Drainage Assessment
for
BRUSHNECK COVE STORMWATER MANAGEMENT IMPROVEMENTS
Asylum Road
Warwick, Rhode Island

NOVEMBER 2011

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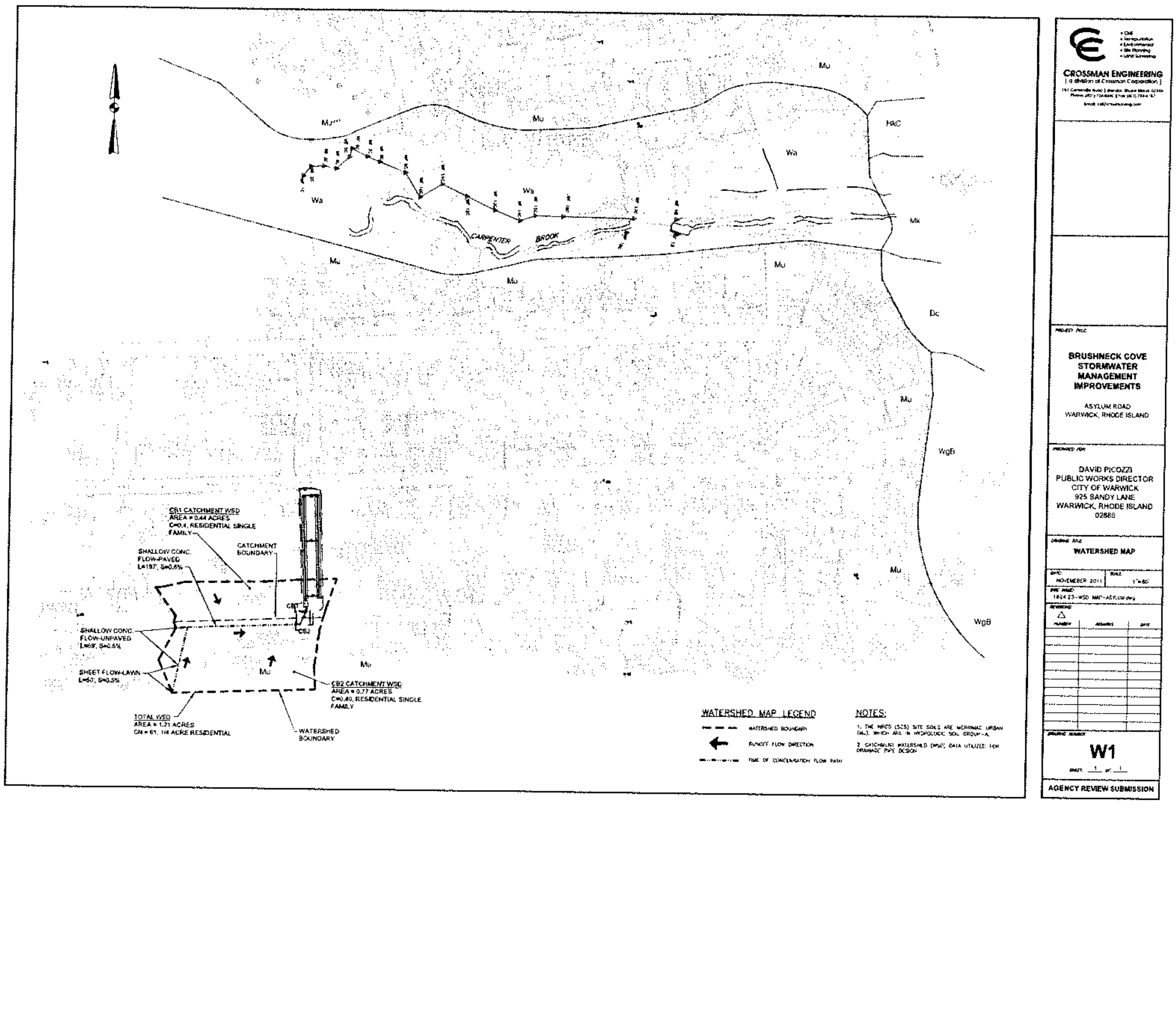
ATTACHMENT B-1



ATTACHMENT B-2

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SECTION 1: INTRODUCTION

Section 1: Introduction

This drainage assessment has been prepared for stormwater management improvements to the existing closed drainage system on Asylum Road in Warwick, Rhode Island. This project is part of a larger effort by the City and RIDEM to increase stormwater runoff infiltration within the Brushneck Cove watershed. The site is located within a residential neighborhood generally formed around Keeley Avenue, Wellington Avenue and Asylum Road. The site locus is illustrated in Figure 1. The USGS Map for the project area and site photographs are shown in the appendix.

Stormwater runoff from the residential neighborhood generally drains in a northerly direction towards the Carpenter Brook, which flows easterly to Brushneck Cove. Currently, stormwater runoff either flows directly into Carpenter Brook by surface flow and roadway gutter flow or it is collected by a closed drainage system which conveys it to the brook with limited pretreatment. The closed drainage system is located on Asylum Road, and on a portion of Wellington Avenue.

The project proposes to retrofit a portion of the existing closed drainage system on Asylum Road by re-routing the flow from two catch basins into an underground infiltration trench system which is sized to recharge the runoff volume from storms up to the 10-year frequency event. During larger storm events excess runoff will overflow into the existing closed drainage system. An oil and grit separator chamber will provide pretreatment of the runoff prior to entering the infiltration trench system.

The Stormwater Management System has been designed with Best Management Practices (BMP) as outlined in the Rhode Island Stormwater Design and Installation Standards Manual, December 2010 for stormwater retrofit projects. In general, the proposed retrofit system is designed to provide additional water quality treatment and groundwater recharge. The improvements are designed to accommodate peak flows from the 2, 10 and 100-year storm events.

An Operation and Maintenance Schedule for the Stormwater Management System is provided in Section 3 of this document. This provides the Owner with specific maintenance recommendations for the proposed BMPs after construction. In addition, operation and maintenance of the proposed BMPs must be in conformance with the City of Warwick's existing stormwater pollution prevention plan for its municipal stormwater collection system.

<u>Anticipated Local and State Permits:</u>

The project will require approval from the RI Department of Environmental Management Underground Injection Control Program for the proposed infiltration trench system. No Local permits are required.

Figure 1 – Locus Map

SECTION 2: METHODOLOGY

Section 2: Methodology

2.1 Stormwater Runoff

The existing and proposed runoff hydrographs have been computed utilizing the "Hydrocad Version 9.10" software package.

Generally, the methodology encompasses the Soil Conservation Services (SCS) unit hydrograph method used in TR-20 that provided a basis for TR-55. The hydrologic data is the same information required for TR-55 and includes watershed areas, SCS runoff curve numbers, watershed slope and the travel length from the most remote watershed point. With this data, complete SCS hydrographs can be developed for a 24-hour Type-III storm. The watershed time of concentration is computed internally using the SCS "TR-55 Method," but if special conditions exist, the time can be adjusted manually.

2.2 Detention Ponds

The detention ponds will be designed by modeling stage/storage/discharge relationships with the "Hydrocad" program. The input data required is:
Discharge:

- Orifice: Outlet diameter
- Pipe: Outlet diameter
  - Manning's N-Value
  - Invert
  - Length
  - Slope
- Weir: Crest length
  - Crest elevation
  - Weir coefficient

2.3 Stage/Storage

The "Hydrocad" program provides surface areas at various stage elevations based on the input data. Then, the "Hydrocad" program automatically routes hydrographs through detention facilities to determine the resulting outflow while also combining hydrographs to determine cumulative sub-watershed flows.

2.4 Drainage Pipe Sizing

The drainage pipe system will be designed by utilizing the "Hydraflow Storm Sewer" Version 8 software package developed by Intellisolve. In general, the methodology is based upon the Standard Step (Energy Equation) and the Manning's equation. All drainage lines are designed for the 100-year frequency storm event. Rainfall Intensity Duration data was obtained for Kent County Rhode Island from the website "Extreme Precipitation in New England and New York" ("http://precip.eas.cornell.edu").

