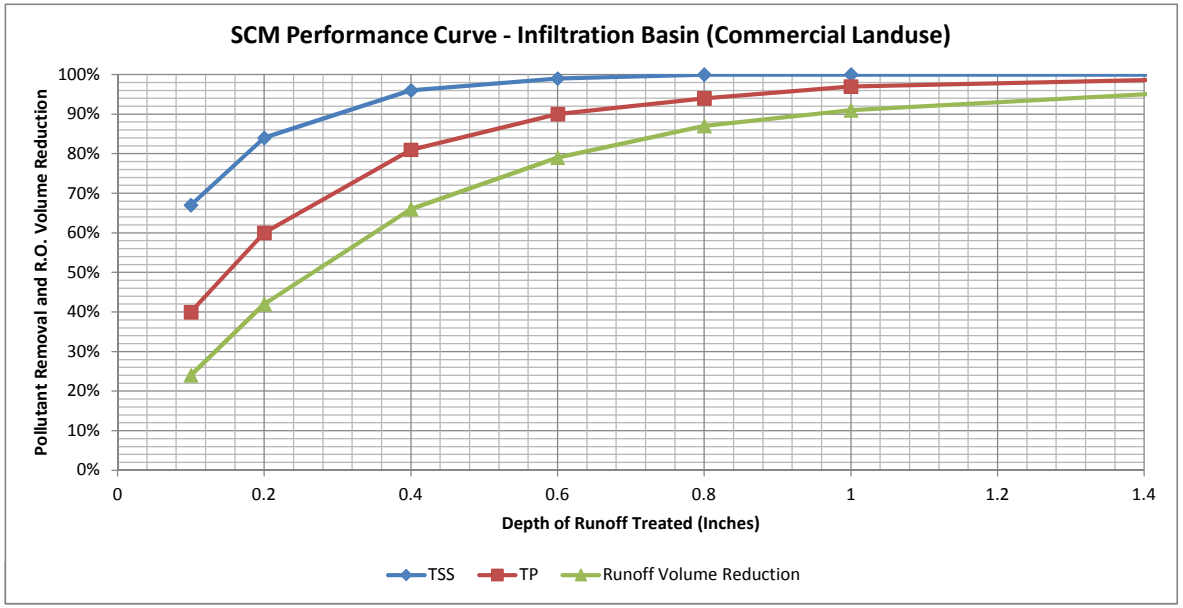
For Site #2		
Total DA Runoff Treated=	0.15	in
Total DA=	18.8	ac
TSS Removal=	24.5%	
TP Removal=	4.5%	
Volume Reuction=	--	
Est. TSS Removed per year=	5148	lbs
Est. TP Removed per year=	1.4	lbs
NCDOT R/W Runoff Treated=	0.3	in
NCDOT DA=	2.9	ac
TSS Removal=	35%	
TP Removal=	7%	
Volume Reuction=	--	
Est. TSS Removed per year=	1118	lbs
Est. TP Removed per year=	0.3	lbs



	0.1	0.2	0.4	0.6	0.8	1	1.5	2
TSS	67%	84%	96%	99%	100%	100%	100%	100%
TP	40%	60%	81%	90%	94%	97%	99%	100%
Runoff Volume Reduction	24%	42%	66%	79%	87%	91%	96%	98%

Soil Infiltration 1.02 in/hr

For Site #2		
Total DA Runoff Treated=	0.15	in
Total DA=	18.8	ac
TSS Removal=	75.5%	
TP Removal=	50.0%	
Volume Reuction=	33.0%	
Est. TSS Removed per year=	15865	lbs
Est. TP Removed per year=	15.6	lbs
NCDOT R/W Runoff Treated=	0.3	in
NCDOT DA=	2.9	ac
TSS Removal=	90%	
TP Removal=	71%	
Volume Reuction=	54%	
Est. TSS Removed per year=	2917	lbs
Est. TP Removed per year=	3.4	lbs



Appendix B

Calculation Worksheets for Time of Concentration (Tc) Values

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North Carolina Department of Transportation
Highway Stormwater Program

NRCS Method Time of Concentration [1]

Project Name:	Southeast Whiteoak TMDL - Report of Findings 2013 - Site 2 Impervious Drainage Area		
TIP / Project No.:			
Designer:	A. Nice	**Date:**	8/7/2013
Checked By:	B. Jacobson	**Date:**	8/20/2013

Input 2 Yr 24-hr Rainfall Depth (P_2):	**4.45**	**in.**	**Total t_c [2] =**	**0.15**	**hrs.**
				9	**min.**

Sheet Flow

Flow Parameter	Segment ID 1	2	3	4	5	Units
Surface Type	Gravel					
Manning's n	0.011					
Sheet Flow Length (≤ 300 ft), L	180					ft
Surface Slope, s	0.005					ft/ft
Flow Time	0.048	0.00	0.00	0.00	0.00	hrs.

Sheet Flow Time = $\frac{[0.007 * (n * L)^{0.8}]}{(P_2)^{0.5} * s^{0.4}}$

Total Sheet Flow Time = **0.05** **hrs.**

Shallow Concentrated Flow

Flow Parameter	Segment ID 1	2	3	4	5	Units
Surface Description	Paved	Paved				
Flow Length, L	280					ft
Water Course Slope, s	0.005					ft/ft
Average Velocity, v	1.44	0.00	0.00	0.00	0.00	ft/s
Flow Time	0.054	0.00	0.00	0.00	0.00	hrs.

Paved: $v = 20.3282 * s^{1/2}$ Unpaved: $v = 16.1345 * s^{1/2}$

Shallow Concentrated Flow Time = L / (3600 * v)

Total Shallow Concentrated Flow Time = **0.05** **hrs.**

Channel Flow (or Pipe Flow)

Flow Parameter	Segment ID 1	2	3	4	5	Units
Flow Area, A	3.1					ft^2
Wetted Perimeter, P	6.3					ft
Channel Slope, s	0.005					ft/ft
Channel Manning's n	0.013					
Channel Flow Length, L	894					ft
Hydraulic Radius, R	0.5					ft
Velocity, v	5.11					ft/s
Flow Time	0.049	0.00	0.00	0.00	0.00	hrs.

R = A / P $v = (1.49 * R^{2/3} * s^{1/2}) / n$

Channel Flow Time = L / (3600 * v)

Total Channel Flow Time = **0.049** **hrs.**

Notes:

1. USDA-NRCS. 1986. *Urban Hydrology for Small Watersheds: TR-55*. United States Department of Agriculture Natural Resources Conservation Service, Conservation Engineering Division.
2. For NCDOT storm drain pipe systems, a default minimum value of 10 minutes or 0.167 hours should be used for time of concentration.

North Carolina Department of Transportation
Highway Stormwater Program

NRCS Method Time of Concentration [1]

Project Name:	Southeast Whiteoak TMDL - Report of Findings 2013 - Site 2 Pervious Drainage Area		
TIP / Project No.:			
Designer:	A. Nice	**Date:**	8/7/2013
Checked By:	B. Jacobson	**Date:**	8/20/2013

Input 2 Yr 24-hr Rainfall Depth (P_2):	**4.45**	**in.**	**Total t_c [2] =**	**0.46**	**hrs.**
				27	**min.**

Sheet Flow

Flow Parameter	Segment ID 1	2	3	4	5	Units
Surface Type	Grass					
Manning's n	0.150					
Sheet Flow Length (≤ 300 ft), L	230					ft
Surface Slope, s	0.010					ft/ft
Flow Time	0.356	0.00	0.00	0.00	0.00	hrs.

Sheet Flow Time = $\frac{[0.007 * (n * L)^{0.8}]}{(P_2)^{0.5} * s^{0.4}}$

Total Sheet Flow Time = **0.36** **hrs.**

Shallow Concentrated Flow

Flow Parameter	Segment ID 1	2	3	4	5	Units
Surface Description	Unpaved	Paved				
Flow Length, L	200	150				ft
Water Course Slope, s	0.005	0.005				ft/ft
Average Velocity, v	1.14	1.44	0.00	0.00	0.00	ft/s
Flow Time	0.049	0.029	0.00	0.00	0.00	hrs.

Paved: $v = 20.3282 * s^{1/2}$ Unpaved: $v = 16.1345 * s^{1/2}$

Shallow Concentrated Flow Time = L / (3600 * v)

Total Shallow Concentrated Flow Time = **0.08** **hrs.**

Channel Flow (or Pipe Flow)

Flow Parameter	Segment ID 1	2	3	4	5	Units
Flow Area, A	3.1					ft^2
Wetted Perimeter, P	6.3					ft
Channel Slope, s	0.005					ft/ft
Channel Manning's n	0.013					
Channel Flow Length, L	475					ft
Hydraulic Radius, R	0.5					ft
Velocity, v	5.11					ft/s
Flow Time	0.026	0.00	0.00	0.00	0.00	hrs.

R = A / P $v = (1.49 * R^{2/3} * s^{1/2}) / n$

Channel Flow Time = L / (3600 * v)

Total Channel Flow Time = **0.026** **hrs.**

Notes:

1. USDA-NRCS. 1986. *Urban Hydrology for Small Watersheds: TR-55*. United States Department of Agriculture Natural Resources Conservation Service, Conservation Engineering Division.
2. For NCDOT storm drain pipe systems, a default minimum value of 10 minutes or 0.167 hours should be used for time of concentration.

Appendix C

Seasonal High Water Table Determination and Hydraulic Conductivity Analysis

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CAROLINA ECOSYSTEMS, INC.

3040 NC Hwy 42 West; Clayton, NC 27520
P:919-359-1102 – F:919-585-5570

July 30, 2013

Heath Wadsworth, PE
Call Sign Engineers
3040 NC Hwy 42 West Suite B
Clayton, NC

RE: Seasonal high water table determination and hydraulic conductivity analysis for proposed two urban stormwater retention areas (BMPs) located adjacent to NC HWY 24 near Cedar Point in Carteret County, NC

Dear Mr. Wadsworth;

Carolina Ecosystems, Inc. (CEI) performed a site evaluation per your request on the above referenced locations. The purpose of the evaluation was to determine the depth to the seasonal high water table and establish baseline soil hydraulic conductivity (Ksat) rates for stormwater basin design calculations. Two locations were evaluated at each of the two sites.

The seasonal high water table determinations were made using soil indicators taken from profile descriptions made at each site. The soil profile descriptions were made from hand auger borings. The Ksat data was collected in-situ from a constant head permeameter in the unsaturated zone of the soil profile. The constant-head well permeameter technique was utilized for the Ksat analysis. A detailed description of the method can be provided upon request.

The soil at each location was disturbed in the upper part of the soil horizon (see attached soil profile descriptions). However, the soil series observed at each location was similar to the Seabrook soil series. The Seabrook series is well drained and composed largely of sandy marine parent material. Due to the sandy nature of the soil to a depth of 96" the human disturbance in the upper soil profile should not significantly impact the Ksat data or affect any stormwater design parameters.

One Ksat test were conducted at each location on each site for a total of four tests. The soil horizon tested at each location was 18-24 inches above the seasonal high water table indicators. However, based on the soil profile descriptions significant variations in Ksat data is not expected at any depth in the unsaturated zone. The Ksat results were generated from data collected from consistent consecutive permeameter readings following meter stabilization. The seasonal high water table determinations and Ksat data is summarized in the following table.

Site	Location	Seasonal High Water Table Depth (inches)	Ksat (in/hr)
1	1	65	13.2
1	2	59	18.3
2	1	34	17.3
2*	2	32*	16.3

*A borehole could not be drilled in the bottom of the existing channel due to the presence of stone used to stabilize the channel. Seasonal high water table indicators were taken from borehole approximately 20" higher in elevation and ~3' adjacent to the desired test location. Depth to the seasonal high water table was calculated at 20" higher than indicators found in the soil profile.

It should be noted that the seasonal high water table determinations were made based on observed soil indicators and were not measured or monitored. The actual water table may vary from soil indicators. Additionally soil properties are inherently variable and inclusions of other soil types may exist within the study areas. This report represents the professional opinion of the evaluating scientist of the seasonal high water table depth. The Ksat results provided in this report should be utilized for design guidance as Ksat results are also subject to soil variability.

The attached map shows the locations of soil profile locations as well as the Ksat test locations.

If you have any questions or concerns, please contact me at your earliest convenience.

Sincerely,

Alex Adams
NC Licensed Soil Scientist #1247

Attachments: Soil Profile Descriptions, Project Map

CAROLINA
ECOSYSTEMS, INC.

3040 NC Hwy 42 West; Clayton, NC 27520
P:919-359-1102 – F:919-585-5570

Representative Soil Profile Descriptions

Site #1, Location #1
1-5% Slope

Horizon	Depth	Color	Texture	Structure
Ap	0-38"	10YR 3/2	sandy loam	granular/single grained
		2.5Y 6/6, 10YR 4/3		
C1	38-56"	2.5Y 7/6	sand	single grained
C2	56-65"	10YR 5/3	sand	single grained

*Prominent pore linings of 7.5YR 5/8 starting at 65"

Site #1, Location #2
1-5% Slope

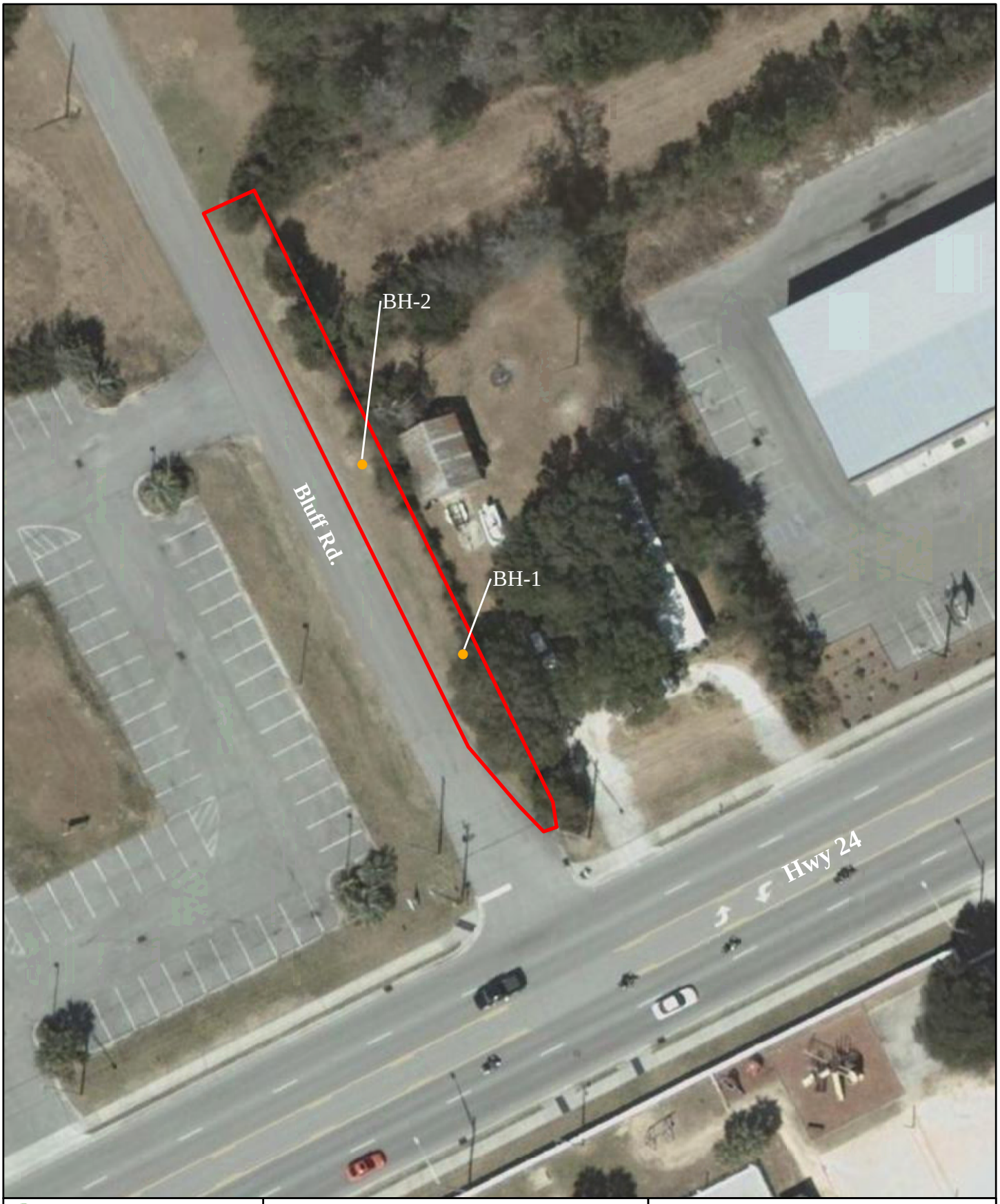
Horizon	Depth	Color	Texture	Structure
Ap	0-29"	10YR 3/2	sandy loam	granular/single grained
		2.5Y 6/6, 10YR 4/3		
C1	38-56"	2.5Y 7/6	sand	single grained
C2	56-65"	10YR 5/3	sand	single grained

Site #2, Location #1
1-5% Slope

Horizon	Depth	Color	Texture	Structure
Ap	0-5"	10YR 2/1	sandy loam	granular/single grained
		10YR 7/2		
C1	5-30"	2.5Y 7/3	sand	single grained
C2	30-60"	10YR 5/3	sand	single grained
		10YR6/6 oxidized root channels		

Site #2, Location #2
3-5% Slope

Horizon	Depth	Color	Texture	Structure
Ap	0-5"	2.5Y 6/2	sandy loam	granular/single grained
C1	5-38"	2.5Y 7/6	sand	single grained
C2	38-60"	10YR 5/3	sand	single grained
		10YR6/6 oxidized root channels		
C3	60-96"	2.5Y 5/6	sand	single grained



CAROLINA ECOSYSTEMS, INC.
3040 NC 42 West; Clayton, NC 27520
P: (919)-606-9145 F:(919)-585-5570

Date: July 2013

2010 Statewide Aerial

N

0 25 50 100 Feet

Site 1: Borehole Locations

SE White Oak Stormwater Control

Carteret County, NC

CAROLINA ECOSYSTEMS, INC.
3040 NC 42 West; Clayton, NC 27520
P: (919)-606-9145 F:(919)-585-5570

Date: July 2013

2010 Statewide Aerial

N

0 50 100 200 Feet

Site 2: Borehole Locations

SE White Oak Stormwater Control

Carteret County, NC

Appendix D

HydroCAD® Simulation Summary reports

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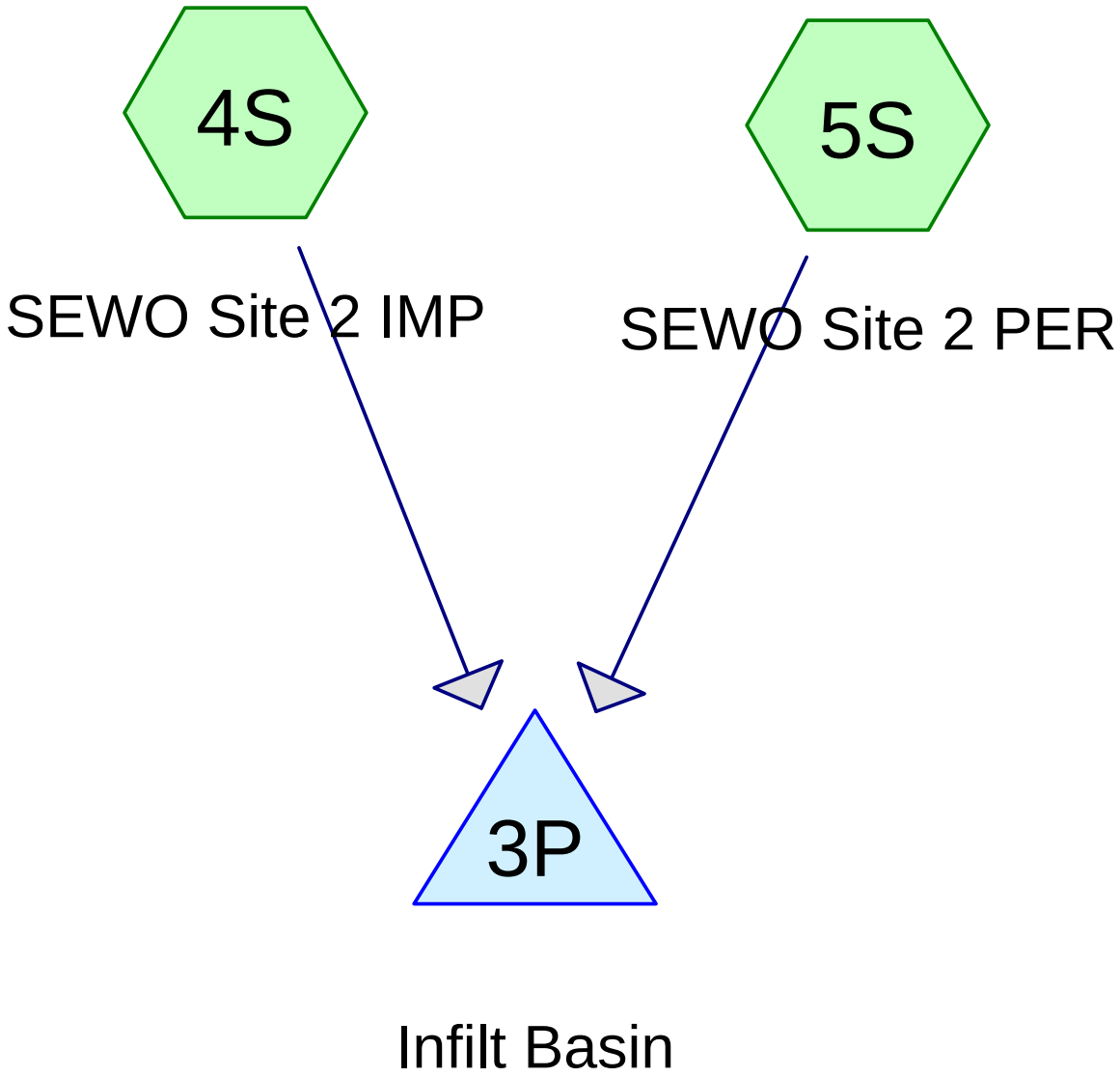
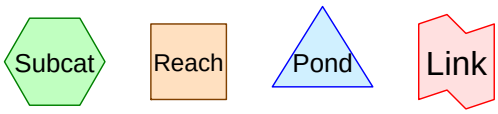




Routing Diagram for SEWO Site 2
Prepared by {enter your company name here}, Printed 8/20/2013
HydroCAD® 10.00 s/n 05704 © 2011 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
7.650	45	Woods, Poor, HSG A (5S)
4.540	49	50-75% Grass cover, Fair, HSG A (5S)
10.870	98	(4S)
23.060	**71**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
12.190	HSG A	5S
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
10.870	Other	4S
23.060		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
4.540	0.000	0.000	0.000	0.000	4.540	50-75% Grass cover, Fair	5S
0.000	0.000	0.000	0.000	10.870	10.870		4S
7.650	0.000	0.000	0.000	0.000	7.650	Woods, Poor	5S
12.190	**0.000**	**0.000**	**0.000**	**10.870**	**23.060**	**TOTAL AREA**	

Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.07"
Tc=10.0 min CN=98 Runoff=0.74 cfs 0.063 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=17.33' Storage=241 cf Inflow=0.74 cfs 0.063 af
Discarded=0.51 cfs 0.063 af Primary=0.00 cfs 0.000 af Outflow=0.51 cfs 0.063 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.063 af Average Runoff Depth = 0.03"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

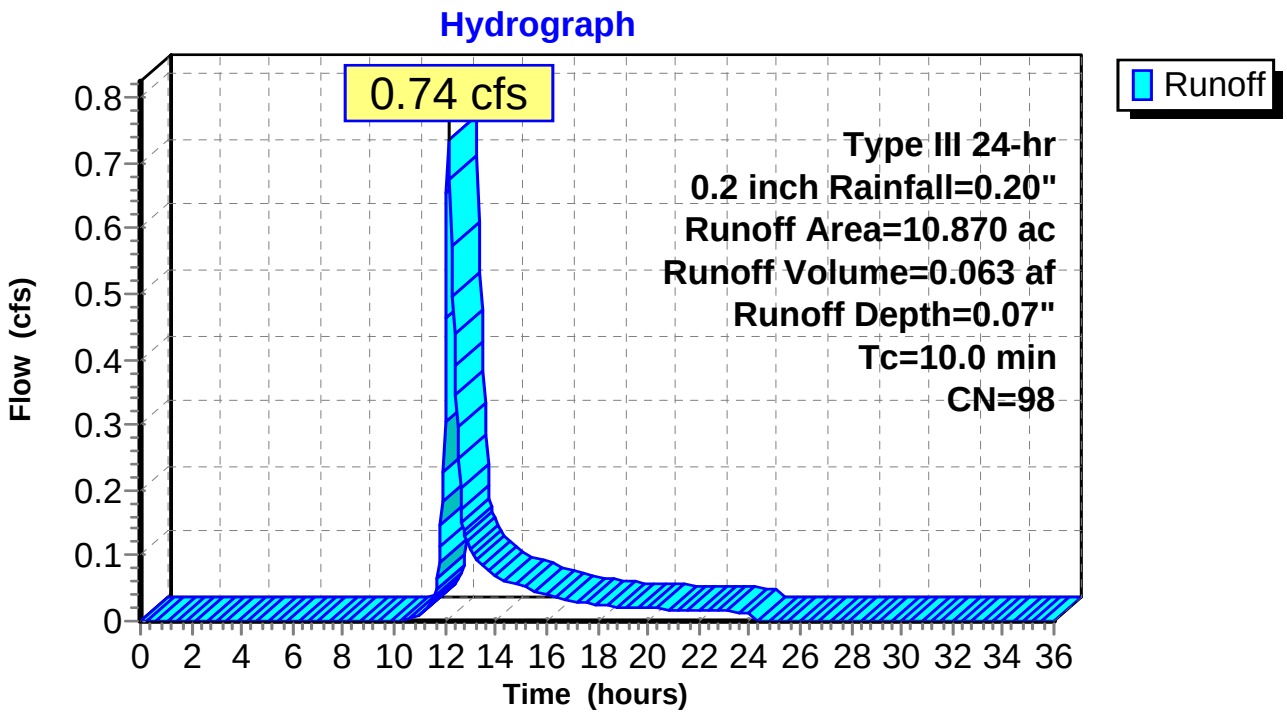
Runoff = 0.74 cfs @ 12.15 hrs, Volume= 0.063 af, Depth= 0.07"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.2 inch Rainfall=0.20"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

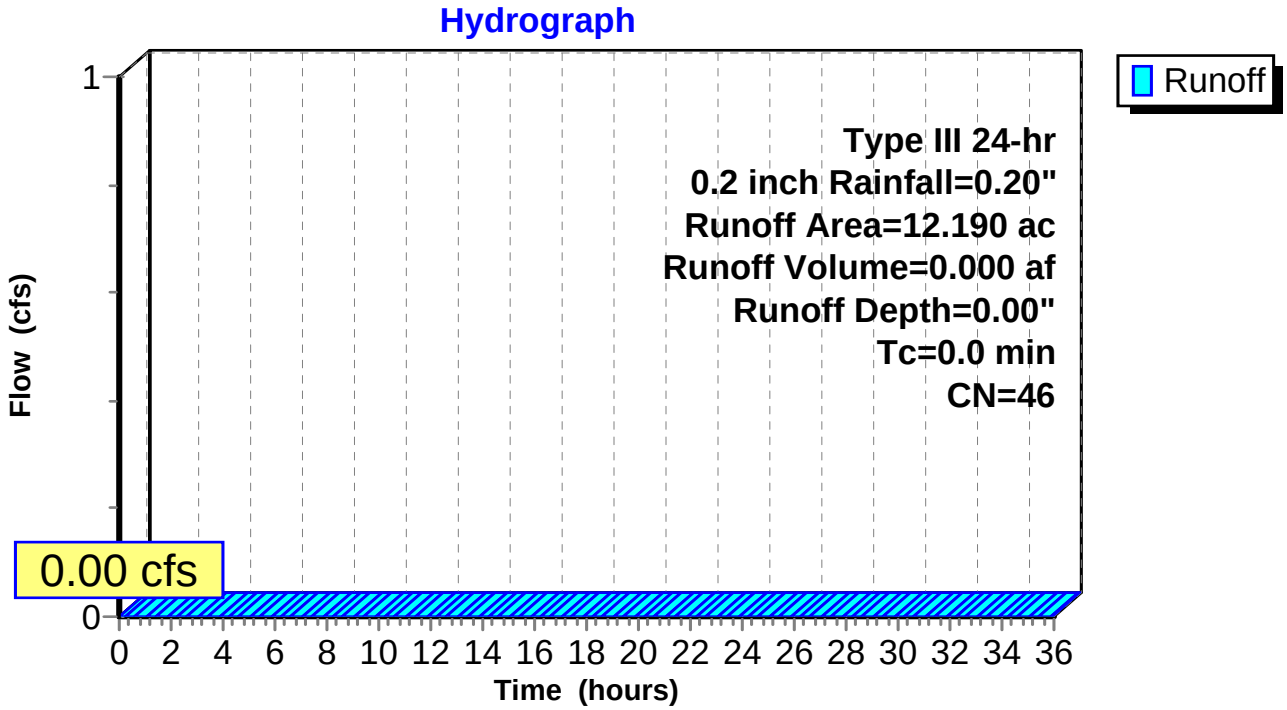
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.2 inch Rainfall=0.20"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.03" for 0.2 inch event
Inflow = 0.74 cfs @ 12.15 hrs, Volume= 0.063 af
Outflow = 0.51 cfs @ 12.30 hrs, Volume= 0.063 af, Atten= 31%, Lag= 8.7 min
Discarded = 0.51 cfs @ 12.30 hrs, Volume= 0.063 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 17.33' @ 12.30 hrs Surf.Area= 1,219 sf Storage= 241 cf

Plug-Flow detention time= 3.2 min calculated for 0.063 af (100% of inflow)
Center-of-Mass det. time= 3.2 min (864.5 - 861.3)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

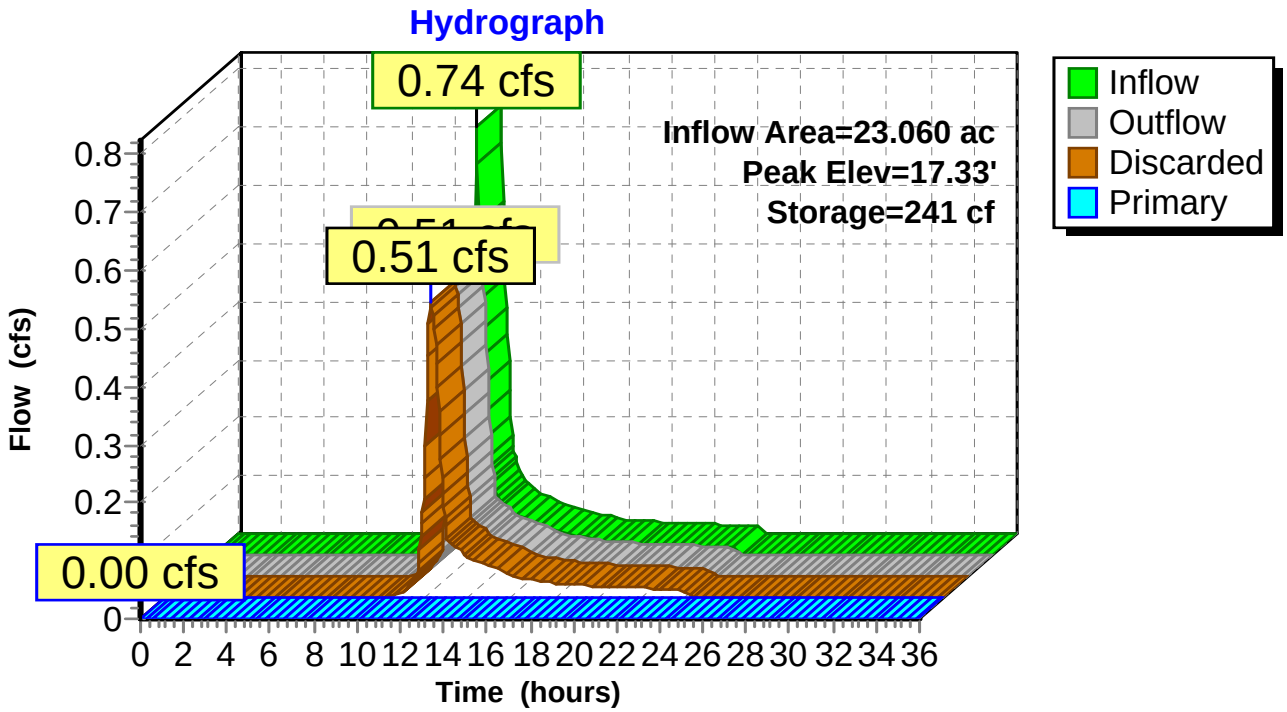
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=0.51 cfs @ 12.30 hrs HW=17.33' (Free Discharge)
└**1=Exfiltration** (Controls 0.51 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=17.00' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.08"
Tc=10.0 min CN=98 Runoff=0.90 cfs 0.076 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=17.39' Storage=327 cf Inflow=0.90 cfs 0.076 af
Discarded=0.59 cfs 0.076 af Primary=0.00 cfs 0.000 af Outflow=0.59 cfs 0.076 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.076 af Average Runoff Depth = 0.04"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

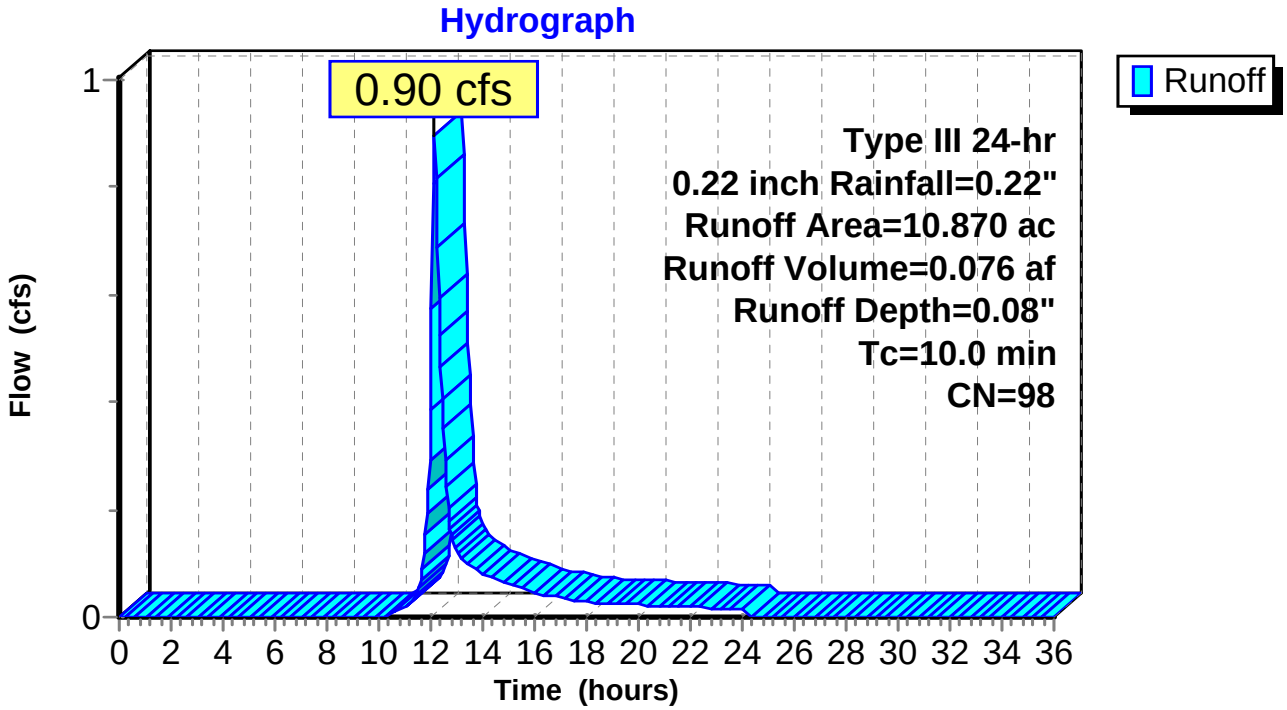
Runoff = 0.90 cfs @ 12.15 hrs, Volume= 0.076 af, Depth= 0.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.22 inch Rainfall=0.22"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