SECTION 3: STORMWATER MANAGEMENT SYSTEM – MAINTENANCE & OPERATION

3.0 Stormwater Management System – Maintenance & Operation

3.1 Responsibility

The City of Warwick Department of Public Works, or their designee, will be responsible for performing maintenance of the proposed drainage system improvements and the existing drainage system components.

Contact Information: City of Warwick Department of Public Works
952 Sandy Lane
Warwick, RI 02889
Telephone Number: 401-738-2000, ext. 6500

3.2 Catch Basins, Manholes and Drain Lines

An inspection must occur on an annual basis by qualified personnel to ensure proper operation. The inspection should, as a minimum, concentrate on the following:

- Damage to grate/cover
- Evidence of standing water
- Debris removal
- Structural alignment/integrity

Any deficiency noted during the inspection will be immediately repaired or replaced. Catch basins must be cleaned on an annual basis. All removed sediment is to be tested to determine pollutant content. The sediment is to be properly disposed in upland areas based upon the test results and local, state and federal regulations.

3.3 Oil and Grit Separator

An inspection must occur on an annual basis by qualified personnel to ensure proper operation. The inspection should, as a minimum, concentrate on the following:

- Damage to covers
- Evidence of clogged baffle orifices and/or elbows, such as standing water deeper than 5 feet in the sediment storage and oil separation chambers.
- Debris removal
- Sediment and Oil/Grease accumulation
- Structural alignment/integrity
- Inlet and Outlet free of debris

Any deficiency noted during the inspection must be immediately repaired or replaced. The chamber must be inspected on an annual basis and if necessary cleaned. Removed sediment is to be properly disposed in upland areas based upon the test results and local, state and federal regulations. Removed hazardous liquids (petroleum products) and debris are to be properly disposed based upon local, state and federal regulations

3.4 Infiltration System

The infiltration systems shall be inspected annually and after storm events equal to or greater than the 1-year, 24 hour storm event. If the infiltration system does not drain after three days (72 hours), the drain lines shall be cleaned. Any deficiency noted during the inspection will be immediately repaired or replaced.

3.4 Sample Checklist

The following pages contain a sample drainage system maintenance checklist, which can be utilized by the Owner or their designee.

Sample Stormwater
Management Systems
Inspection and Maintenance Log

Site:
Address:
Date:
Inspector:

Item			Inspection OK	Service Required	Service Performed	Supervisor Notified
1.0	Catch basins					
	1.1	Sediment and debris accumulation within 6" of Outlet Service Required	☐	☐	☐	☐
	1.2	Frame and Grate in Good Condition	☐	☐	☐	☐
	1.3	Inlet and Outlet Pipes Free of Debris	☐	☐	☐	☐
	1.4	Integrity of Catch basin Structure	☐	☐	☐	☐
	1.5	Describe Service Provided:				
2.0	Manholes					
	2.1	Invert free of sediment and debris	☐	☐	☐	☐
	2.2	Frame and Cover in Good Condition	☐	☐	☐	☐
	2.3	Inlet and Outlet Pipes free of debris	☐	☐	☐	☐
	2.4	Integrity of Manhole Structure	☐	☐	☐	☐
	2.5	Describe Service Provided:				
3.0	Oil and Grit Separator					
	3.1	Sediment and Oil/Grease Accumulation	☐	☐	☐	☐
	3.2	Frame and Covers in Good Condition	☐	☐	☐	☐
	3.3	Inlet and Outlet Pipes Free of Debris	☐	☐	☐	☐

	3.4	Evidence of clogged baffle orifices and/or elbows, such as standing water deeper than 5 feet in the sediment storage and oil separation chambers	☐	☐	☐	☐
	3.5	Integrity of Structure	☐	☐	☐	☐
	3.6	Describe Service Provided:				
4.0	Infiltration Drain Lines – Annual Inspection					
	4.1	Observation well cap maintained; Observation Well clear of debris	☐	☐	☐	☐
	4.2	No standing water in Observation well after precedent 72 hour dry period	☐	☐	☐	☐
	4.3	Describe Service Provided:				
5.0	Miscellaneous					
	5.1	Excessive sediment accumulation on driveways, parking lots and sidewalks	☐	☐	☐	☐
	5.2	Evidence of erosion within landscape areas or on adjacent parcels	☐	☐	☐	☐
	5.3	Describe Service Provided:				
6.0	General Comments:					

SECTION 4: WATERSHED ANALYSIS SUMMARY

Section 4: Watershed Analysis Summary

This section details conformance of the proposed project with the Rhode Island Stormwater Design and Installation Standards Manual, December 2010.

4.1 Site Soils

Site Soils were identified from Map No. 68 of the Soil Survey of Rhode Island prepared by the USDA, Soil Conservation Service. The site contains the following SCS soil types:

Mu – Merrimac Urban Land Complex

The Merrimac Urban Land Complex soils are well drained Merrimac soils formed in glacial outwash deposits located in upland areas that are suitable for community development. Merrimac Urban Land Complex soils are in Hydrologic Soil Group – A.

Seasonal high groundwater elevations were determined by an on-site soil evaluation test pit performed in April 2011. The test pit data sheets are shown in the Appendix.

4.2 Watershed Analysis Summary

The watershed to the proposed BMP structure contains 1.21 acres and is situated within a larger residential neighborhood with ¼ acre lots. In general, the neighborhood and the subject watershed, drain in northerly direction towards the Carpenter Brook, which flows in an easterly direction to Brushneck Cove. The subject closed drainage system collects stormwater runoff from Asylum Road and Wellington Avenue, and conveys it to the Carpenter Brook via a trunk line situated within the Boyle Avenue right-of-way.

The proposed improvements consist of re-routing stormwater runoff from two existing catch basins into an underground infiltration system which is sized to recharge the runoff volume from storms up to the 10-year frequency event. During larger storm events the excess runoff will be discharged into the aforementioned trunk line. An oil and grit separator chamber will provide pretreatment of the runoff prior to entering the infiltration system. The following Sections 4.3, 4.4 and 4.5 detail the pretreatment design and the infiltration system design.

Hydrographs were developed for the watershed and the infiltration system routing. For the infiltration system routing the Hydrocad program determined the exfiltration rate and volume using the design infiltration rate and the system surface areas. Calculations for the 2, 10 and 100-year storm events and the watershed map are shown in the Appendix. Tables 1 and 2 summarize the results of the analysis.

Table 1: Watershed Data

Surface	Area (ac)	CN	A x CN
¼ Acre Residential (38% Impervious)	1.21	61	73.81
Totals	1.21		73.81
		Weighted CN =	61

Table 2: Watershed Analysis Results

Condition	Peak Flow, Q (cfs)[Runoff Volume (ac-ft)]		
	2-Year	10-Year	100-Year
Inflow (Hyd. #1S)	0.52[0.049]	1.80[0.126]	6.34[0.402]
Infiltration System Overflow (Hyd. #1P, Primary Outflow)	0.00[0.00]	0.00[0.00]	4.69[0.185]
% Reduction	100%[100%]	100%[100%]	26%[54%]

4.3 Water Quality Volume (WQ_v) and Water Quality Flow (WQ_f)

Area of Impervious Surfaces within the contributing watershed (I) = 0.46 acres

Water Quality Volume (**WQ_v**) = 0.46 acres x 43,560 sf/Acre x 1"/12"/ft = **1,670 cf**

Water Quality Flow (**WQ_f**):

P=1.2 inches
Q= 1,670 cf/(1.21 acres x 43,560 sf/acre) = 0.032 ft = 0.384 inches
$CN = 1000/[10 + 5(1.2) + 10(0.384) - 10((0.384)^2 + 1.25(0.384x1.2))^{.5}] = 88.2$
$I_a=200/88.2 - 2 = 0.232$
$I_a/P = 0.232/1.2 = 0.19$, use 0.2
Time of Concentration from Hydrocad = 2.6 min. ~ 0.10 hrs
From TR-55 Figure 4-III, q_u = 625 csm/in
Drainage Area in Square Miles (A) = 1.21 Acres/640 ac./mi.^{2} = 0.0019 mi.^{2}
$WQ_f = q_u \times A \times Q = 625 \times 0.0019 \times 0.384 =$ 0.456 cfs

4.4 Oil and Grit Separator Design

An oil and grit separator is proposed for pretreatment of stormwater runoff prior to entering the infiltration trenches. The structure will constructed as specified in the Massachusetts Stormwater Handbook Structural BMP Specifications. The Massachusetts specifications allow a 25% TSS Removal credit for the structure if the permanent pool (sediment storage chamber and oil separation chamber) has a minimum volume equal to 400 cubic feet per acre of impervious surfaces and if the permanent pool is at least 4 feet deep. The RIDEM Stormwater design manual also requires the structure to provide a 60 second detention time.