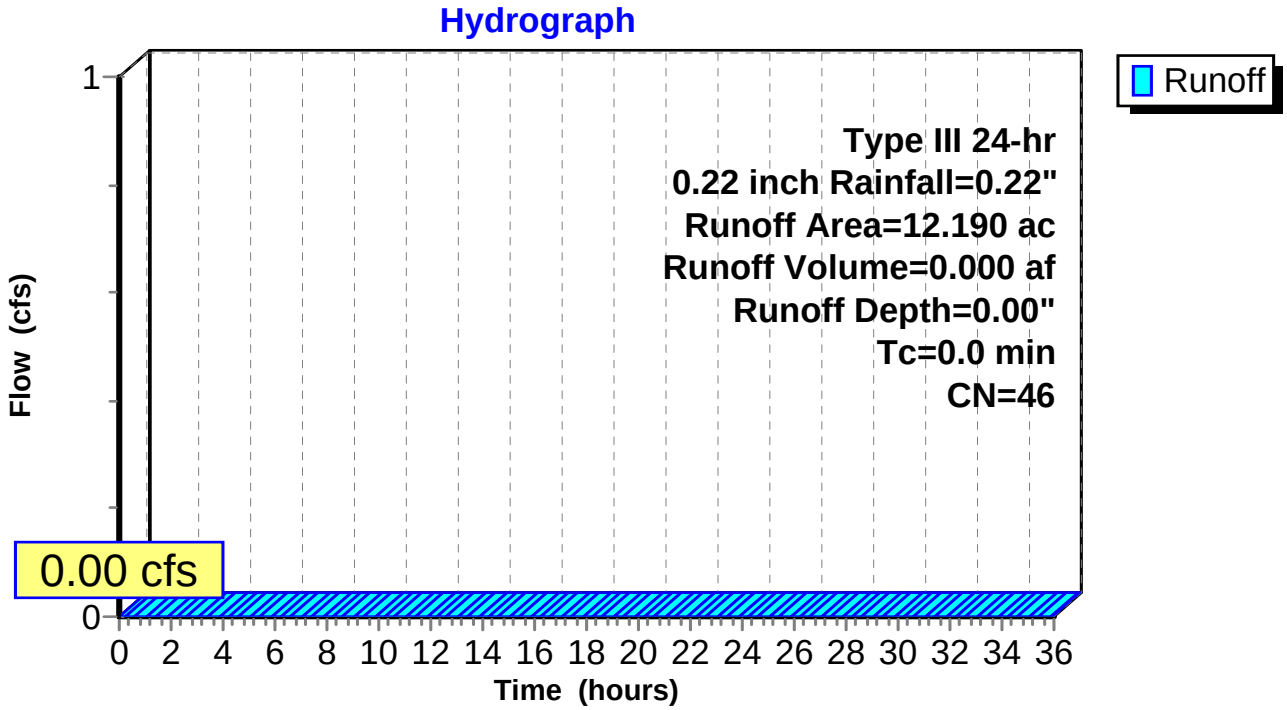
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.22 inch Rainfall=0.22"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.04" for 0.22 inch event
Inflow = 0.90 cfs @ 12.15 hrs, Volume= 0.076 af
Outflow = 0.59 cfs @ 12.31 hrs, Volume= 0.076 af, Atten= 34%, Lag= 9.3 min
Discarded = 0.59 cfs @ 12.31 hrs, Volume= 0.076 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 17.39' @ 12.31 hrs Surf.Area= 1,411 sf Storage= 327 cf

Plug-Flow detention time= 3.8 min calculated for 0.076 af (100% of inflow)
Center-of-Mass det. time= 3.8 min (859.5 - 855.7)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

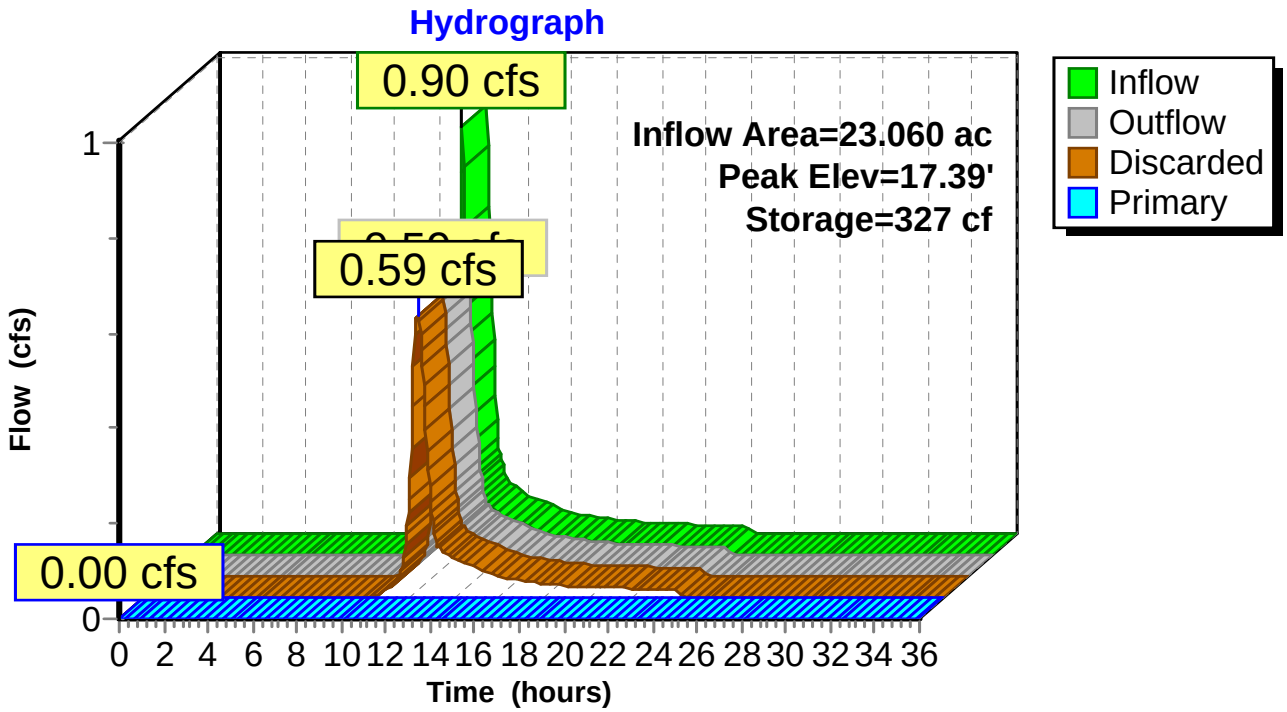
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=0.59 cfs @ 12.31 hrs HW=17.39' (Free Discharge)
└**1=Exfiltration** (Controls 0.59 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=17.00' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.15"
Tc=10.0 min CN=98 Runoff=1.59 cfs 0.131 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=17.64' Storage=760 cf Inflow=1.59 cfs 0.131 af
Discarded=0.93 cfs 0.131 af Primary=0.00 cfs 0.000 af Outflow=0.93 cfs 0.131 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.131 af Average Runoff Depth = 0.07"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

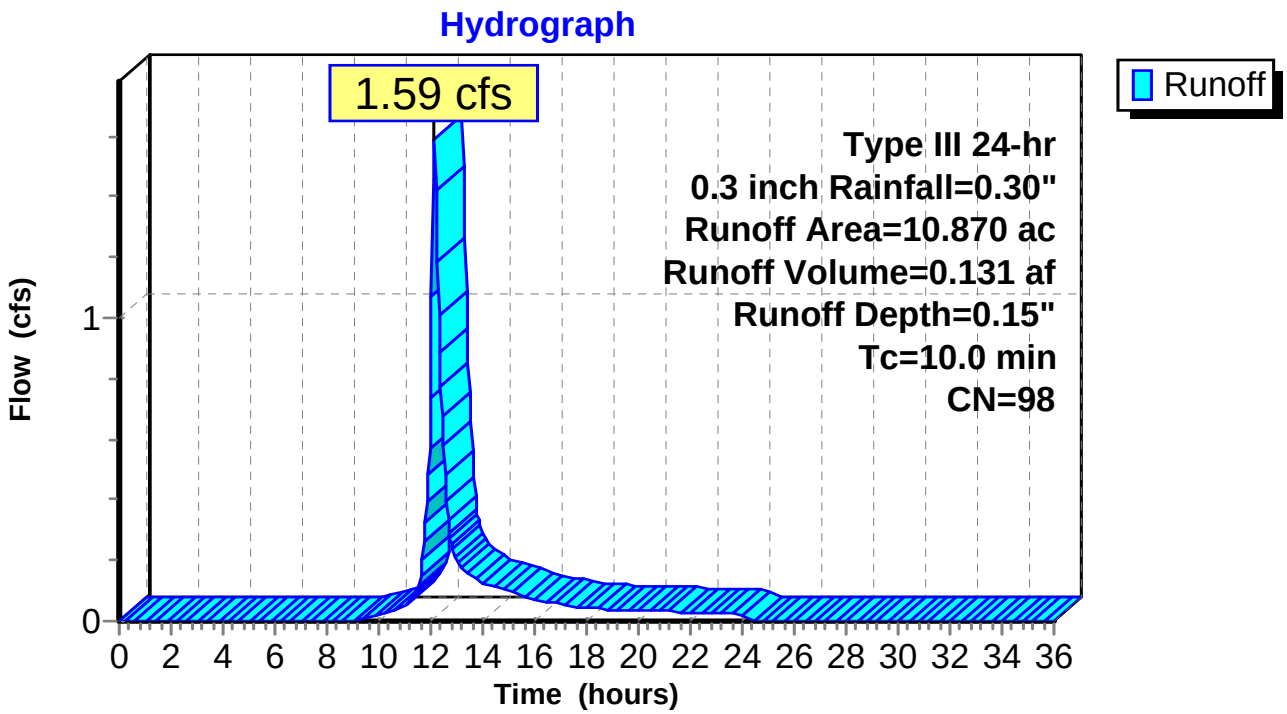
Runoff = 1.59 cfs @ 12.15 hrs, Volume= 0.131 af, Depth= 0.15"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.3 inch Rainfall=0.30"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

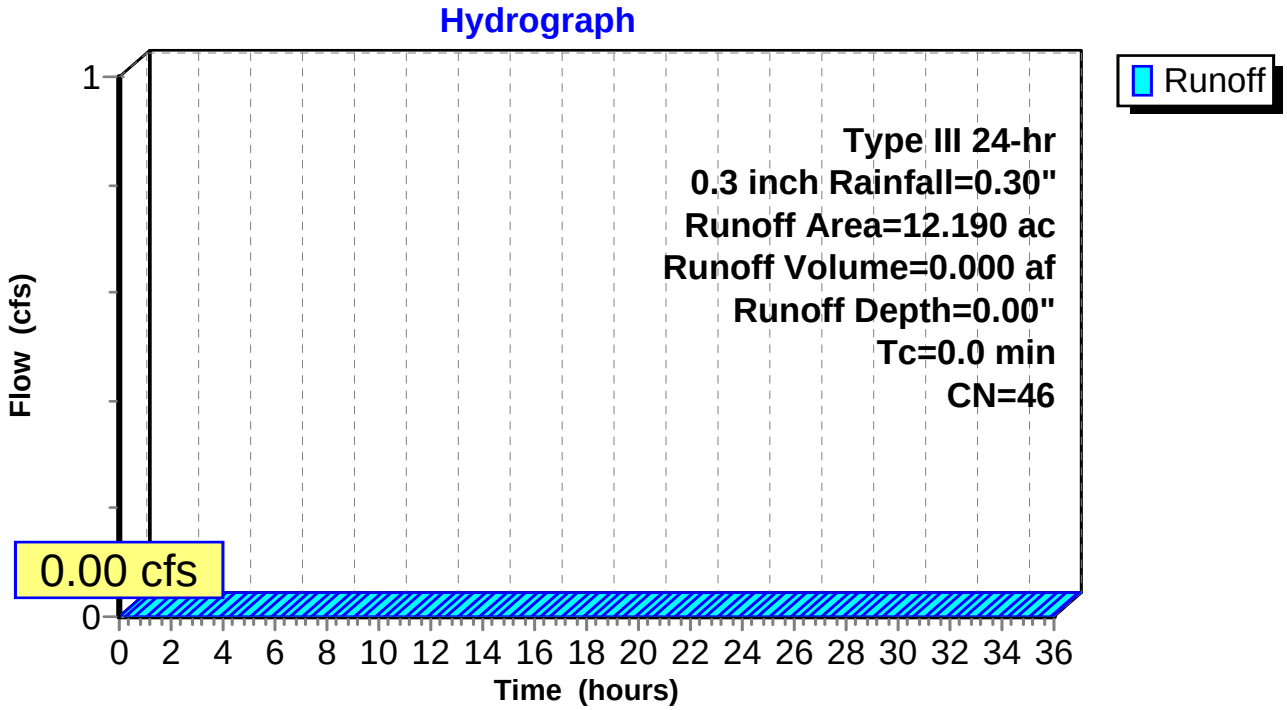
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.3 inch Rainfall=0.30"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.07" for 0.3 inch event
Inflow = 1.59 cfs @ 12.15 hrs, Volume= 0.131 af
Outflow = 0.93 cfs @ 12.33 hrs, Volume= 0.131 af, Atten= 41%, Lag= 11.1 min
Discarded = 0.93 cfs @ 12.33 hrs, Volume= 0.131 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 17.64' @ 12.33 hrs Surf.Area= 2,132 sf Storage= 760 cf

Plug-Flow detention time= 5.9 min calculated for 0.131 af (100% of inflow)
Center-of-Mass det. time= 5.9 min (845.5 - 839.6)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

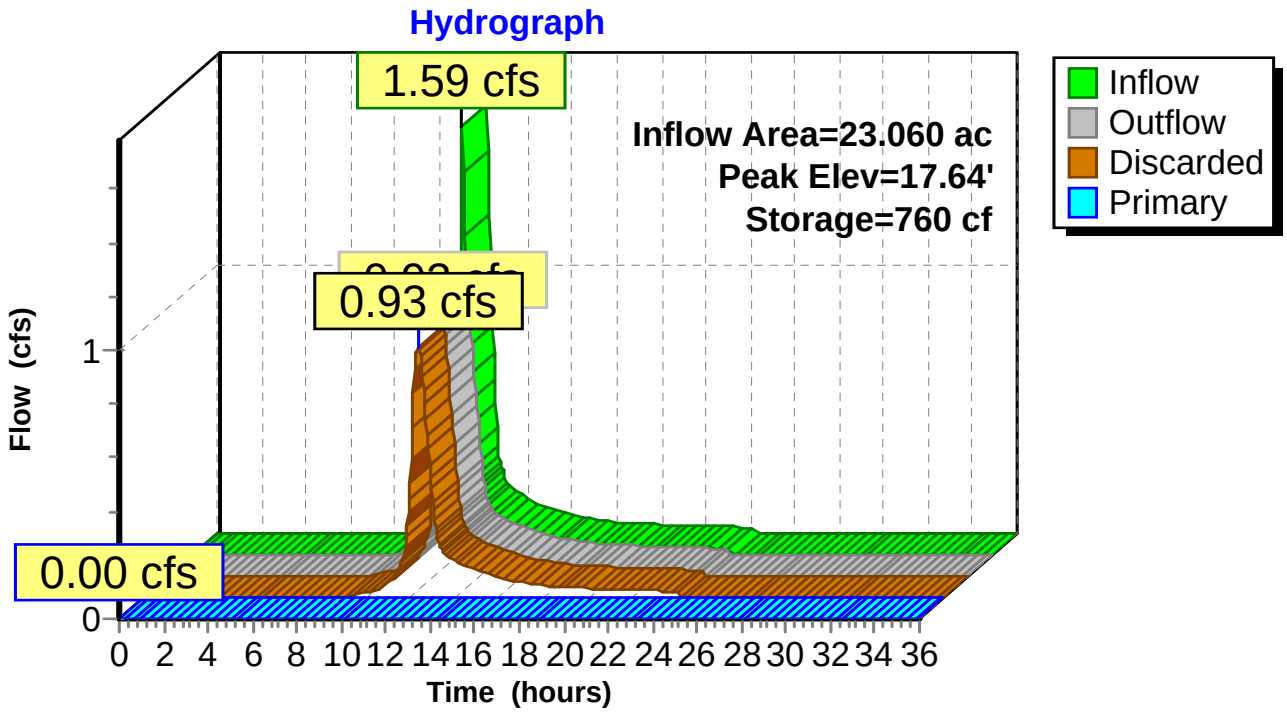
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=0.93 cfs @ 12.33 hrs HW=17.64' (Free Discharge)
└**1=Exfiltration** (Controls 0.93 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=17.00' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.32"
Tc=10.0 min CN=98 Runoff=3.48 cfs 0.288 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=18.15' Storage=2,247 cf Inflow=3.48 cfs 0.288 af
Discarded=1.72 cfs 0.288 af Primary=0.00 cfs 0.000 af Outflow=1.72 cfs 0.288 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.288 af Average Runoff Depth = 0.15"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

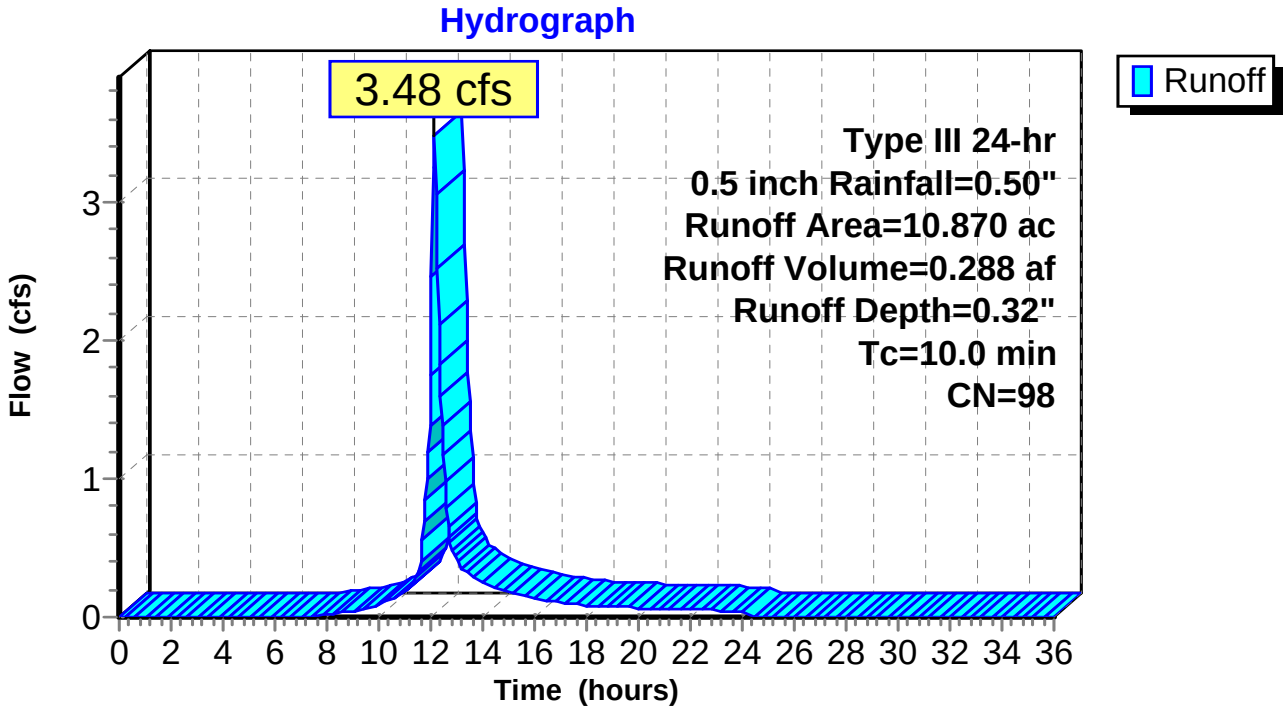
Runoff = 3.48 cfs @ 12.14 hrs, Volume= 0.288 af, Depth= 0.32"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5 inch Rainfall=0.50"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