Area of Impervious Surfaces (A) = 0.46 acres
Minimum Volume of Permanent Pool = 0.46 acres x 400 cf/Acre = 184 cf
25-year storm peak flow = 3.29 cfs
60 second detention volume for 25-year storm = 3.29 cfs x 60 seconds = 197 cf
Minimum Permanent Pool Volume = 197 cf
Proposed Permanent Pool Volume:
Pool Volume in Sediment Storage Chamber = 5' deep x 6' wide x 4.5' long = 135 cf
Pool Volume in Oil Separation Storage Chamber = 5' deep x 6' wide x 3' long = 90 cf
Total Volume of Permanent Pool = 135 cf + 90 cf = 225 cf

The peak flow capacity of the structure is sized to pass the 100-year storm peak inflow. Capacity calculations for the sediment storage chamber baffle and the oil separation chamber baffle are shown in the appendix. The sediment storage chamber baffle has two 10" diameter orifices and the oil separation chamber has three 12" diameter elbows.

4.5 Infiltration System Design

The proposed infiltration system consists of two interconnected infiltration trenches located in an unimproved section of the Boyle Avenue right-of-way. Existing single family residences are situated on both sides of the right-of-way which are served by public water and public sewer. A summary of the horizontal setbacks as required in Table 5-2 of the stormwater design manual is shown below in Table 3.

Table 3: Horizontal Setbacks from the Infiltration System

	Minimum (ft)	Proposed (ft)
Public Drinking Water Supply Well - Drilled	200	> 200
Public Drinking Water Supply Well - Gravel	400	> 400
Private Drinking Water Wells	100	> 100
Surface Water Drinking Water Supply Impoundment	200	> 200
Tributaries that Discharge to a Surface Drinking Water Impoundment	100	> 100
Coastal Features	50	450 (brook)
All other Surface Waters	50	450 (brook)
Up-gradient from Natural slopes >15%	50	120
Down-gradient from Building Structures	25	20
Up-gradient from Building Structures	50	20
On-site Wastewater Treatment Systems	25	Project Area is sewered

A soil evaluation test pit was performed on April 4, 2011 by Crossman Engineering, which found a coarse to loamy coarse sands from the subsoil layer (21") down to 84" and a loamy sands from 84" to the bottom of the test pit at 96". No redox features and no groundwater seepage were observed in the test pit. The seasonal high groundwater elevation was determined to be deeper than 84". An adjacent soil boring performed for the gravity sewer system design on Asylum, indicated a groundwater depth of 11.7'. A copy of the sewer system design plan and profile is shown in the appendix. The seasonal high groundwater depth utilized for design was set to the bottom of the test pit at 96" (elevation = 28.0), however the actual elevation could be lower.

An infiltration test was performed at a depth of 54"with a double ring infiltrometer which determined an infiltration rate of over 4 inches/min. However, the limiting soil layer for infiltration was considered to be the loamy sand layer below 84", therefore a design infiltration rate of 2.41 inches per hour from Table 5-3 of the stormwater design manual was utilized.

Each infiltration trench is 178' long x 7' wide and 3.5' deep, with an 18" diameter perforated pipe located in the center for distribution surrounded by crushed stone and a 10" diameter overflow pipe. The two trenches are interconnected with 18" diameter pipe. The invert of the 18" diameter distribution pipe was set at elevation 31.0 to maintain a minimum slope from the oil and grit separator, the bottom elevation of the crushed stone was set 6" below at elevation 30.5, and the invert elevation of the 10" overflow pipe was set at 32.25.

To verify the infiltration system's ability to recharge stormwater under high groundwater conditions, the response of the water table was predicted by using the "Colorado State University Pit and Well" (CSUPAW) computer program which is based upon the Hantush Method (1967). The program modeled the mound created by the 100-storm event infiltration volume determined by the Hydrocad program over a 24 hour (1-day) period with groundwater levels at the seasonal high elevation. The input data is shown below:

<u>Groundwater Mound Analysis Input Data:</u>

1. Dimension of Recharge Basin: Width* = 14', Length = 178' (*combined width of both trenches)
2. Recharge Rate: 100-yr storm, 24-hour exfiltration volume = 0.203 ac-ft. = 8,843 cf
   = (8,843 cf/day)/(178'x 14') = 3.55 ft/day
3. Transmissivity (T): T = (Aquifer thickness) x (Permeability)
   Average Permeability Rate = $1x10^{-4}$m/sec (Fine to Coarse Sand) = 28.3 ft/day
   Aquifer Thickness ~ 20 feet (No refusal at 17'in adjacent sewer system soil boring)
   T = (28.3 ft/day)(20 feet) = 566 sf/day
4. Average Specific Yield = 25% (Sand)
5. Analysis Duration = 1 day
6. Recharge Period = 1 day
7. Range of Model = 100 feet
8. Depth to Groundwater from bottom of System = 2 feet (El. 30.5 – El. 28 = 2.5 feet)

A simulation was performed along the short axis (90 degrees to the trenches) and along the long axis. For the 100-year storm event the analysis determined a rise of 2.105 feet directly beneath the infiltration system and a rise of 1.493 feet at a distance of 20 feet on the short axis. The results showed that under these extreme conditions the resulting mound does not affect operation of the proposed system. The analysis output data are shown in the appendix.

SECTION 5: DRAINAGE PIPE DESIGN

Section 5: Drainage Pipe Design

The drainage pipe design has been modeled by using the "Hydraflow" Storm Sewer program, also developed by Intellisolve. In general, the methodology is based upon the Standard Step (Energy Equation) Method and Manning's equations. The Standard Step applied Bernoulli's energy equation between the downstream and upstream ends of each line to compute the hydraulic profile. Manning's equation determines the head loss due to pipe friction. All drainage lines will be designed to accommodate a 100-year storm event and included runoff from the future parking area and future building additions.

Table 1: Sub-Catchment Breakdown of Surface Areas

Area Number	Total Area (AC)	Residential (AC)	
CB #1	0.44	0.44	
CB #2	0.77	0.77	

The following runoff coefficients (C) were utilized for the above areas:

Single Family Residential = 0.40

SECTION 6: APPENDIX

a. Stormwater Management Checklist – Appendix A

APPENDIX A: STORMWATER MANAGEMENT CHECKLIST

The first thing that applicants and designers must do before beginning a project is to make sure they are familiar with the 11 minimum standards listed in Manual Chapter Three, as projects must meet all 11 standards. Next, designers should review the available LID site planning and design strategies and BMPs in Manual Chapters Four through Seven to determine which would work best at their site. This checklist serves as a guide for engineers and designers to refer to during all stages of a project to ensure that they are meeting all applicable requirements. In addition, designers must include a completed checklist with their final stormwater management plan.