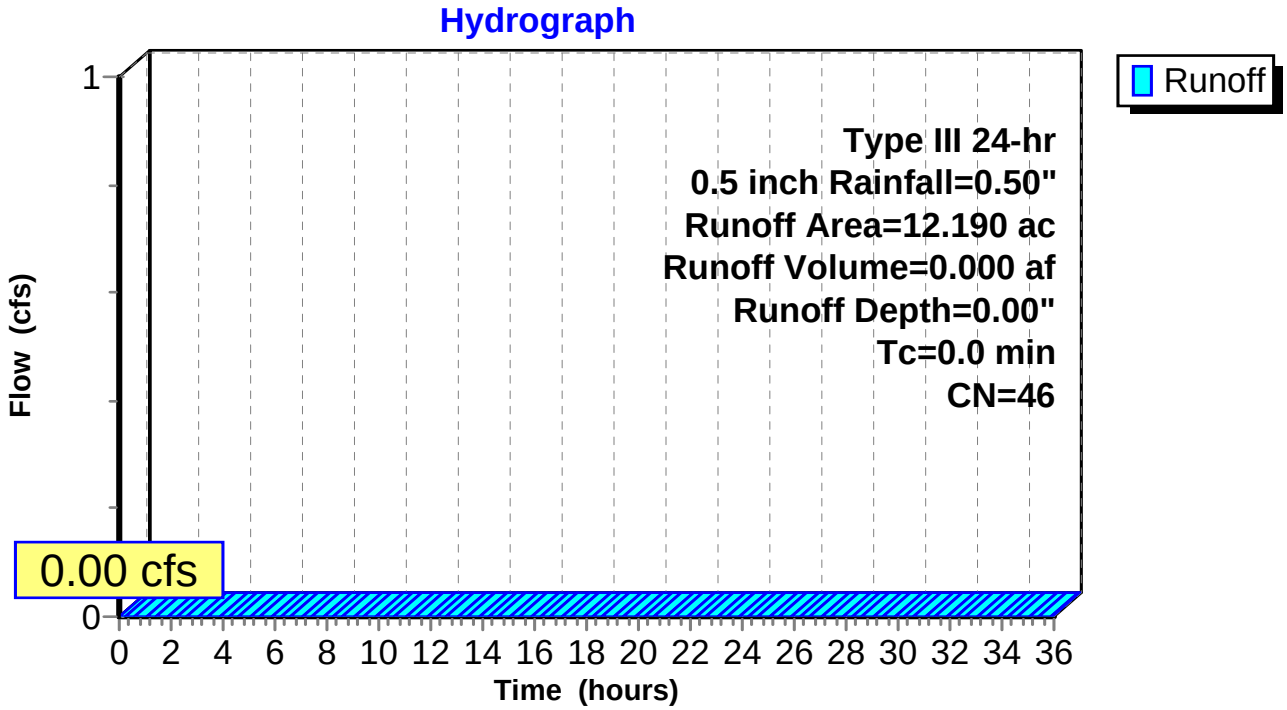
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.5 inch Rainfall=0.50"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area =	23.060 ac, 47.14% Impervious, Inflow Depth = 0.15" for 0.5 inch event				
Inflow =	3.48 cfs @	12.14 hrs,	Volume=	0.288 af	
Outflow =	1.72 cfs @	12.37 hrs,	Volume=	0.288 af,	Atten= 51%, Lag= 13.9 min
Discarded =	1.72 cfs @	12.37 hrs,	Volume=	0.288 af	
Primary =	0.00 cfs @	0.00 hrs,	Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 18.15' @ 12.37 hrs Surf.Area= 3,685 sf Storage= 2,247 cf

Plug-Flow detention time= 10.4 min calculated for 0.288 af (100% of inflow)
Center-of-Mass det. time= 10.3 min (827.3 - 817.0)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

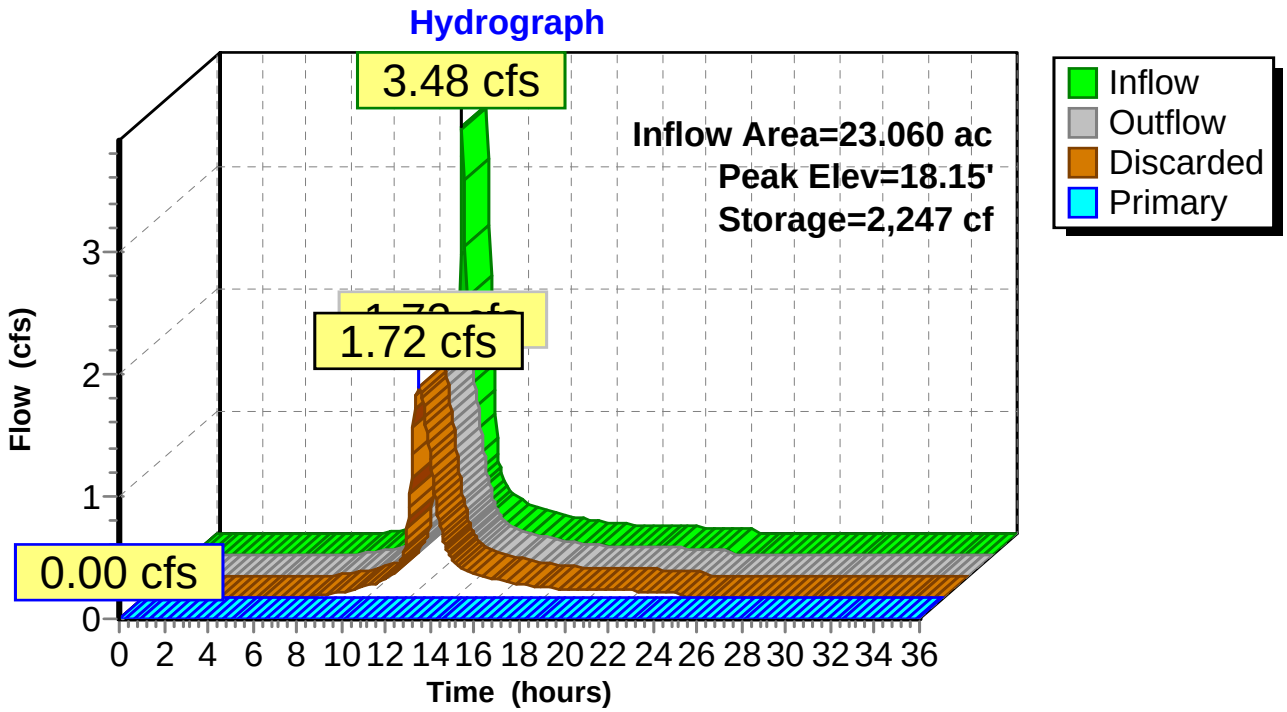
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=1.72 cfs @ 12.37 hrs HW=18.15' (Free Discharge)
└**1=Exfiltration** (Controls 1.72 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=17.00' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.47"
Tc=10.0 min CN=98 Runoff=5.04 cfs 0.422 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=18.49' Storage=3,654 cf Inflow=5.04 cfs 0.422 af
Discarded=2.30 cfs 0.422 af Primary=0.00 cfs 0.000 af Outflow=2.30 cfs 0.422 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.422 af Average Runoff Depth = 0.22"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

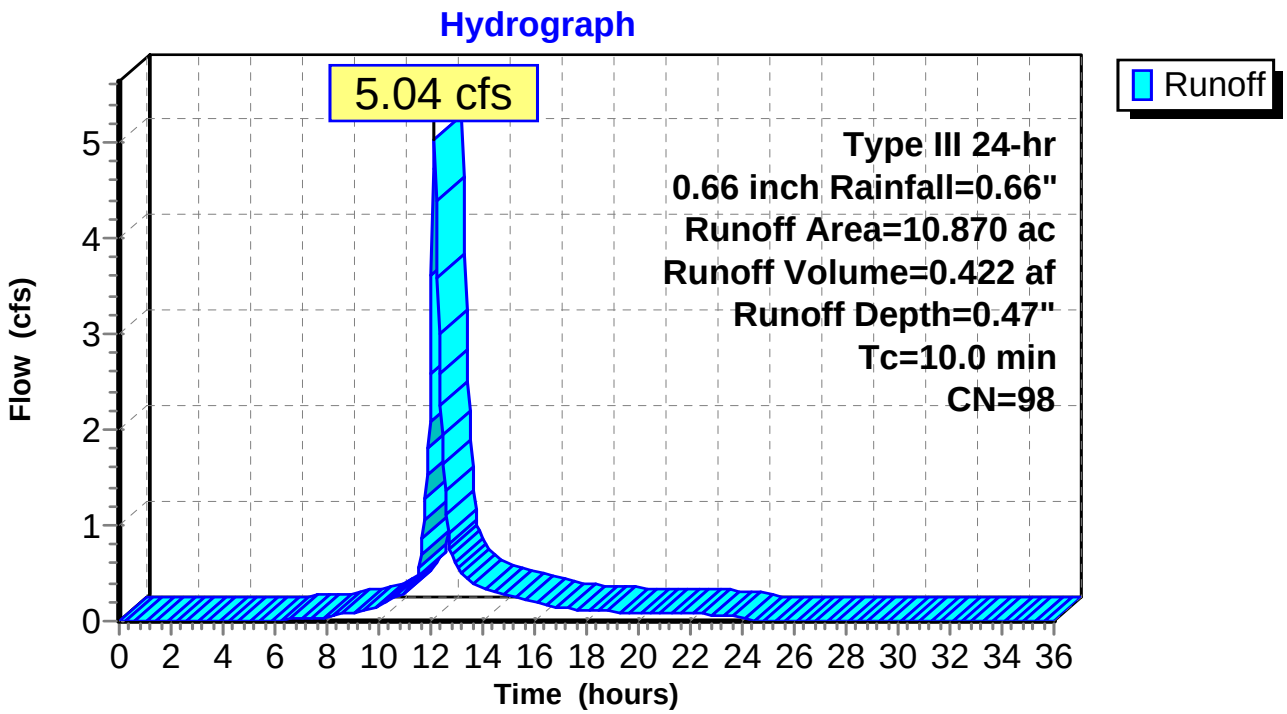
Runoff = 5.04 cfs @ 12.14 hrs, Volume= 0.422 af, Depth= 0.47"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.66 inch Rainfall=0.66"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

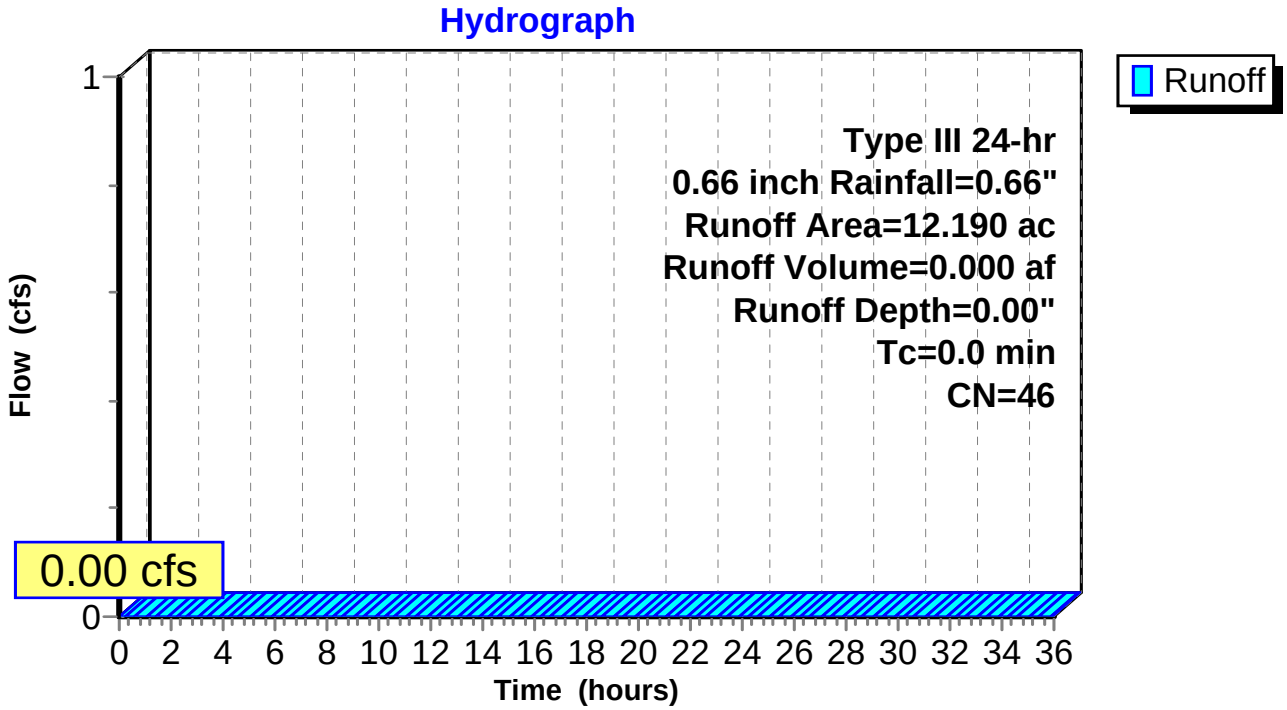
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.66 inch Rainfall=0.66"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.22" for 0.66 inch event
Inflow = 5.04 cfs @ 12.14 hrs, Volume= 0.422 af
Outflow = 2.30 cfs @ 12.39 hrs, Volume= 0.422 af, Atten= 54%, Lag= 15.2 min
Discarded = 2.30 cfs @ 12.39 hrs, Volume= 0.422 af
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 18.49' @ 12.39 hrs Surf.Area= 4,753 sf Storage= 3,654 cf

Plug-Flow detention time= 13.1 min calculated for 0.421 af (100% of inflow)
Center-of-Mass det. time= 13.1 min (819.3 - 806.2)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

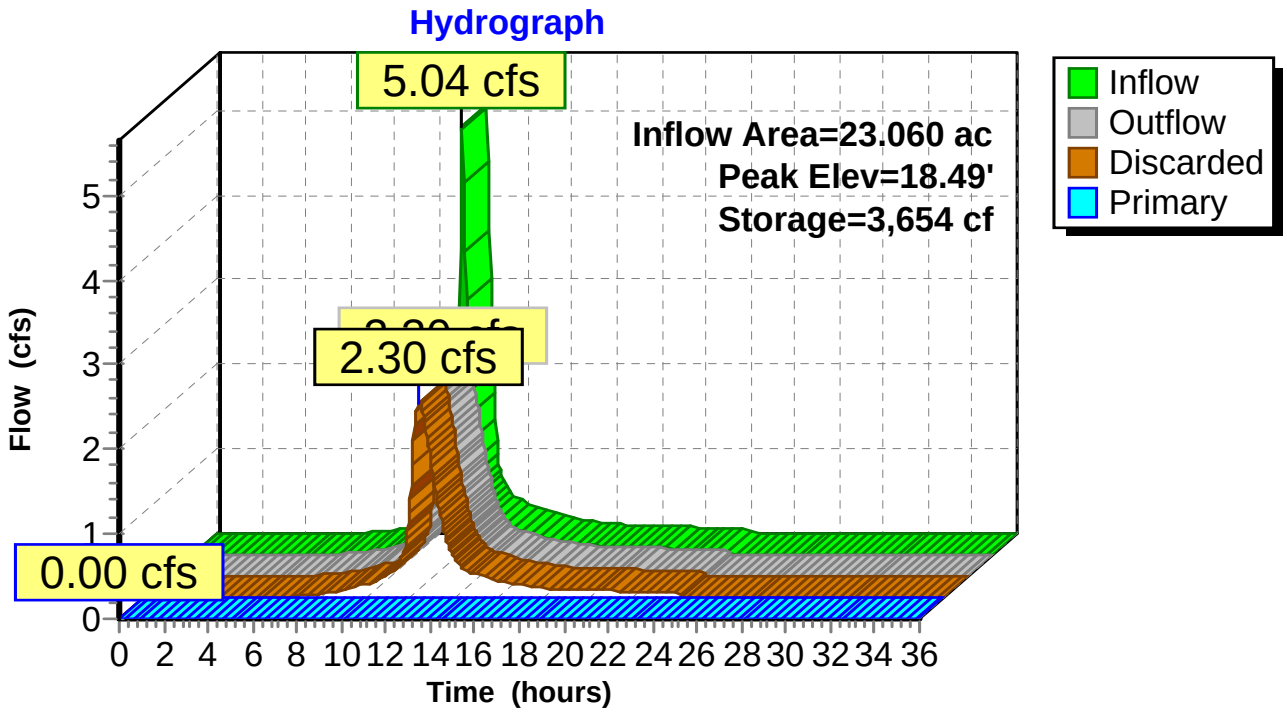
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=2.30 cfs @ 12.39 hrs HW=18.48' (Free Discharge)
└**1=Exfiltration** (Controls 2.30 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=17.00' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.57"
Tc=10.0 min CN=98 Runoff=6.12 cfs 0.516 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=18.61' Storage=4,253 cf Inflow=6.12 cfs 0.516 af
Discarded=2.52 cfs 0.497 af Primary=1.14 cfs 0.020 af Outflow=3.67 cfs 0.516 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.516 af Average Runoff Depth = 0.27"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

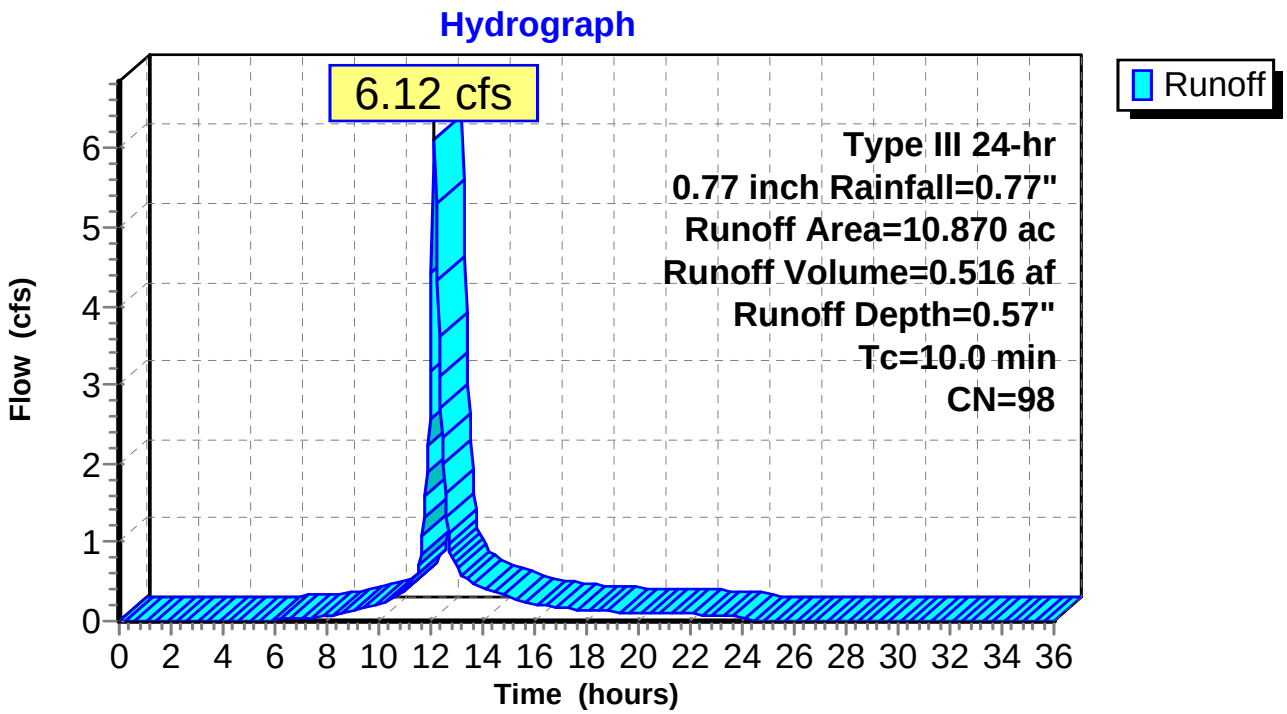
Runoff = 6.12 cfs @ 12.14 hrs, Volume= 0.516 af, Depth= 0.57"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.77 inch Rainfall=0.77"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