A.1 CHECKLIST FOR STORMWATER MANAGEMENT PLAN PREPARATION AND REVIEW

A.1.1 General Information

- [X] Applicant name, mailing address, and telephone number
- [X] Contact information for the licensed professional(s) responsible for site plans and stormwater management plan
- [X] Common address and legal description of project site
- [X] Vicinity map
- [NA] Existing zoning and land use at the project site (MUNICIPAL RIGHT-OF-WAY)
- [X] Proposed land use – indicate if land use meets definition of a LUHPPL (see Manual Table 3-2)
- [X] General Project Narrative
- [X] Project type (new development or redevelopment) STORMWATER SYSTEM RETROFIT

A.1.2 Existing and Proposed Mapping and Plans

- [X] Existing and proposed mapping and plans (scale not greater than 1" = 40') with North arrow that illustrate at a minimum:
  - [X] Existing and proposed site topography (2-foot contours required). 10-foot contours accepted for off-site areas.
  - [X] Existing and proposed drainage area delineations and drainage flow paths, mapped according to the DEM *Guidance for Preparation of Drainage Area Maps* (included in Appendix K). Drainage area boundaries need to be complete; include off-site areas in both mapping and analyses, as applicable.
  - [X] Perennial and intermittent streams, in addition to areas subject to storm flowage (ASSFs) NONE IN PROJECT AREA

- [X] Mapping of predominant soils from USDA soil surveys, especially hydric soil groups as well as location of site-specific borings and/or test pits (on drainage area maps only – not site plans)
- [X] Boundaries of existing predominant vegetation and proposed limits of clearing
- [X] Location and field-verified boundaries of resource protection areas such as freshwater and coastal wetlands, lakes, ponds, coastal shoreline features and required setbacks (e.g., buffers, water supply wells, septic systems)
- [NA] Location of floodplain and, if applicable, floodway limits and relationship of site to upstream and downstream properties and drainages
- [X] Location of existing and proposed roads, buildings, and other structures including limits of disturbance
- [X] Existing and proposed utilities (e.g., water, sewer, gas, electric) and easements
- [X] Location of existing and proposed conveyance systems such as grass channels, swales, and storm drains
- [NA] Location and dimensions of channel modifications, such as bridge or culvert crossings
- [X] Location, size, and limits of proposed LID planning and site design techniques (type of practice, depth, area). LID techniques should be labeled clearly on the plan and a key should be provided that corresponds to a tabular description.
- [X] Location, size, and limits of disturbance of proposed stormwater treatment practices (type of practice, depth, area). Stormwater treatment practices (BMPs) should be labeled with numbers that correspond to the table in Section A.1.5.
- [X] Soils information from test pits or borings at the location of proposed stormwater management facilities, including but not limited to soil descriptions, depth to seasonal high groundwater, depth to bedrock, and estimated hydraulic conductivity. Soils information will be based on site test pits or borings logged by a DEM-licensed Class IV soil evaluator or RI-registered PE.
- [NA] 8.5 x 11 inch copy of site plan for public notice, as applicable.

A.1.3 Minimum Stormwater Management Standards

[X] **Minimum Standard 1: LID Site Planning and Design Strategies**

Document specific LID site planning and design strategies and associated methods that were employed for the project in the following table:

LID Site Planning and Design Checklist

The applicant must document specific LID site planning and design strategies applied for the project (see Manual Chapter Four and the *RI Community LID Guidance Manual* for more details regarding each strategy). If a particular strategy was not used, a justification and description of proposed alternatives must be provided. If a strategy is not applicable (N/A), applicants must describe why a certain method is not applicable at their site. For example, preserving wetland buffers may be not applicable for sites located outside any jurisdictional wetland buffers. In communities where conservation development or other low-impact development site planning and design processes exist, following the local community conservation development option may help a project achieve this standard.

1. Strategies to Avoid the Impacts

A. Preservation of Undisturbed Areas

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Limits of disturbance clearly marked on all construction plans.
- ☐ Mapped soils by Hydrologic Soil Group (HSG).
- ☐ Building envelopes avoid steep slopes, forest stands, riparian corridors, HSG D soils, and floodplains.
- ☐ New lots, to the extent practicable, have been kept out of freshwater and coastal wetland jurisdictional areas.
- ☐ Important natural areas (i.e., undisturbed forest, riparian corridors, and wetlands) identified and protected with permanent conservation easement.
- ☐ Percent of natural open space calculation is provided.
- ☐ Other (describe):

Explain constraints when a strategy is applied and/or proposed alternatives in space below:

PROJECT IS A MUNICIPAL STORMWATER RETROFIT PROJECT. WORK IS PROPOSED WITHIN EXISTING UNDEVELOPED, BUT CLEARED, MUNICIPAL RIGHT-OF-WAY.

B. Preservation of Buffers and Floodplains

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following:

- ☐ Applicable vegetated buffers of coastal and freshwater wetlands and perennial and intermittent streams have been preserved, where possible.
- ☐ Limits of disturbance included on all construction plans that protect applicable buffers
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

LID Site Planning and Design Checklist

C. Minimized Clearing and Grading

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Site fingerprinting to extent needed for building footprints, construction access and safety (i.e., clearing and grading limited to 15 feet beyond building pad or 5 feet beyond road bed/shoulder).
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

D. Locating Sites in Less Sensitive Areas

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ A site design process, such as conservation development, used to avoid or minimize impacts to sensitive resources such as floodplains, steep slopes, erodible soils, wetlands, hydric soils, surface waters, and their riparian buffers.
- ☐ Development located in areas with least hydrologic value (e.g., soil groups A and B)
- ☐ Development on steep slopes, grading and flattening of ridges has been avoided to the maximum extent practicable.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

E. Compact Development

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ A site design technique (e.g., conservation development) used to concentrate development to preserve as much undisturbed open space as practicable and reduce impervious cover.
- ☐ Reduced setbacks, frontages, and right- of- way widths have been used where practicable.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

LID Site Planning and Design Checklist

F. Work with the Natural Landscape Conditions, Hydrology, and Soils

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Stormwater management system mimics pre-development hydrology to retain and attenuate runoff in upland areas (e.g., cuts and fills limited and BMPs distributed throughout site; trees used for interception and uptake).
- ☐ The post-development time of concentration (t_c) should approximate pre-development t_c.
- ☐ Flow velocity in graded areas as low as practicable to avoid soil erosion (i.e., slope grade minimized). Velocities shall not exceed velocities in Appendix B, Table B-2.
- ☐ Plans show measures to prevent soil compaction in areas designated as Qualified Pervious Areas (QPAs) for better infiltration.
- ☐ Site designed to locate buildings, roadways and parking to minimize grading (cut and fill quantities)
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

2. Strategies to Reduce the Impacts

Reduce Impervious Cover

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Reduced roadway widths
- ☐ Reduced sidewalk area
- ☐ Other (describe):
- ☐ Reduce driveway areas
- ☐ Reduced cul-de-sacs
- ☐ Reduced building footprint
- ☐ Reduced parking lot area

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

3. Strategies to Manage the Impacts

A. Disconnecting Impervious Area

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Impervious surfaces have been disconnected to QPAs to the extent possible.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

LID Site Planning and Design Checklist

B. Mitigation of Runoff at the point of generation

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Roof runoff has been directed to a QPA, such as a yard or vegetated area.
- ☐ Roof runoff has been directed to a lower impact practice such as a rain barrel or cistern.
- ☐ A green roof has been designed to reduce runoff.
- ☐ Small-scale BMPs applied at source.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A. PROJECT PROPOSES TO INCREASE STORMWATER INFILTRATION.

C. Stream/Wetland Restoration

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Historic drainage patterns have been restored by removing closed drainage systems and/or restoring degraded stream channels and/or wetlands.
- ☐ Removal of invasive species.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

D. Reforestation

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Low maintenance, native vegetation has been proposed.
- ☐ Trees are proposed to be planted or conserved to reduce runoff volume, increase nutrient uptake, and provide shading and habitat.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

E. Source Control

☒ Not Applied or N/A. *Use space below to explain why:*

Select from the following list:

- ☐ Source control techniques such as street sweeping or pet waste management have been proposed.
- ☐ Other (describe):

Explain constraints and/or proposed alternatives in space below:

SEE RESPONSE IN SECTION A.

☒ **Minimum Standard 2: Groundwater Recharge** (SEE NOTE)

Demonstrate that groundwater recharge criteria for the site have been met. Include:

NA The required recharge volume (Re_v) in acre-feet (See Manual Section 3.3.2)

NA LID Stormwater Credit from Checklist Section A.1.4 to be applied to recharge requirement, if applicable, with the following calculations (See Manual Section 4.6.1):

- the recharge area (Re_a) in acres for the site
- the site impervious area draining to QPAs
- the new Re_v requirement

NA Specific BMPs from Checklist Section A.1.5 that will be used to meet the recharge requirement. *Note: Only BMPs listed in Manual Table 3-5, List of BMPs Acceptable for Recharge may be used to meet the recharge requirement.*

NOTE: PROJECT PROPOSES TO RETROFIT EXISTING MUNICIPAL DRAINAGE SYSTEM BY ADDING AN INFILTRATION TRENCH SYSTEM.