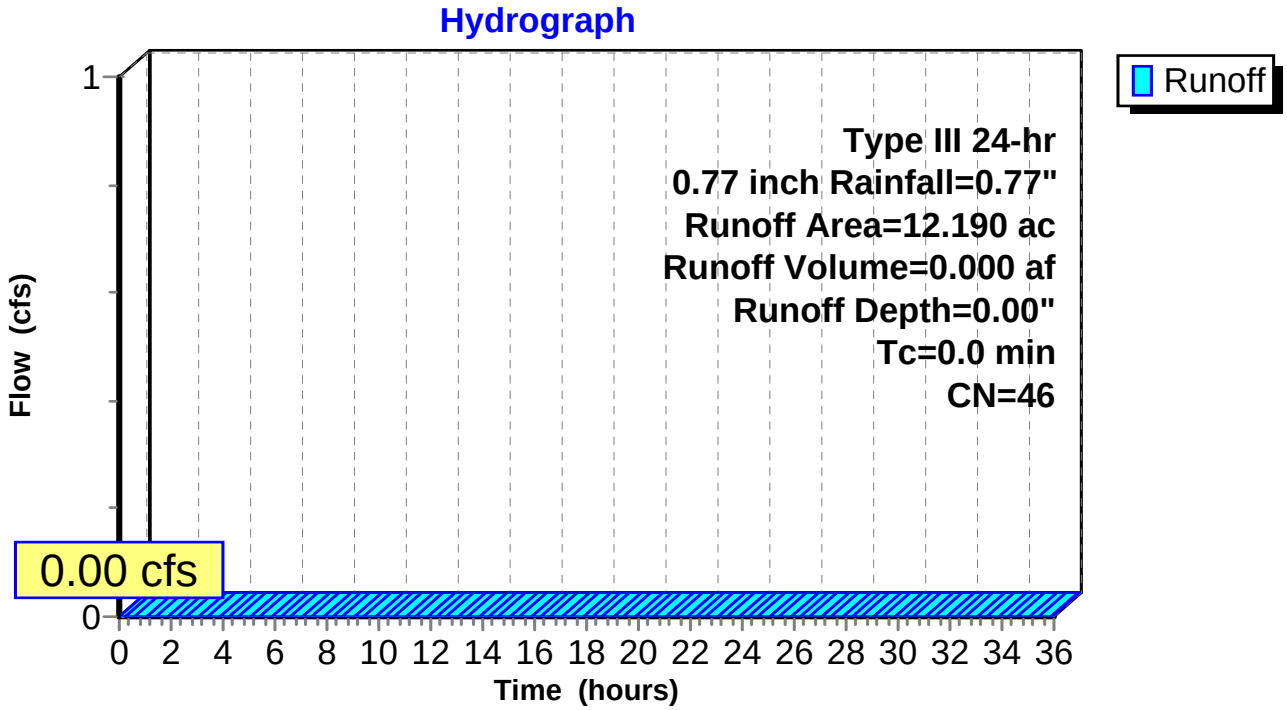
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.77 inch Rainfall=0.77"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.27" for 0.77 inch event
Inflow = 6.12 cfs @ 12.14 hrs, Volume= 0.516 af
Outflow = 3.67 cfs @ 12.31 hrs, Volume= 0.516 af, Atten= 40%, Lag= 10.1 min
Discarded = 2.52 cfs @ 12.31 hrs, Volume= 0.497 af
Primary = 1.14 cfs @ 12.31 hrs, Volume= 0.020 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 18.61' @ 12.31 hrs Surf.Area= 5,140 sf Storage= 4,253 cf

Plug-Flow detention time= 13.3 min calculated for 0.515 af (100% of inflow)
Center-of-Mass det. time= 13.3 min (813.9 - 800.6)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

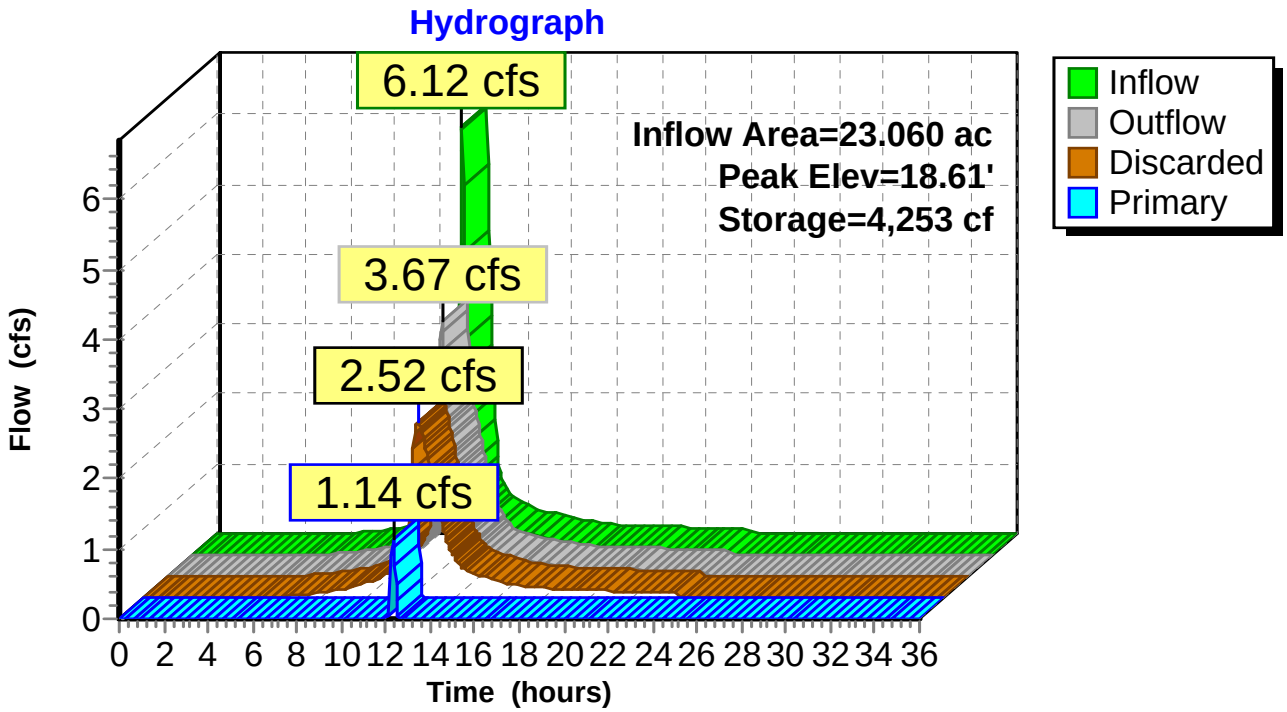
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=2.52 cfs @ 12.31 hrs HW=18.60' (Free Discharge)
└**1=Exfiltration** (Controls 2.52 cfs)

Primary OutFlow Max=1.12 cfs @ 12.31 hrs HW=18.60' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 1.12 cfs @ 0.79 fps)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.69"
Tc=10.0 min CN=98 Runoff=7.39 cfs 0.629 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=18.69' Storage=4,691 cf Inflow=7.39 cfs 0.629 af
Discarded=2.67 cfs 0.574 af Primary=2.72 cfs 0.055 af Outflow=5.39 cfs 0.629 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.629 af Average Runoff Depth = 0.33"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

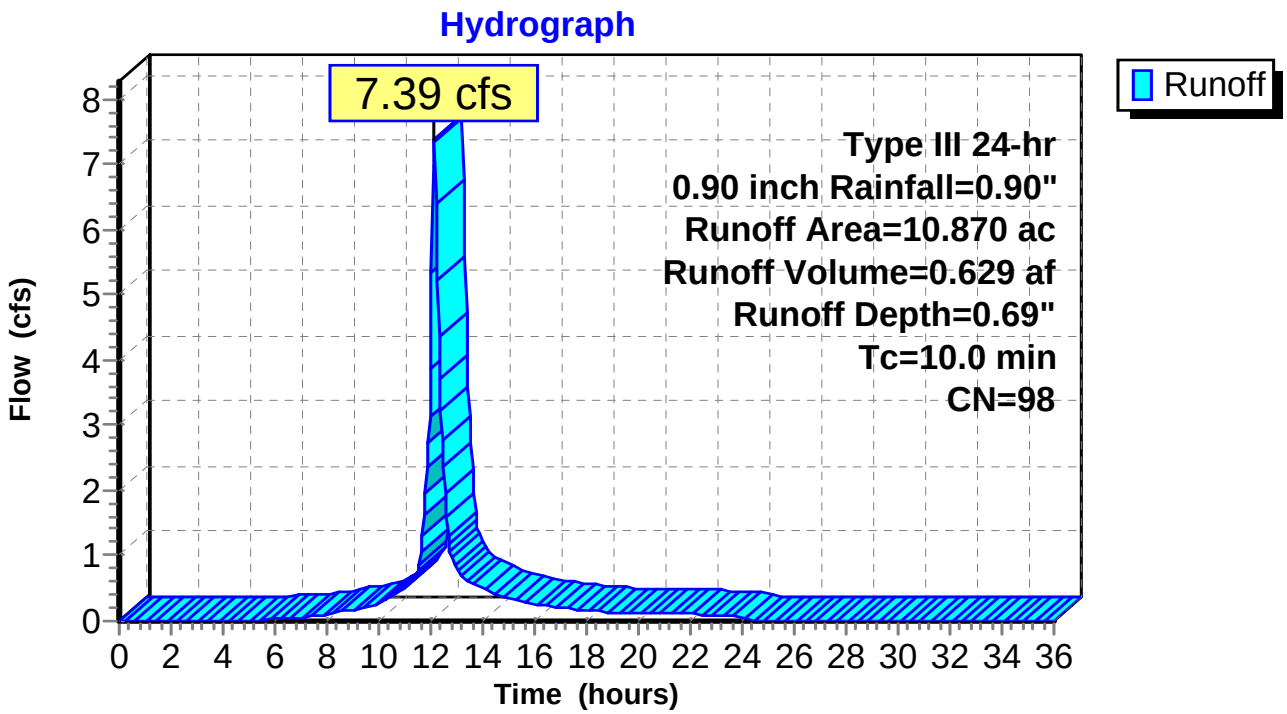
Runoff = 7.39 cfs @ 12.14 hrs, Volume= 0.629 af, Depth= 0.69"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.90 inch Rainfall=0.90"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

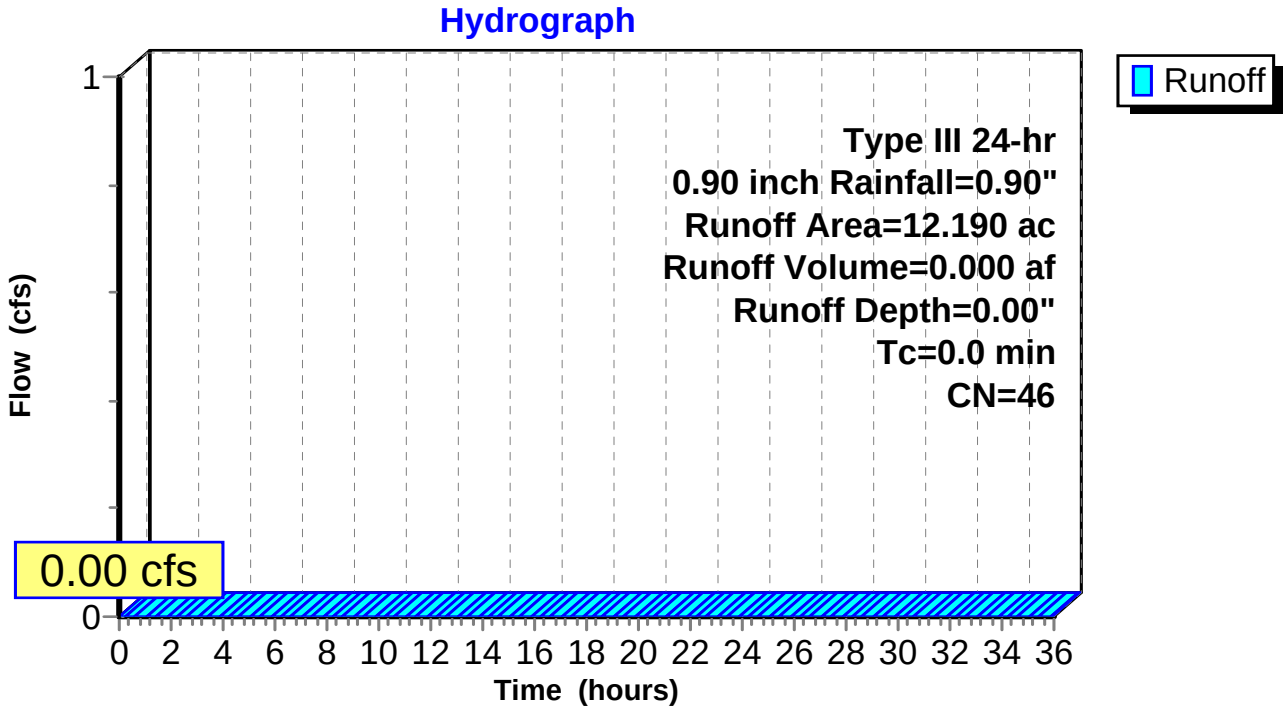
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 0.90 inch Rainfall=0.90"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.33" for 0.90 inch event
Inflow = 7.39 cfs @ 12.14 hrs, Volume= 0.629 af
Outflow = 5.39 cfs @ 12.25 hrs, Volume= 0.629 af, Atten= 27%, Lag= 6.9 min
Discarded = 2.67 cfs @ 12.25 hrs, Volume= 0.574 af
Primary = 2.72 cfs @ 12.25 hrs, Volume= 0.055 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 18.69' @ 12.25 hrs Surf.Area= 5,406 sf Storage= 4,691 cf

Plug-Flow detention time= 13.0 min calculated for 0.628 af (100% of inflow)
Center-of-Mass det. time= 13.0 min (808.1 - 795.1)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

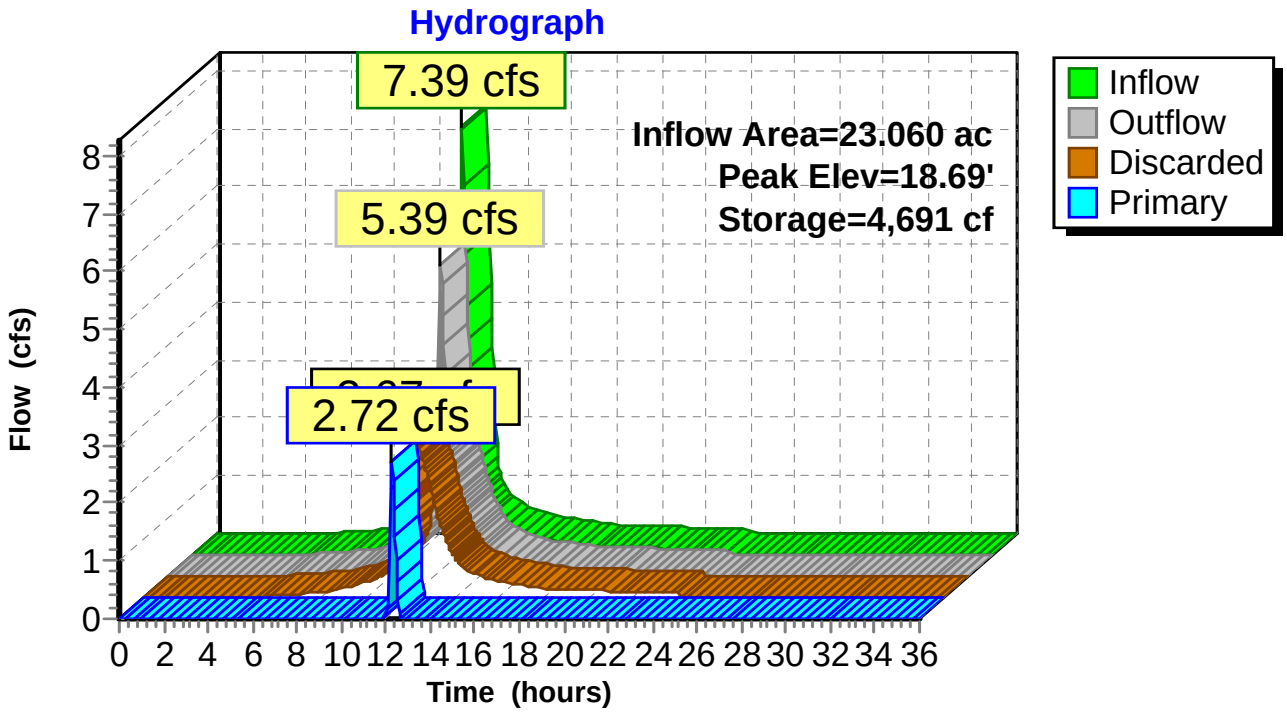
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=2.67 cfs @ 12.25 hrs HW=18.69' (Free Discharge)
└**1=Exfiltration** (Controls 2.67 cfs)

Primary OutFlow Max=2.68 cfs @ 12.25 hrs HW=18.69' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 2.68 cfs @ 1.06 fps)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=0.89"
Tc=10.0 min CN=98 Runoff=9.33 cfs 0.804 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=18.78' Storage=5,220 cf Inflow=9.33 cfs 0.804 af
Discarded=2.85 cfs 0.688 af Primary=5.12 cfs 0.116 af Outflow=7.97 cfs 0.804 af

Total Runoff Area = 23.060 ac Runoff Volume = 0.804 af Average Runoff Depth = 0.42"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

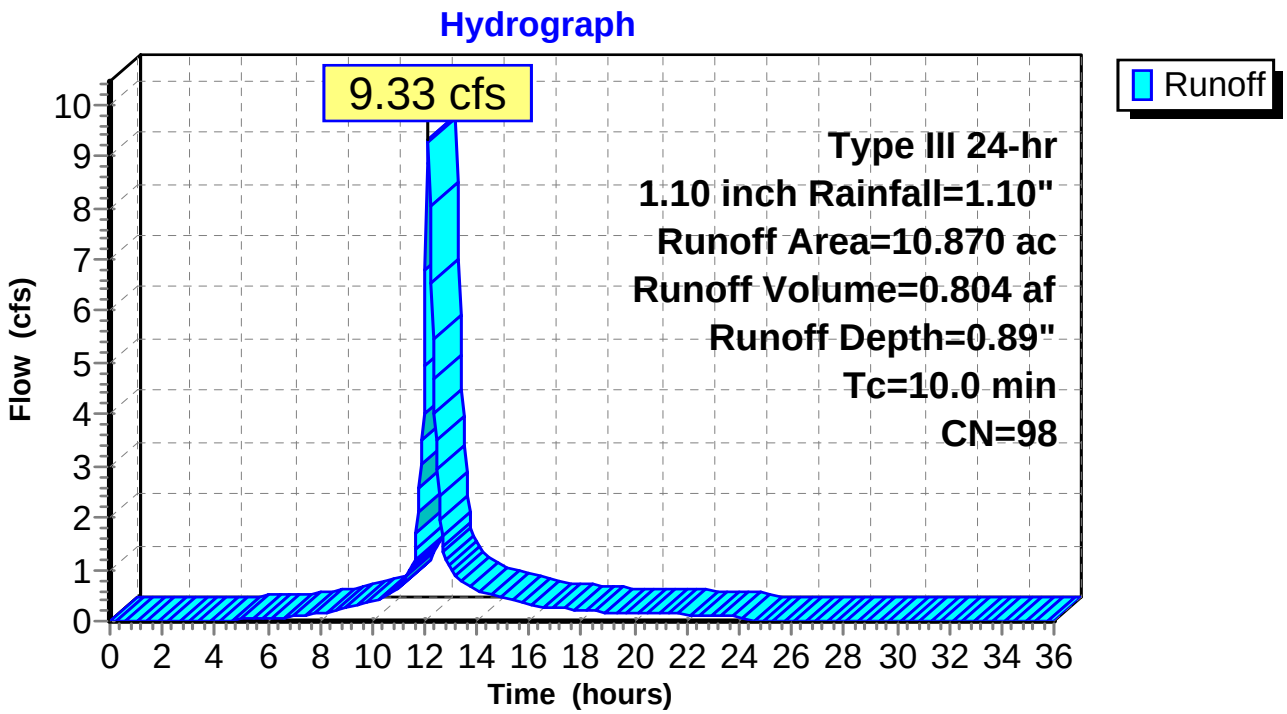
Runoff = 9.33 cfs @ 12.14 hrs, Volume= 0.804 af, Depth= 0.89"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 1.10 inch Rainfall=1.10"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

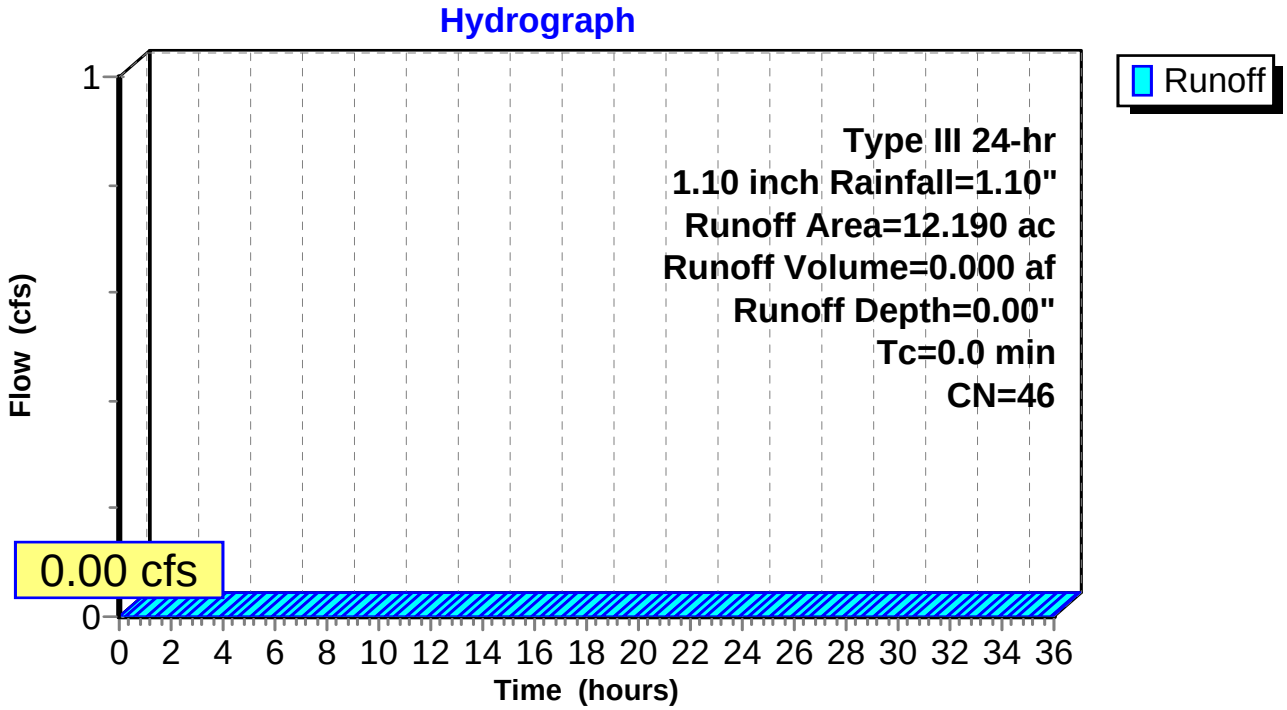
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 1.10 inch Rainfall=1.10"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.42" for 1.10 inch event
Inflow = 9.33 cfs @ 12.14 hrs, Volume= 0.804 af
Outflow = 7.97 cfs @ 12.21 hrs, Volume= 0.804 af, Atten= 15%, Lag= 4.5 min
Discarded = 2.85 cfs @ 12.21 hrs, Volume= 0.688 af
Primary = 5.12 cfs @ 12.21 hrs, Volume= 0.116 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 18.78' @ 12.21 hrs Surf.Area= 5,710 sf Storage= 5,220 cf

Plug-Flow detention time= 12.7 min calculated for 0.803 af (100% of inflow)
Center-of-Mass det. time= 12.6 min (801.1 - 788.5)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

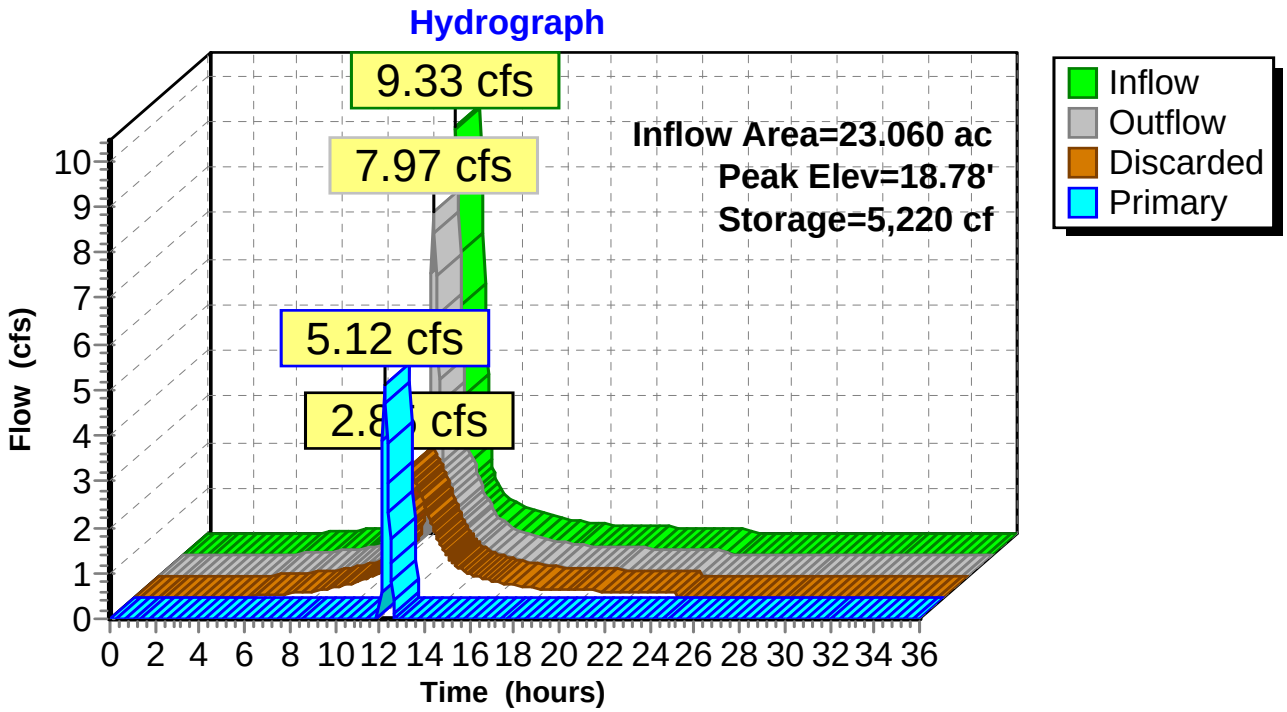
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=2.84 cfs @ 12.21 hrs HW=18.78' (Free Discharge)
└**1=Exfiltration** (Controls 2.84 cfs)

Primary OutFlow Max=4.96 cfs @ 12.21 hrs HW=18.78' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 4.96 cfs @ 1.32 fps)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=1.18"
Tc=10.0 min CN=98 Runoff=12.22 cfs 1.070 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=18.88' Storage=5,783 cf Inflow=12.22 cfs 1.070 af
Discarded=3.03 cfs 0.854 af Primary=8.13 cfs 0.217 af Outflow=11.16 cfs 1.070 af

Total Runoff Area = 23.060 ac Runoff Volume = 1.070 af Average Runoff Depth = 0.56"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

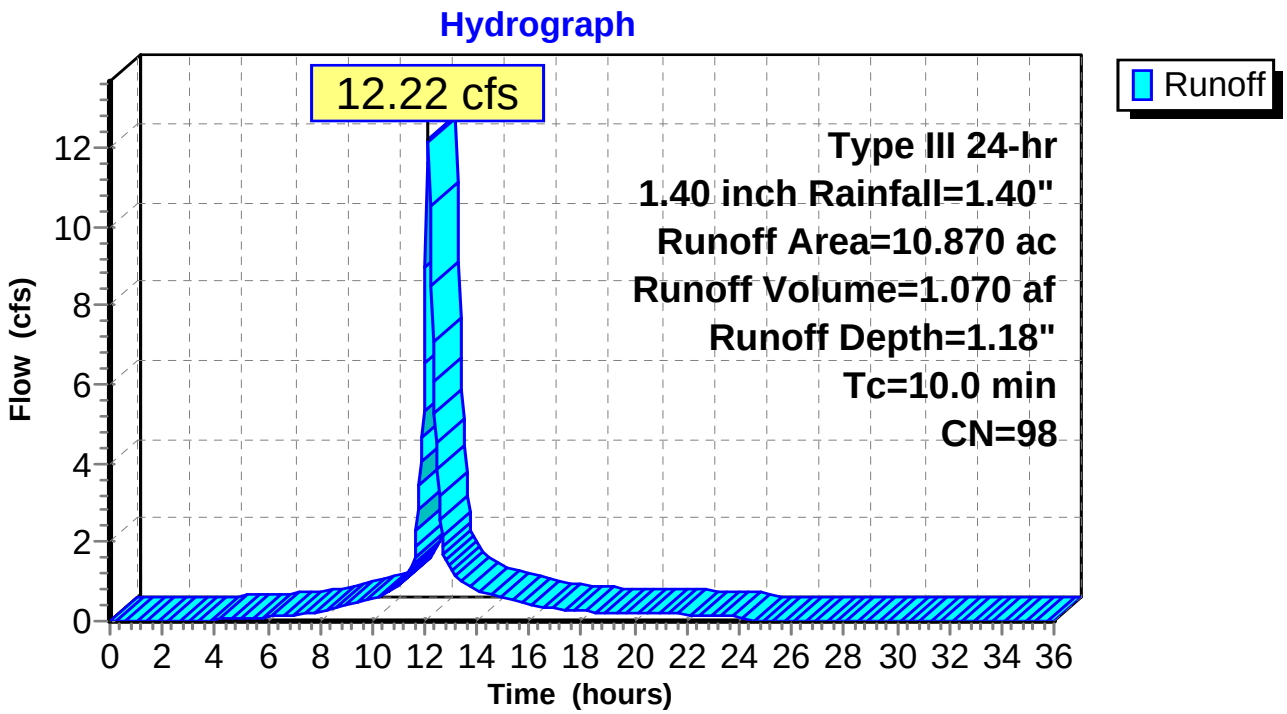
Runoff = 12.22 cfs @ 12.14 hrs, Volume= 1.070 af, Depth= 1.18"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 1.40 inch Rainfall=1.40"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

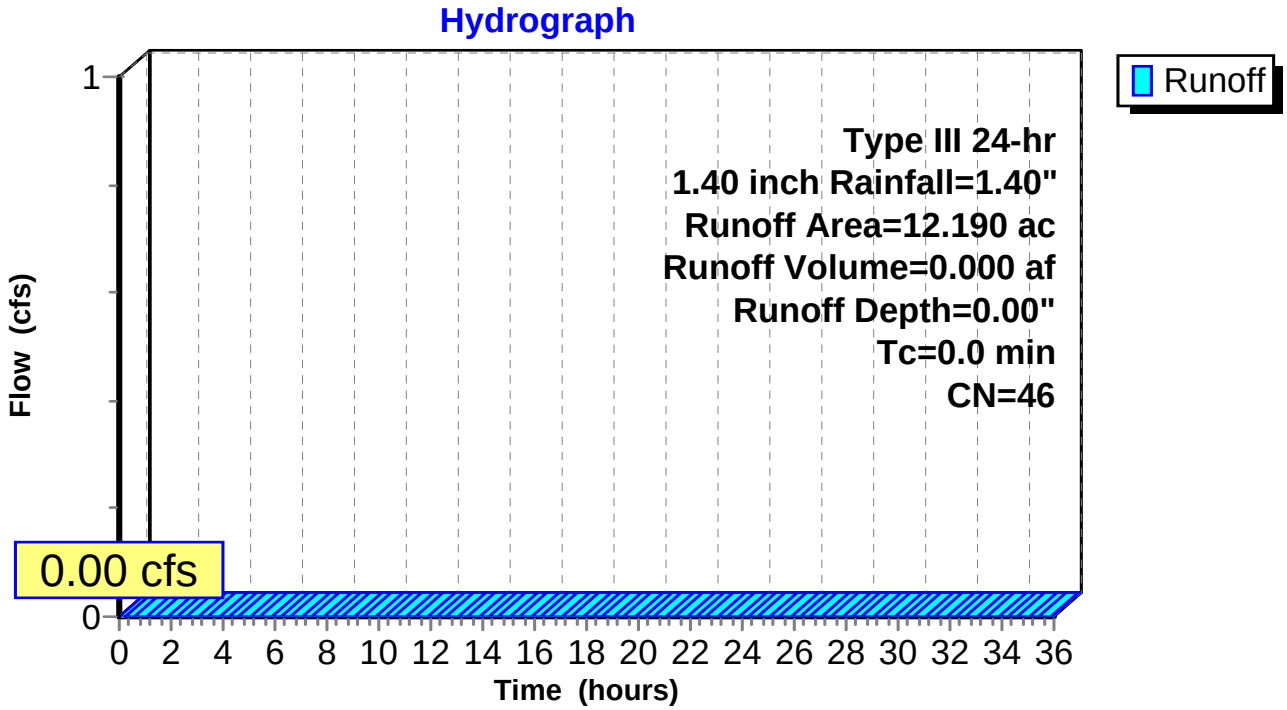
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 1.40 inch Rainfall=1.40"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.56" for 1.40 inch event
Inflow = 12.22 cfs @ 12.14 hrs, Volume= 1.070 af
Outflow = 11.16 cfs @ 12.19 hrs, Volume= 1.070 af, Atten= 9%, Lag= 3.1 min
Discarded = 3.03 cfs @ 12.19 hrs, Volume= 0.854 af
Primary = 8.13 cfs @ 12.19 hrs, Volume= 0.217 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 18.88' @ 12.19 hrs Surf.Area= 6,017 sf Storage= 5,783 cf

Plug-Flow detention time= 12.4 min calculated for 1.069 af (100% of inflow)
Center-of-Mass det. time= 12.4 min (793.4 - 781.0)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

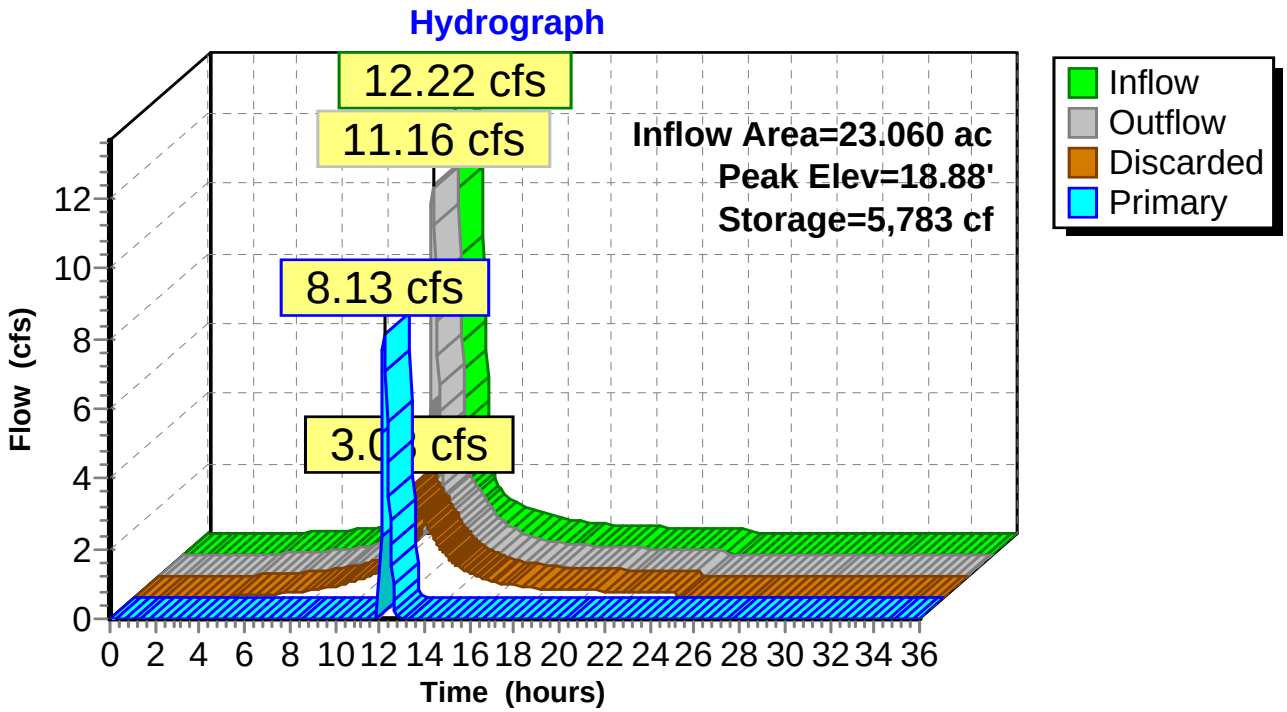
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=3.03 cfs @ 12.19 hrs HW=18.88' (Free Discharge)
└**1=Exfiltration** (Controls 3.03 cfs)

Primary OutFlow Max=8.00 cfs @ 12.19 hrs HW=18.88' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 8.00 cfs @ 1.57 fps)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=1.77"
Tc=10.0 min CN=98 Runoff=17.93 cfs 1.607 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.00"
Tc=0.0 min CN=46 Runoff=0.00 cfs 0.000 af

Pond 3P: Infilt Basin Peak Elev=19.02' Storage=6,670 cf Inflow=17.93 cfs 1.607 af
Discarded=3.31 cfs 1.168 af Primary=13.46 cfs 0.440 af Outflow=16.77 cfs 1.607 af