☒ **Minimum Standard 3: Water Quality**

Demonstrate that the water quality criteria for the site have been met. Include:

☒ Required water quality volume (WQ_v) in acre-feet or ft^3 (see Manual Section 3.3.3).

NA LID Stormwater Credit from Checklist Section A.1.4 to be applied to water quality requirement, if applicable, with the following calculations (see Manual Section 4.6.1):

- the new impervious area (in acres) for the site
- the new WQ_v in acre-feet or ft^3

☒ Specific BMPs from Checklist Section A.1.5 that will be used to meet water quality volume requirement. *Note: Only BMPs listed in Manual Table 3-6, Acceptable BMPs for Water Quality Treatment may be used to meet the water quality requirement.*

☒ Specify any additional pollutant-specific requirements and/or pollutant removal efficiencies applicable to the site as the result of SAMP, TMDL, or other watershed-specific requirements. NONE

NA **Minimum Standard 4: Conveyance and Natural Channel Protection**

Demonstrate that the conveyance and natural channel protection criteria for the site have been met. Include:

NA Justification for channel protection criterion waiver, if applicable (see Manual Section 3.3.4).

NA Required channel protection volume (CP_v) (see Manual Section 3.3.4).

NA Specific BMPs from Checklist Section A.1.5 that will be used to meet the channel protection requirement. Hydrologic and hydraulic site evaluation as described in Manual Section 3.3.4 should be included in Checklist Section A.1.5 for each channel protection BMP.

NA Minimum Standard 5: Overbank Flood Protection

Demonstrate that the overbank flood protection criteria for the site have been met. Include:

- NA Justification for overbank flood protection criterion waiver, if applicable (see Manual Section 3.3.5).
- NA Pre- and post-development peak discharge rates.
- NA Specific BMPs from Checklist Section A.1.5 that will be used to meet the overbank flood protection requirement. Hydrologic and hydraulic site evaluation as described in Manual Section 3.3.4 should be included in Checklist Section A.1.5 for each overbank flood protection BMP.

NA Minimum Standard 6: Redevelopment and Infill Projects

Demonstrate that criteria for redevelopment and/or infill projects have been met, if applicable. Include:

- NA Description of site that meets redevelopment/infill definition.
- NA Approved off-site location within watershed where stormwater management requirements will be met, if applicable (see Manual Section 3.2.6).
- X Not Applicable.

X Minimum Standard 7: Pollution Prevention

Demonstrate that the project meets the criteria for pollution prevention. Include:

- X Stormwater pollution prevention plan (ONCE COMPLETED, OPERATION, MANAGEMENT AND MAINTENANCE OF THE PROPOSED BMPS MUST BE IN ACCORDANCE WITH THE CITY OF WARWICKS EXISITNG STORMWATER POLLUTION PREVENTION PLAN FOR ITS MUNICIPAL STORMWATER COLLECTION SYSTEM.)

NA Minimum Standard 8: LUHPPLs

Demonstrate that the project meets the criteria for LUHPPLs, if applicable. Include:

- NA Description of any land use activities considered stormwater LUHPPL (see Manual Table 3-2).
- NA Specific BMPs listed in Checklist Section A.1.5 that receive stormwater from LUHPPL drainage areas. These BMP types must be listed in Manual Table 3-3, "Acceptable BMPs for Use at LUHPPLs."
- NA Additional BMPs, if any, that meet RIPDES MSGP requirements.
- X Not Applicable.

X Minimum Standard 9: Illicit Discharges

Applicant asserts that no illicit discharges exist or are proposed to the stormwater management system in accordance with State regulations.

☒ **Minimum Standard 10: Construction Erosion and Sedimentation Control**

Demonstrate that ESC practices will be used during the construction phase and land disturbing activities. Include:

☒ Description of temporary sediment trapping and conveyance practices, including sizing calculations and method of temporary and permanent stabilization (see Manual Section 3.2.9 and *the Rhode Island Soil Erosion and Sediment Control Handbook*).

☒ Description of sequence of construction. Activities should be phased to avoid compacting soil during construction, particularly in the location of infiltrating stormwater practices and qualifying pervious areas for stormwater credits.

☒ Location of construction staging and material stockpiling areas.

☒ **Minimum Standard 11: Stormwater Management System Operation and Maintenance**

Provide a stormwater management system operation and maintenance plan that at a minimum includes:

☒ Name, address, and phone number of responsible parties for maintenance

☒ Description of annual maintenance tasks

☒ Description of applicable easements

☒ Description of funding source

☒ Minimum vegetative cover requirements

☒ Access and safety issues

A.1.4 LID Stormwater Credit (NOT APPLICABLE)

Description of stormwater credit, if applicable. Label qualifying pervious areas (QPAs) on the site map, and document that all stormwater credit requirements listed in Section 4.6 are met. For each QPA, note the impervious area (in acres) that drains to it, and place a check in the appropriate box to demonstrate that it meets the following criteria:

	QPA 1	QPA 2	QPA 3	QPA 4
Impervious Area Draining to QPA (acres)				
QPA Criteria	**Criterion Met?**			
Construction vehicles shall not be allowed to drive over the QPA during construction. If the area becomes compacted, soil must be suitably amended, tilled, and revegetated once construction is complete to restore infiltration capacity.				
QPA infiltration area is at least 10ft from building foundation.				

	QPA 1	QPA 2	QPA 3	QPA 4
Contributing impervious area does not exceed 1,000 ft^2.				
Length of QPA in feet is equal to or greater than the contributing rooftop area in ft^2 divided by 13.3. The maximum contributing flow path from non-rooftop impervious areas is 75ft.				
QPA does not overlap any other QPA.				
Lot is greater than 6,000 ft^2.				
The slope of the QPA is less than or equal to 5.0%.				
Disconnected downspouts draining to QPA are at least 10 feet away from the nearest impervious surface.				
Runoff from rooftops without gutters / downspouts that drains to QPA flows away from the structure as low-velocity sheet flow.				
QPA is located on Hydrologic Soil Group (HSG) A or B soils.				
Depth to groundwater within QPA is 18 inches or greater (has been confirmed by evaluation by a DEM-licensed Class IV soil evaluator or RI-registered PE).				
Runoff is directed over soft shoulders, through curb cuts or level spreaders to QPA.				
Measures are employed at discharge point to prevent erosion and promote sheet flow.				
The flow path through the QPA complies with the setback requirements for structural infiltration BMPs.				
Rooftop runoff draining to QPA from LUHPPLs does not commingle with runoff from any paved surface or areas that may generate higher pollutant loads				
Inspection and maintenance of the QPA is included in the site Operation and Maintenance Plan (Minimum Standard 11).				
The QPA is owned or controlled by the property owner				
There is no history of groundwater seepage and / or basement flooding on the property				

A.1.5 Best Management Practices

Provide detailed information for all structural stormwater best management practices (BMPs) to be implemented. *Note: If a BMP cannot meet the required design criteria in Manual Chapters Five, Six, and Seven, a different BMP should be considered.*

Fill in the following table to document which proposed practices meet which requirement(s). Number each BMP and label them accordingly on the site map:

BMP No.	Type of BMP	Check the function provided by the BMP				
		Pretreatment	Re_v	WQ_v	CP_v	Q_p
1	OIL AND GRIT SEPARATOR	X				
2	INFILTRATION TRENCH SYSTEM FOR STORMWATER RETROFIT		X	X		

In addition, for all structural components of stormwater system (e.g., storm drains, open channels, swales, stormwater BMPs, etc.) provide the following, if applicable:

☒ Hydrologic and hydraulic analysis, including:

NA Study design/analysis points. The existing and proposed condition analyses need to compare the same overall area; thus, common study points are needed for both existing and proposed conditions.