Total Runoff Area = 23.060 ac Runoff Volume = 1.607 af Average Runoff Depth = 0.84"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

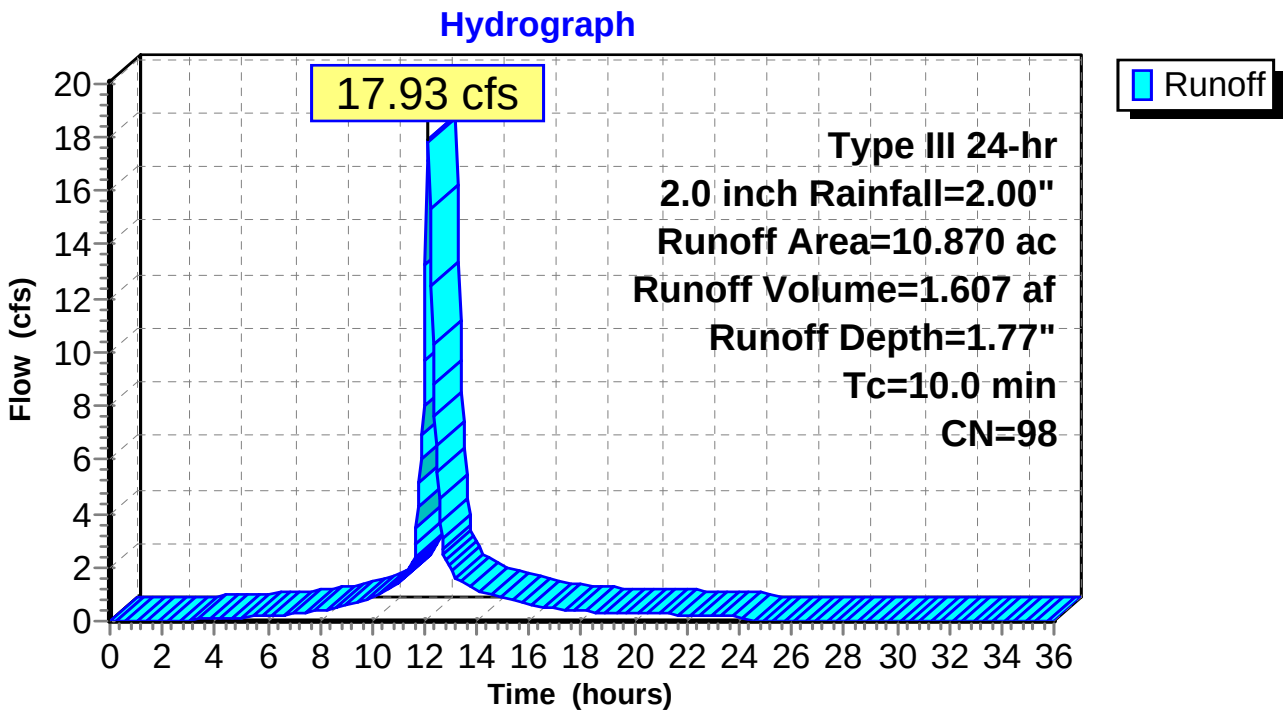
Runoff = 17.93 cfs @ 12.14 hrs, Volume= 1.607 af, Depth= 1.77"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 2.0 inch Rainfall=2.00"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

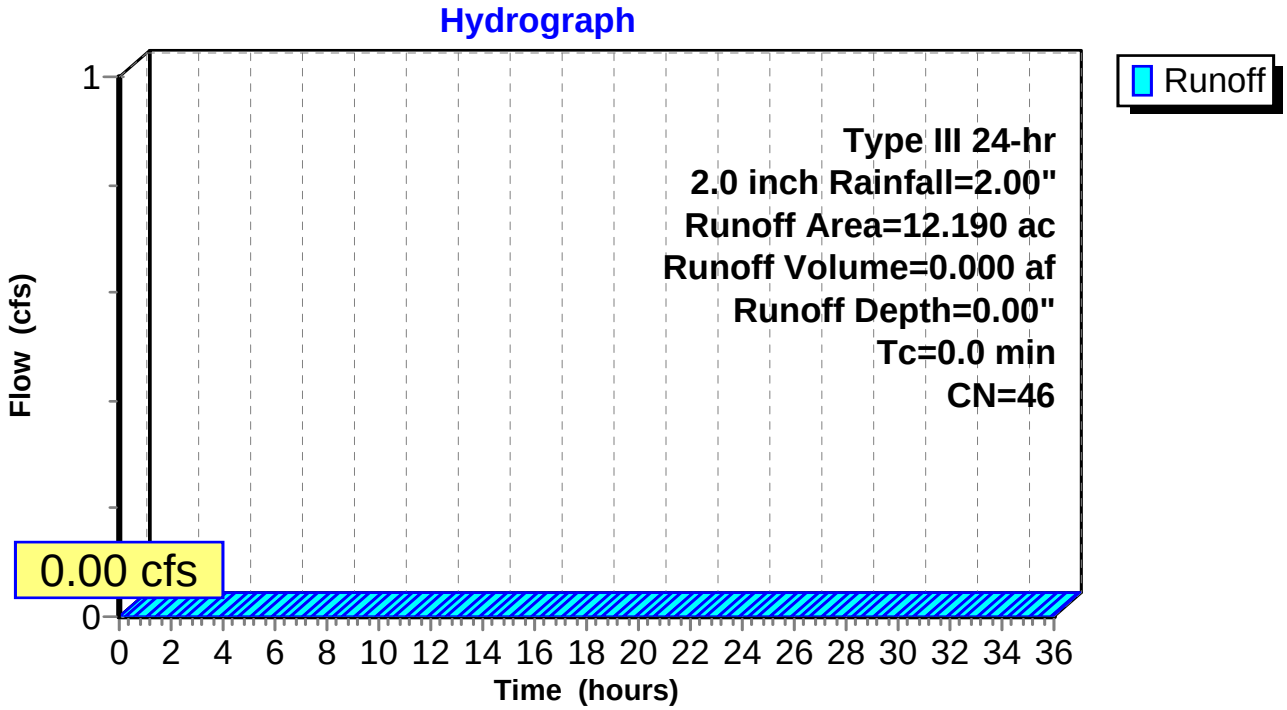
[46] Hint: Tc=0 (Instant runoff peak depends on dt)
[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 2.0 inch Rainfall=2.00"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 0.84" for 2.0 inch event
Inflow = 17.93 cfs @ 12.14 hrs, Volume= 1.607 af
Outflow = 16.77 cfs @ 12.18 hrs, Volume= 1.607 af, Atten= 6%, Lag= 2.4 min
Discarded = 3.31 cfs @ 12.18 hrs, Volume= 1.168 af
Primary = 13.46 cfs @ 12.18 hrs, Volume= 0.440 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 19.02' @ 12.18 hrs Surf.Area= 6,494 sf Storage= 6,670 cf

Plug-Flow detention time= 12.4 min calculated for 1.605 af (100% of inflow)
Center-of-Mass det. time= 12.4 min (783.5 - 771.1)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

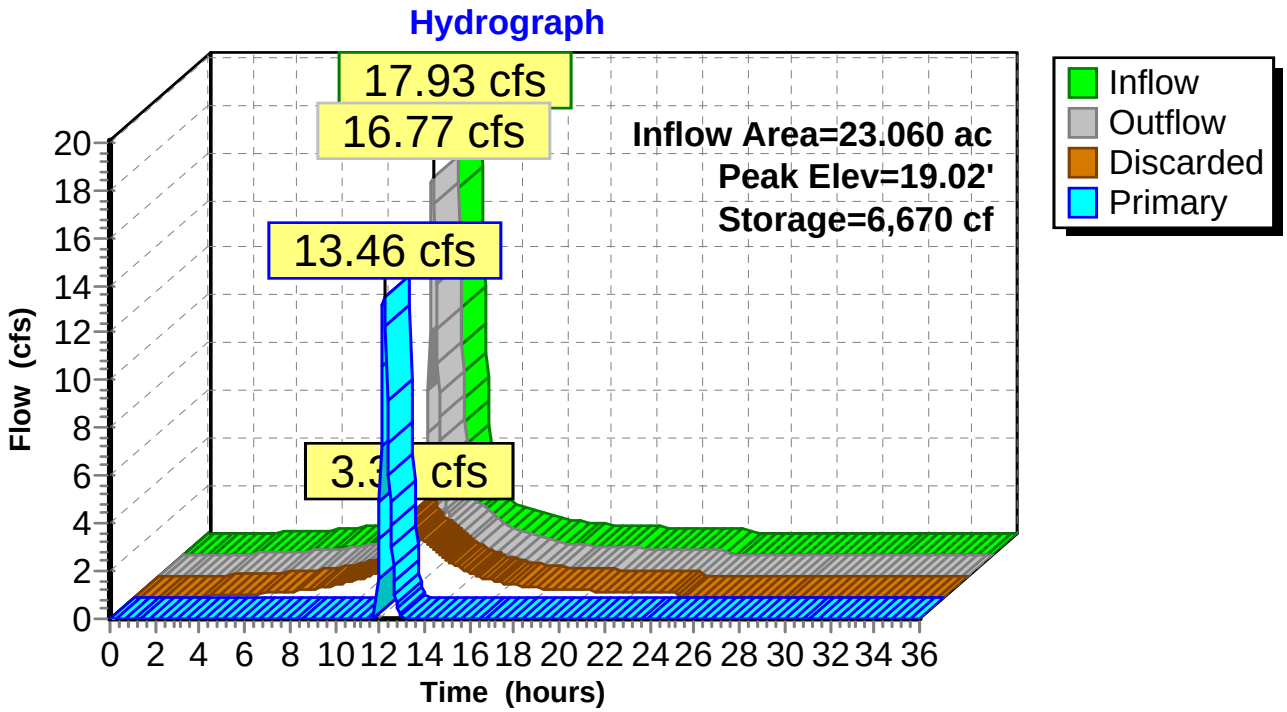
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=3.30 cfs @ 12.18 hrs HW=19.02' (Free Discharge)
└**1=Exfiltration** (Controls 3.30 cfs)

Primary OutFlow Max=13.21 cfs @ 12.18 hrs HW=19.02' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 13.21 cfs @ 1.90 fps)

Pond 3P: Infilt Basin



Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 4S: SEWO Site 2 IMP Runoff Area=10.870 ac 100.00% Impervious Runoff Depth=3.27"
Tc=10.0 min CN=98 Runoff=32.03 cfs 2.959 af

Subcatchment 5S: SEWO Site 2 PER Runoff Area=12.190 ac 0.00% Impervious Runoff Depth=0.10"
Tc=0.0 min CN=46 Runoff=0.17 cfs 0.105 af

Pond 3P: Infilt Basin Peak Elev=19.31' Storage=8,698 cf Inflow=32.03 cfs 3.063 af
Discarded=4.00 cfs 1.964 af Primary=26.18 cfs 1.100 af Outflow=30.17 cfs 3.064 af

Total Runoff Area = 23.060 ac Runoff Volume = 3.063 af Average Runoff Depth = 1.59"
52.86% Pervious = 12.190 ac 47.14% Impervious = 10.870 ac

Summary for Subcatchment 4S: SEWO Site 2 IMP

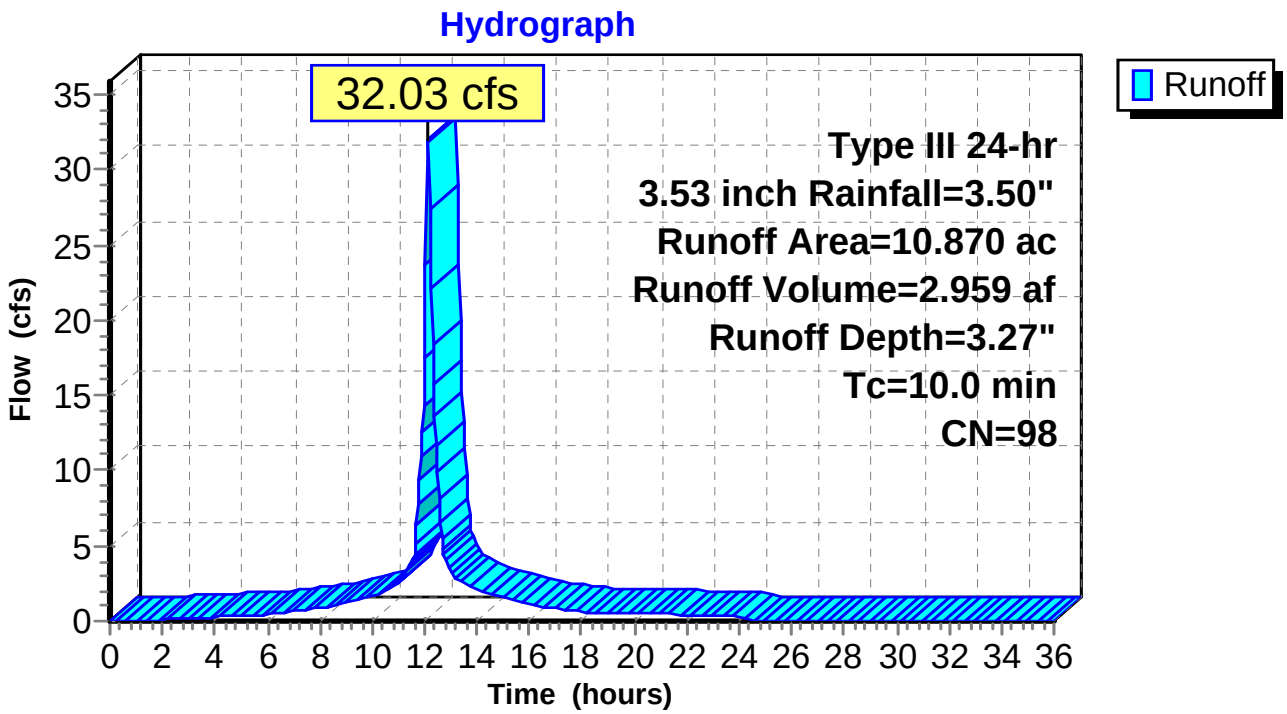
Runoff = 32.03 cfs @ 12.14 hrs, Volume= 2.959 af, Depth= 3.27"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 3.53 inch Rainfall=3.50"

Area (ac)	CN	Description
10.870	98	
10.870		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.0					**Direct Entry,**

Subcatchment 4S: SEWO Site 2 IMP



Summary for Subcatchment 5S: SEWO Site 2 PER

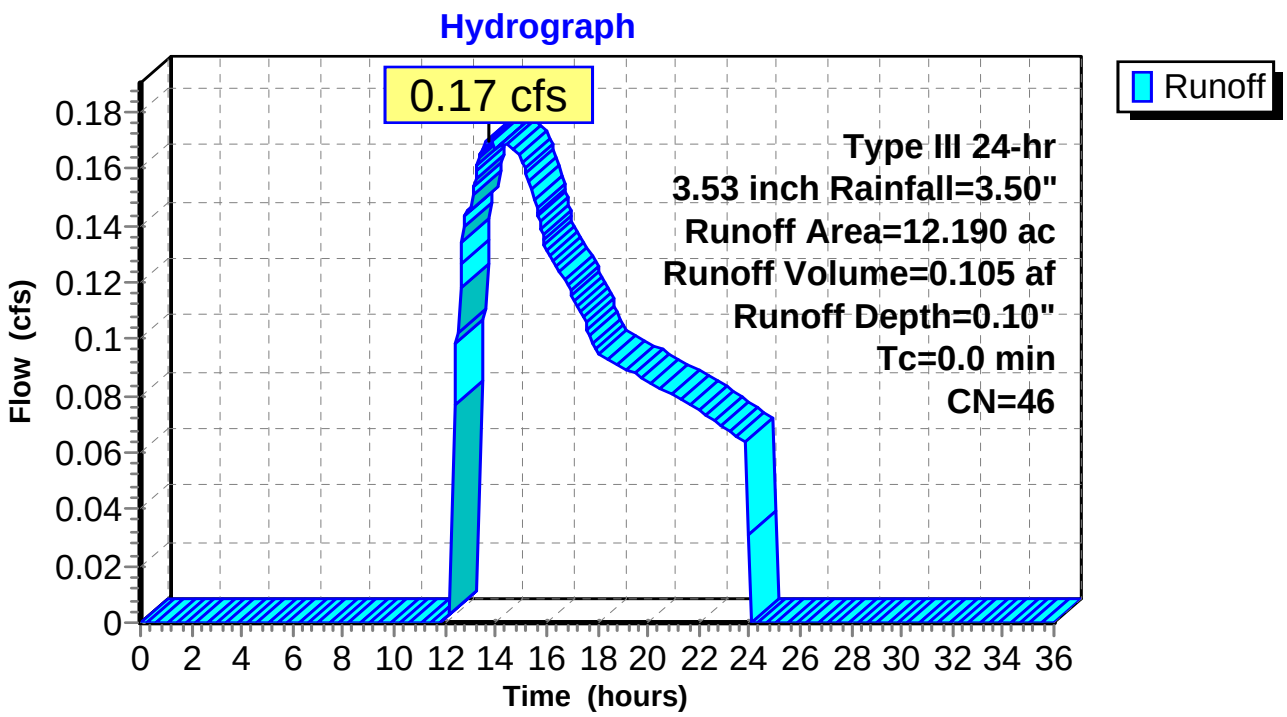
[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 0.17 cfs @ 13.70 hrs, Volume= 0.105 af, Depth= 0.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type III 24-hr 3.53 inch Rainfall=3.50"

Area (ac)	CN	Description
4.540	49	50-75% Grass cover, Fair, HSG A
7.650	45	Woods, Poor, HSG A
12.190	46	Weighted Average
12.190		100.00% Pervious Area

Subcatchment 5S: SEWO Site 2 PER



Summary for Pond 3P: Infilt Basin

Inflow Area = 23.060 ac, 47.14% Impervious, Inflow Depth = 1.59" for 3.53 inch event
Inflow = 32.03 cfs @ 12.14 hrs, Volume= 3.063 af
Outflow = 30.17 cfs @ 12.17 hrs, Volume= 3.064 af, Atten= 6%, Lag= 2.3 min
Discarded = 4.00 cfs @ 12.17 hrs, Volume= 1.964 af
Primary = 26.18 cfs @ 12.17 hrs, Volume= 1.100 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Peak Elev= 19.31' @ 12.17 hrs Surf.Area= 7,695 sf Storage= 8,698 cf

Plug-Flow detention time= 13.1 min calculated for 3.059 af (100% of inflow)
Center-of-Mass det. time= 13.1 min (780.7 - 767.6)

Volume	Invert	Avail.Storage	Storage Description
#1	17.00'	10,250 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

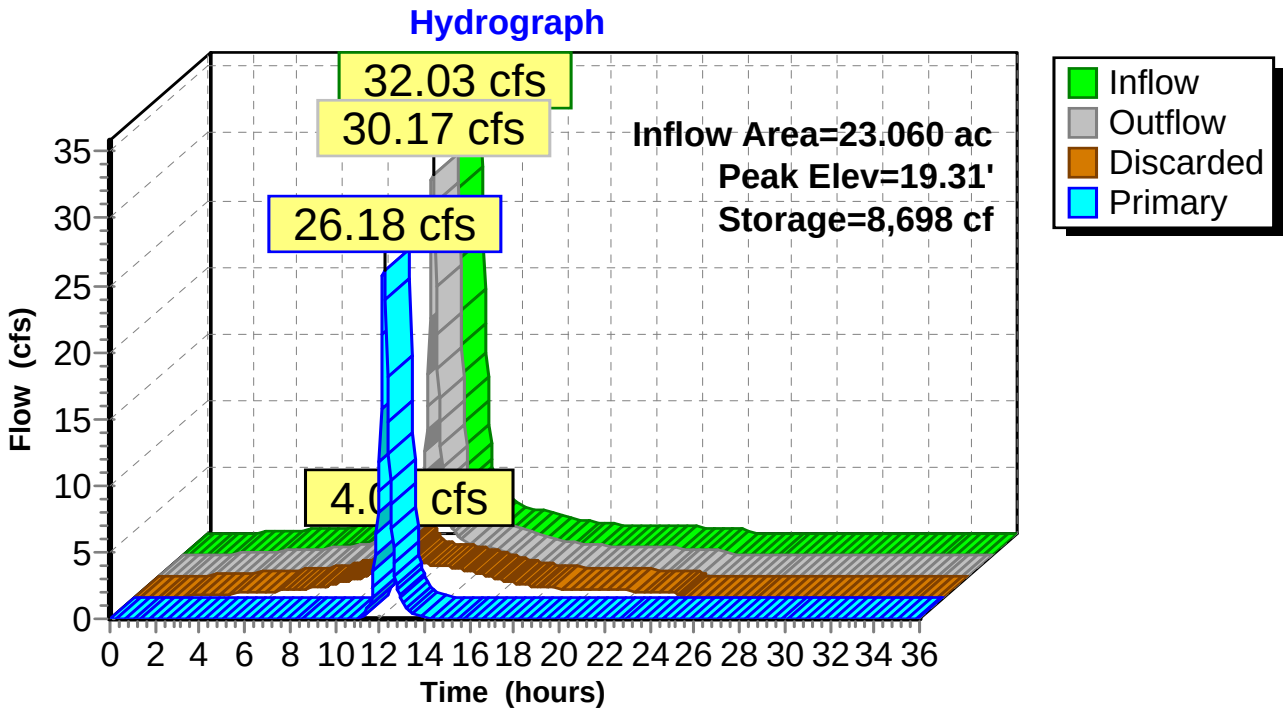
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
17.00	250	0	0
18.00	3,200	1,725	1,725
18.50	4,800	2,000	3,725
19.00	6,400	2,800	6,525
19.50	8,500	3,725	10,250

Device	Routing	Invert	Outlet Devices
#1	Discarded	17.00'	**16.800 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 14.33'
#2	Primary	18.50'	**13.5' long x 3.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 Coef. (English) 2.44 2.58 2.68 2.67 2.65 2.64 2.64 2.68 2.68 2.72 2.81 2.92 2.97 3.07 3.32

Discarded OutFlow Max=3.97 cfs @ 12.17 hrs HW=19.30' (Free Discharge)
└**1=Exfiltration** (Controls 3.97 cfs)

Primary OutFlow Max=25.64 cfs @ 12.17 hrs HW=19.30' (Free Discharge)
└**2=Broad-Crested Rectangular Weir** (Weir Controls 25.64 cfs @ 2.38 fps)

Pond 3P: Infilt Basin



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Appendix E

EPA National Stormwater Calculator
Summary and Results

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National Stormwater Calculator Report

Site Description

Parameter	Current Scenario	Baseline Scenario
Site Area (acres)	23.06	
Hydrologic Soil Group	A	
Hydraulic Conductivity (in/hr)	16.8	
Surface Slope (%)	2	
Precip. Data Source	MOREHEAD CITY 2 WNW	
Evap. Data Source	MOREHEAD CITY 2 WNW	
% Forest	33.17	
% Meadow	0	
% Lawn	19.69	
% Desert	0	
% Impervious	47.14	
Years Analyzed	37	
Ignore Consecutive Wet Days	False	
Wet Day Threshold (inches)	0.10	

LID Control	Current Scenario	Baseline Scenario
Disconnection	0	
Rain Harvesting	0	
Rain Gardens	0	
Green Roofs	0	
Street Planters	0	
Infiltration Basins	0	
Porous Pavement	0	

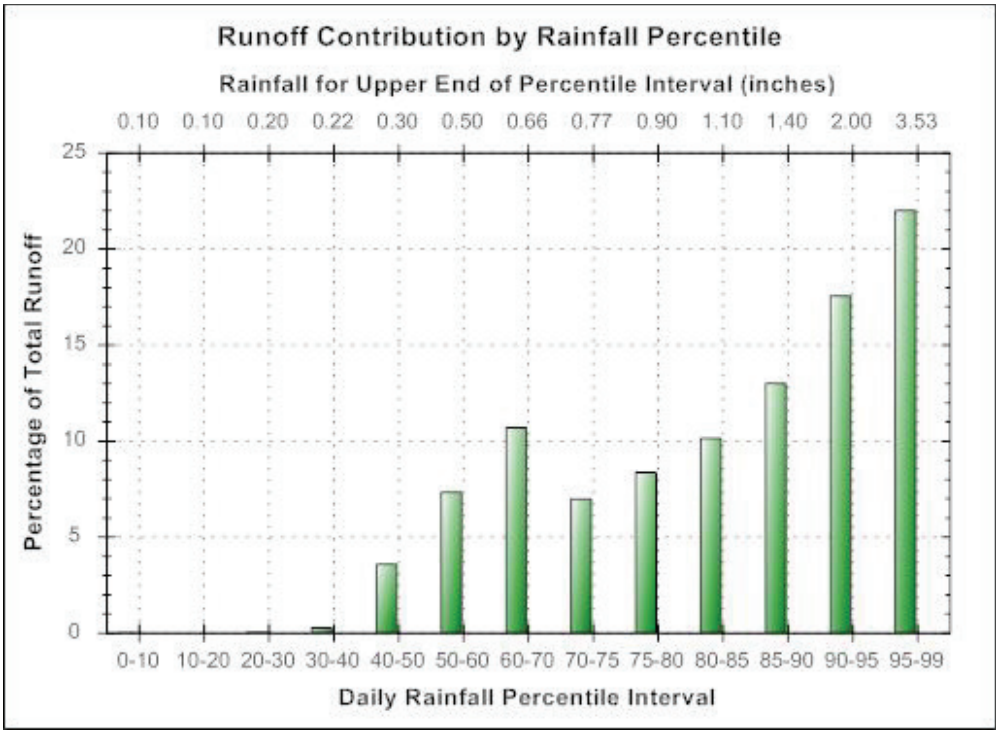
% of impervious area treated / % of treated area used for LID

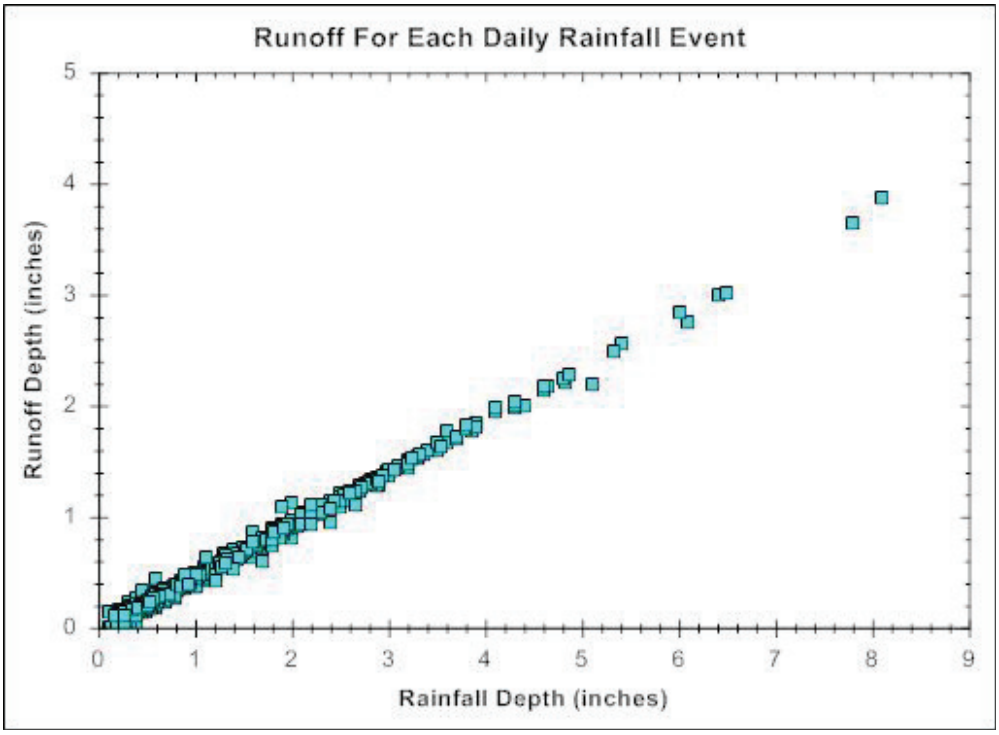
National Stormwater Calculator Report

Summary Results

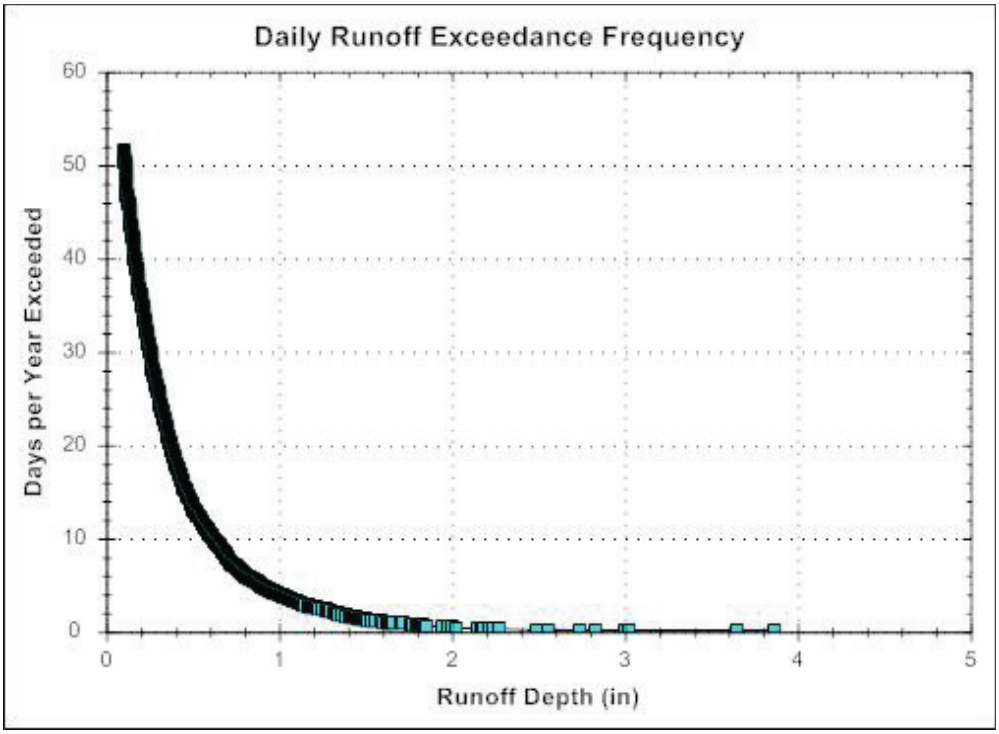
Statistic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	54.66	
Average Annual Runoff (inches)	23.67	
Percent of All Rainfall Retained	56.69	
Days per Year with Rainfall	90.86	
Days per Year with Runoff	51.67	
Percent of Wet Days Retained	43.13	
Smallest Rainfall w/ Runoff (inches)	0.10	
Largest Rainfall w/o Runoff (inches)	0.40	

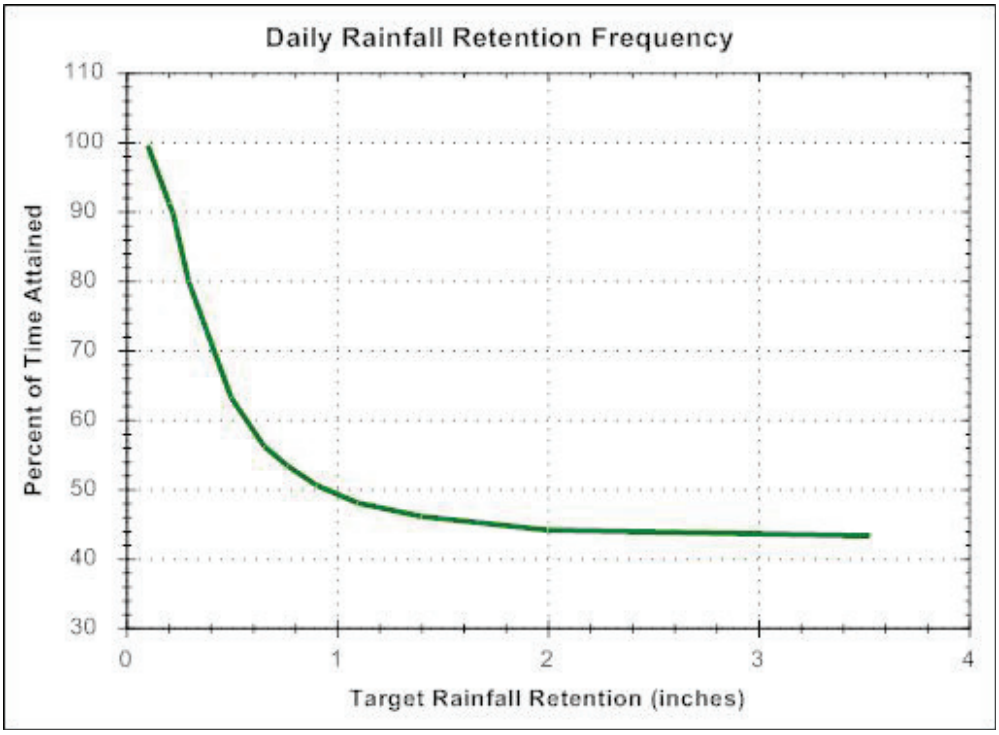
National Stormwater Calculator Report





National Stormwater Calculator Report





Appendix F

Calculations Workbook Used to Estimate
Annual Runoff Volume Reduction

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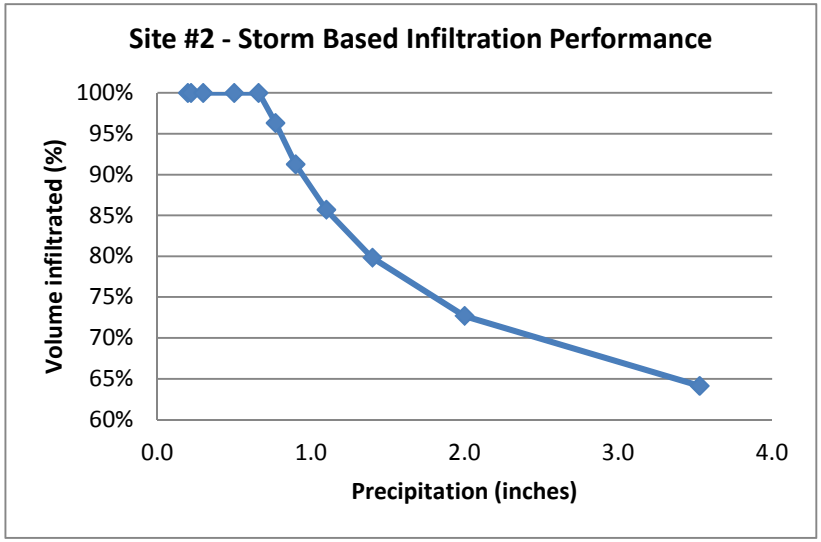
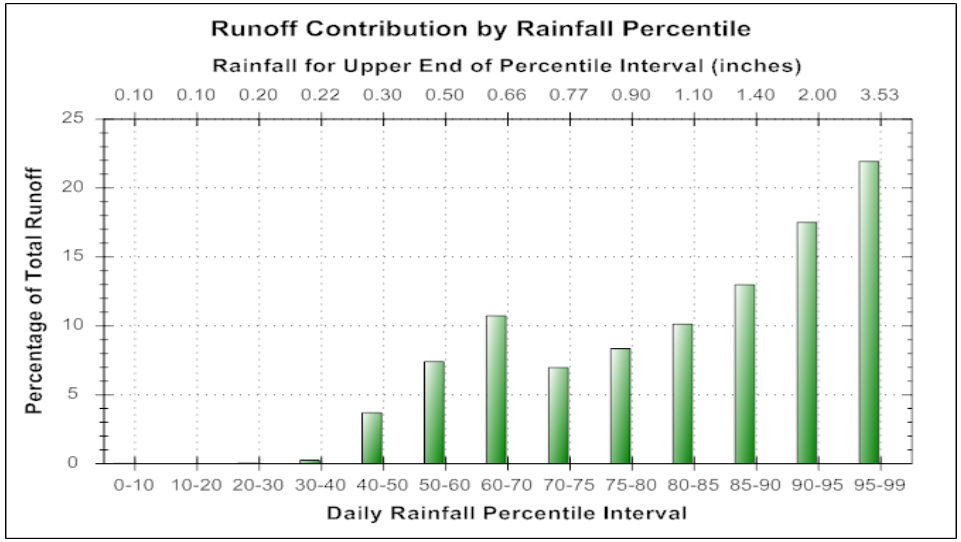
ANNUAL RUNOFF VOLUME CAPTURED
SITE 2: Infiltration Basin

HydroCAD inputs

Rainfall Distribution	SCS Type III 24-hr	
100% Ksat =	16.8	in/hr
Impervious area =	10.87	acres
Lawn/grass area =	4.54	acres
Woods/forest =	7.65	acres
CN impervious =	98	
CN pervious (comp) =	46	
Tc Impervious =	10	minutes
Tc Perviouis =	27	minutes

HydroCAD Results					Apply NSC Results	
Precip Depth (inches)	Storm Runoff Volume (ac-ft)	Storm Infiltrated Volume (ac-ft)	Storm Discharged volume (ac-ft)	Storm Infiltrated Volume (%)	Annual Runoff Contribution (%)	Annual Runoff Captured (%)
0.20	0.063	0.063	0.000	100%	0.0%	0.0%
0.22	0.076	0.076	0.000	100%	0.3%	0.3%
0.30	0.131	0.131	0.000	100%	3.6%	3.6%
0.50	0.288	0.288	0.000	100%	7.3%	7.3%
0.66	0.422	0.422	0.000	100%	10.7%	10.7%
0.77	0.516	0.497	0.019	96%	7.0%	6.7%
0.90	0.629	0.574	0.055	91%	8.4%	7.7%
1.10	0.803	0.688	0.115	86%	10.1%	8.7%
1.40	1.070	0.854	0.216	80%	13.0%	10.4%
2.00	1.607	1.168	0.439	73%	17.6%	12.8%
3.53	3.063	1.964	1.099	64%	22.0%	14.1%
				totals	100.0%	**82.2%**