NOTE: EXISITNG CONDITION ANALYSIS IS NOT APPLICABLE.

- NA – Existing condition analysis for drainage area boundaries, curve numbers, times of concentration, runoff rates, volumes, velocities, and water surface elevations showing methodologies used and supporting calculations.
- – Proposed condition analysis for drainage area boundaries, curve numbers, times of concentration, runoff rates, volumes, velocities, water surface elevations, and routing showing the methodologies used and supporting calculations.
- NA – Downstream Analysis, where required (see Manual Section 3.3.6).
- – Final sizing calculations for structural stormwater BMPs including, contributing drainage area, storage, and outlet configuration.
- – Stage-discharge or outlet rating curves and inflow and outflow hydrographs for storage facilities (e.g., detention, retention, or infiltration facilities).
- NA – Dam breach analysis, where necessary, for earthen embankments over six (6) feet in height, or a capacity of 15 acre-feet or more, and that is a significant or high hazard dam.

[X] Drainage Area Maps prepared in accordance with DEM's *Guidance for Preparation of Drainage Area Maps* (included in Appendix K).

[X] Representative cross-section and profile drawings, notes and details of structural stormwater management practices and conveyances (i.e., storm drains, open channels, swales, etc.), which include:

- – Locations, cross sections, and profiles of all streams and drainage swales and their method of stabilization.
- – Existing and proposed structural elevations (e.g., invert of pipes, manholes, etc.).
- – Design water surface elevations.
- – Structural details of outlet structures, embankments, spillways, stilling basins, grade control structures, conveyance channels, etc.
- – Logs of borings and/or test pit investigations along with supporting soils/geotechnical report.

[NA] Planting plans for structural stormwater BMPs, including:

- – Species, size, planting methods, and maintenance requirements of proposed planting.

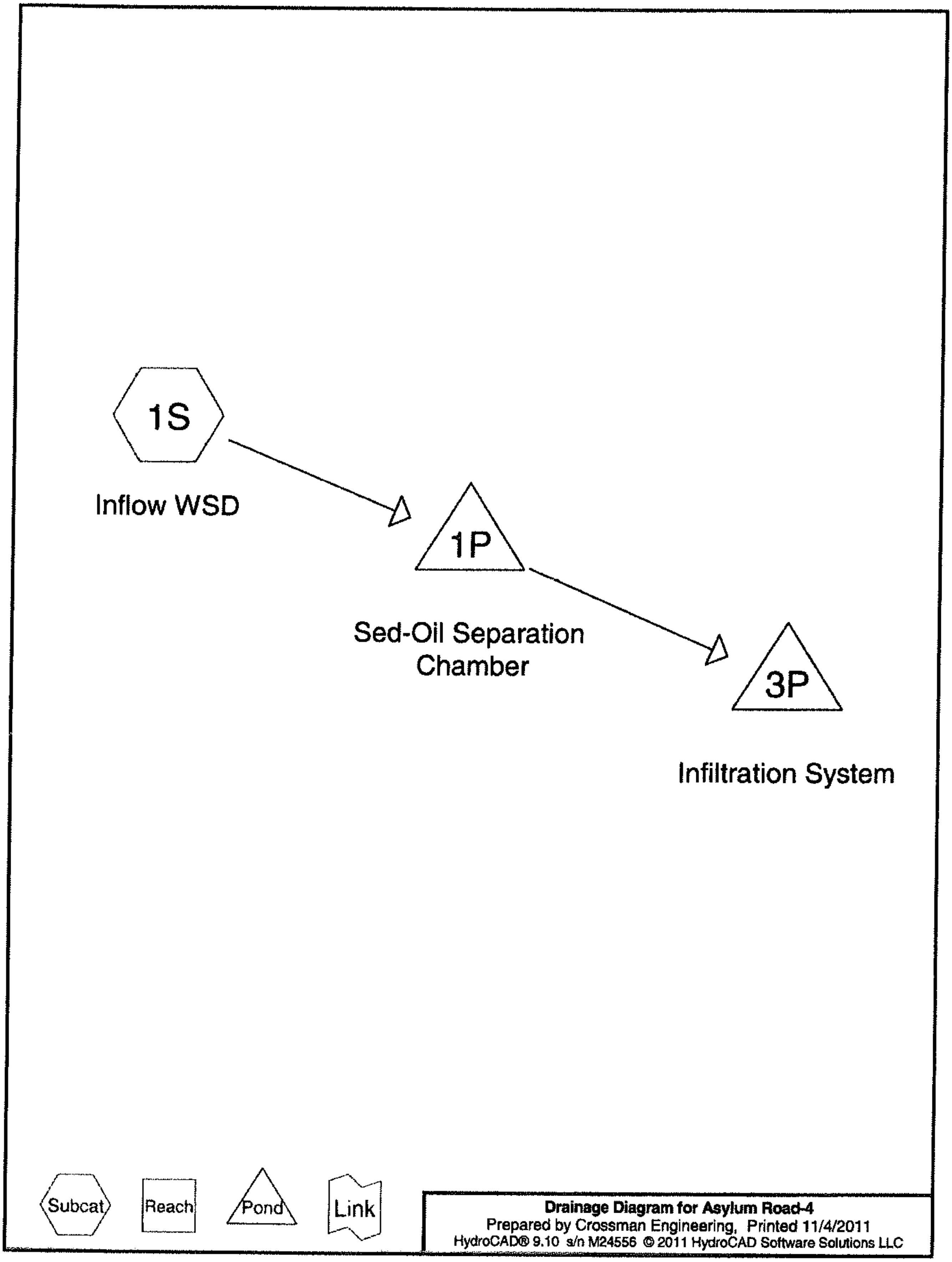
[NA] Structural calculations, where necessary.

[X] Applicable construction specifications.

[X] Identification of all anticipated applicable local and State permits.

[NA] Identification of all anticipated legal agreements related to stormwater (e.g., off-site easements, deed restrictions, and covenants).

b. Stormwater Runoff Calculations


1S
Inflow WSD
1P
Sed-Oil Separation Chamber
3P
Infiltration System
Subcat
Reach
Pond
Link
Drainage Diagram for Asylum Road-4
Prepared by Crossman Engineering, Printed 11/4/2011
HydroCAD® 9.10 s/n M24556 © 2011 HydroCAD Software Solutions LLC

2 YEAR STORM

Time span=5.00-48.00 hrs, dt=0.02 hrs, 2151 points x 3
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: Inflow WSD Runoff Area=1.210 ac 38.00% Impervious Runoff Depth=0.49"
Flow Length=316' Tc=2.6 min CN=61 Runoff=0.52 cfs 0.049 af

Pond 1P: Sed-Oil Separation Chamber Peak Elev=31.18' Storage=5 cf Inflow=0.52 cfs 0.049 af
Outflow=0.52 cfs 0.049 af

Pond 3P: Infiltration System Peak Elev=30.89' Storage=314 cf Inflow=0.52 cfs 0.049 af
Discarded=0.16 cfs 0.049 af Primary=0.00 cfs 0.000 af Outflow=0.16 cfs 0.049 af

Summary for Subcatchment 1S: Inflow WSD

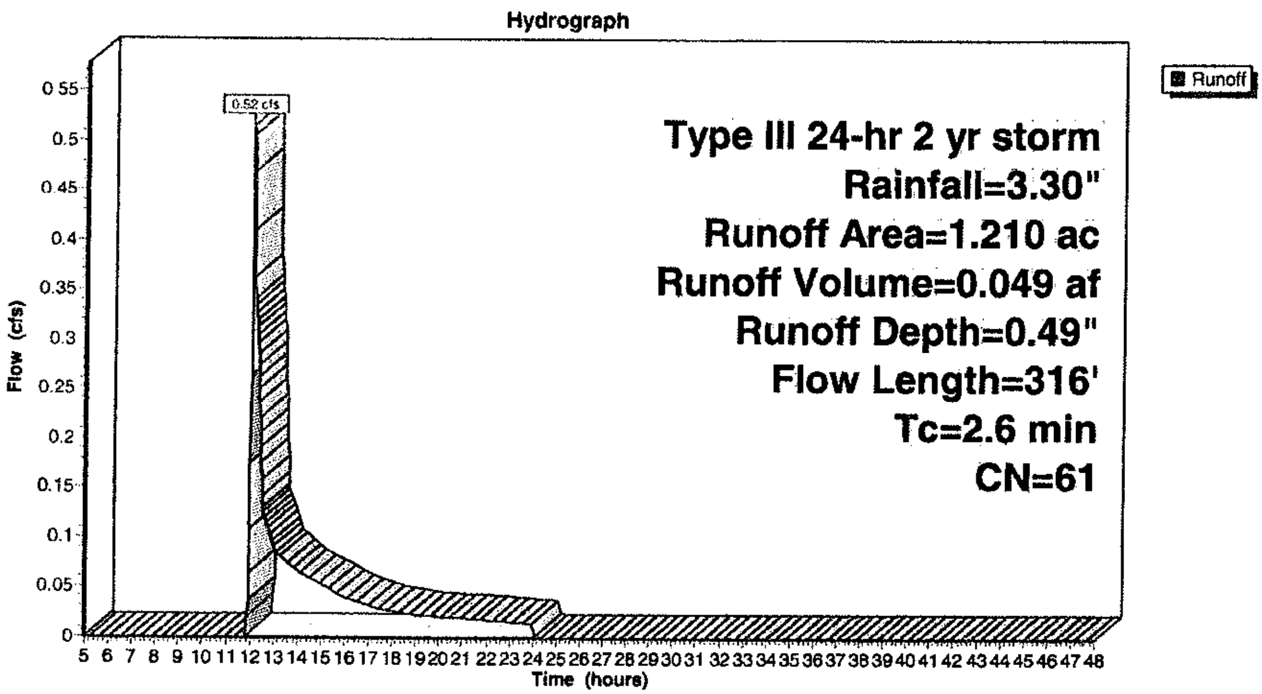
Runoff = 0.52 cfs @ 12.07 hrs, Volume= 0.049 af, Depth= 0.49"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs
Type III 24-hr 2 yr storm Rainfall=3.30"

Area (ac)	CN	Description
1.210	61	1/4 acre lots, 38% imp, HSG A
0.750		62.00% Pervious Area
0.460		38.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.2	50	0.5000	0.37		**Sheet Flow, Lawn** Grass: Dense n= 0.240 P2= 3.30"
0.1	69	0.5000	14.35		**Shallow Concentrated Flow, Driveway** Paved Kv= 20.3 fps
0.3	197	0.6000	11.94	11.94	**Channel Flow, Gutter** Area= 1.0 sf Perim= 20.2' r= 0.05' n= 0.013 Asphalt, smooth
2.6	316	Total			

Subcatchment 1S: Inflow WSD



Summary for Pond 1P: Sed-Oil Separation Chamber

Inflow Area = 1.210 ac, 38.00% Impervious, Inflow Depth = 0.49" for 2 yr storm event
Inflow = 0.52 cfs @ 12.07 hrs, Volume= 0.049 af
Outflow = 0.52 cfs @ 12.07 hrs, Volume= 0.049 af, Atten= 0%, Lag= 0.1 min
Primary = 0.52 cfs @ 12.07 hrs, Volume= 0.049 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs / 3
Peak Elev= 31.18' @ 12.07 hrs Surf.Area= 60 sf Storage= 5 cf

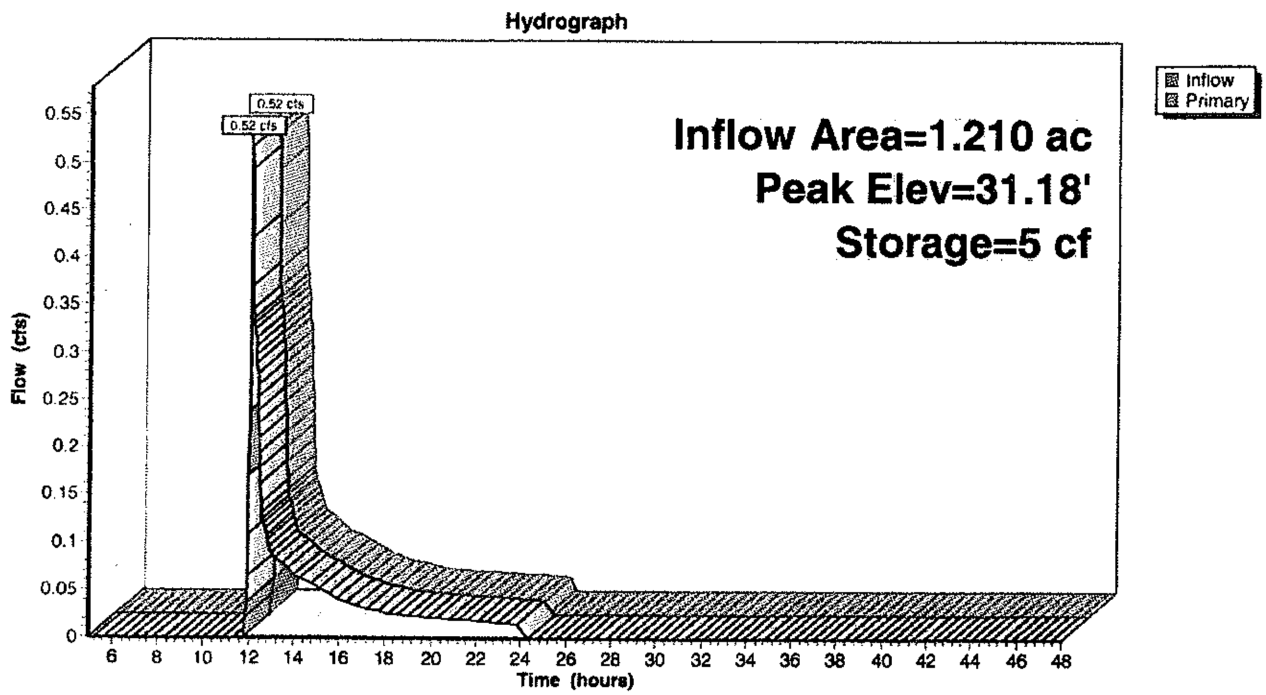
Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 0.0 min (907.8 - 907.7)

Volume	Invert	Avail.Storage	Storage Description
#1	31.10'	180 cf	**6.00'W x 10.00'L x 3.00'H Prismatoid**

Device	Routing	Invert	Outlet Devices
#1	Primary	31.00'	**18.0" Vert. Orifice/Grate X 3.00** C= 0.600

Primary OutFlow Max=0.51 cfs @ 12.07 hrs HW=31.18' TW=30.59' (Dynamic Tailwater)
└─**1=Orifice/Grate** (Orifice Controls 0.51 cfs @ 1.44 fps)

Pond 1P: Sed-Oil Separation Chamber



Summary for Pond 3P: Infiltration System

Inflow Area = 1.210 ac, 38.00% Impervious, Inflow Depth = 0.49" for 2 yr storm event
Inflow = 0.52 cfs @ 12.07 hrs, Volume= 0.049 af
Outflow = 0.16 cfs @ 12.51 hrs, Volume= 0.049 af, Atten= 70%, Lag= 26.2 min
Discarded = 0.16 cfs @ 12.51 hrs, Volume= 0.049 af
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs / 3
Peak Elev= 30.89' @ 12.51 hrs Surf.Area= 2,492 sf Storage= 314 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 10.3 min (918.1 - 907.8)

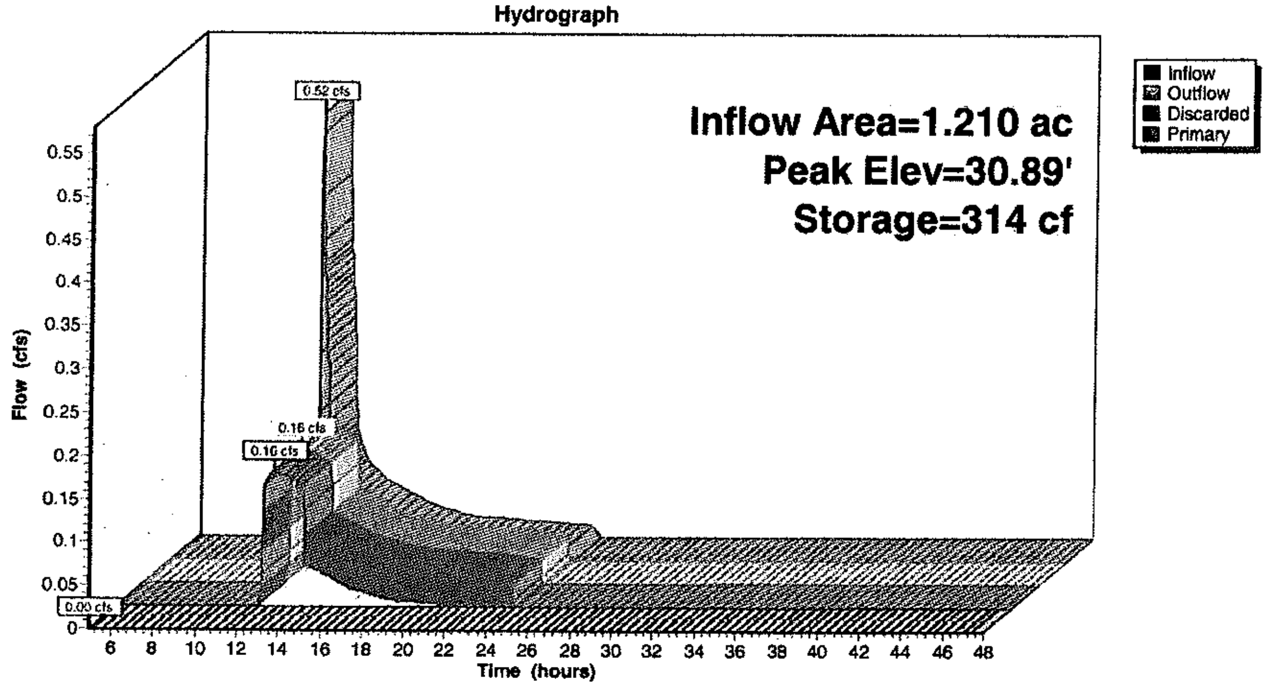
Volume	Invert	Avail.Storage	Storage Description
#1	30.50'	1,270 cf	**7.00'W x 178.00'L x 3.50'H Prismatoid** 4,361 cf Overall - 514 cf Embedded = 3,847 cf x 33.0% Voids
#2	31.00'	315 cf	**18.0" D x 178.0'L Pipe Storage** Inside #1 514 cf Overall - 2.5" Wall Thickness = 315 cf
#3	31.00'	38 cf	**4.00'D x 3.00'H Vertical Cone/Cylinder** -Impervious
#4	30.50'	1,270 cf	**7.00'W x 178.00'L x 3.50'H Prismatoid** 4,361 cf Overall - 514 cf Embedded = 3,847 cf x 33.0% Voids
#5	31.00'	315 cf	**18.0" D x 178.0'L Pipe Storage** Inside #4 514 cf Overall - 2.5" Wall Thickness = 315 cf
#6	31.00'	38 cf	**4.00'D x 3.00'H Vertical Cone/Cylinder** -Impervious
		3,244 cf	Total Available Storage

Device	Routing	Invert	Outlet Devices
#1	Discarded	30.50'	**2.410 in/hr Exfiltration over Wetted area**
#2	Primary	32.25'	**10.0" Round Culvert** L= 9.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 32.25' / 31.00' S= 0.1389 '/' Cc= 0.900 n= 0.015
#3	Primary	32.25'	**10.0" Round Culvert** L= 5.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 32.25' / 31.00' S= 0.2500 '/' Cc= 0.900 n= 0.015

Discarded OutFlow Max=0.16 cfs @ 12.51 hrs HW=30.89' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.16 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=30.50' (Free Discharge)
├─**2=Culvert** (Controls 0.00 cfs)
└─**3=Culvert** (Controls 0.00 cfs)

Pond 3P: Infiltration System



10 YEAR STORM

Time span=5.00-48.00 hrs, dt=0.02 hrs, 2151 points x 3
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: Inflow WSD Runoff Area=1.210 ac 38.00% Impervious Runoff Depth=1.25"
Flow Length=316' Tc=2.6 min CN=61 Runoff=1.80 cfs 0.126 af

Pond 1P: Sed-Oil Separation Chamber Peak Elev=32.19' Storage=66 cf Inflow=1.80 cfs 0.126 af
Outflow=1.79 cfs 0.126 af

Pond 3P: Infiltration System Peak Elev=32.19' Storage=1,694 cf Inflow=1.79 cfs 0.126 af
Discarded=0.21 cfs 0.126 af Primary=0.00 cfs 0.000 af Outflow=0.21 cfs 0.126 af

Summary for Subcatchment 1S: Inflow WSD

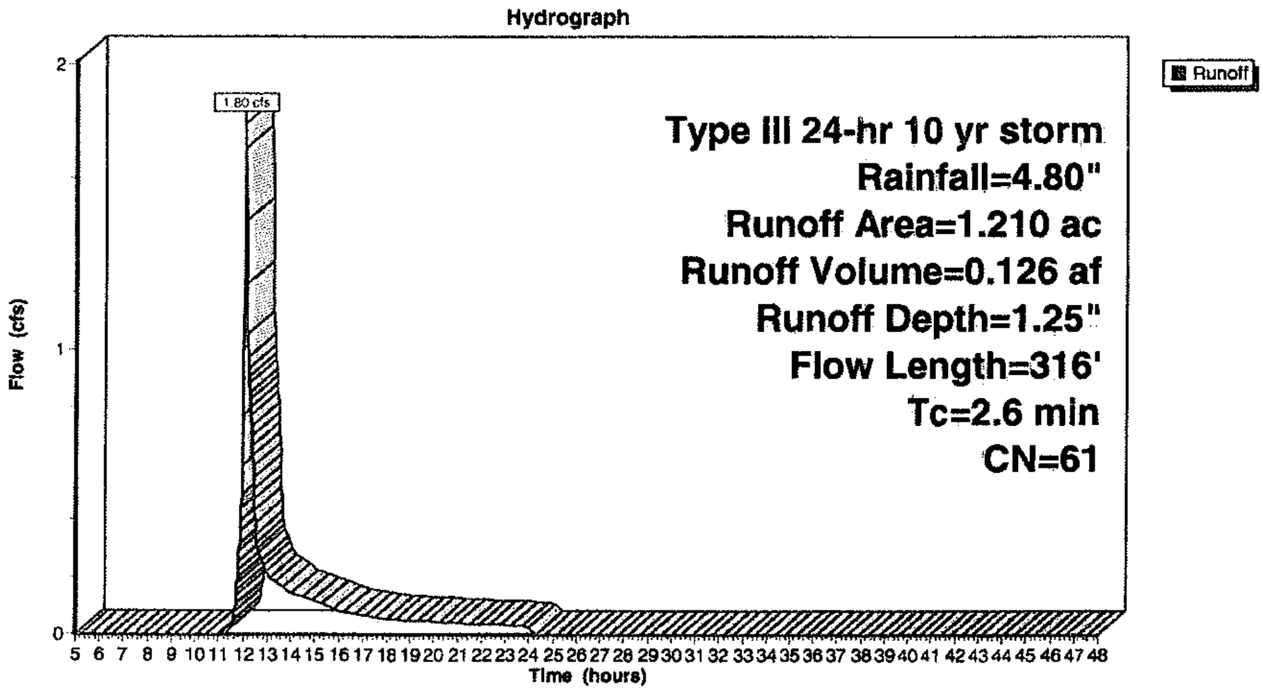
Runoff = 1.80 cfs @ 12.05 hrs, Volume= 0.126 af, Depth= 1.25"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs
Type III 24-hr 10 yr storm Rainfall=4.80"

Area (ac)	CN	Description
1.210	61	1/4 acre lots, 38% imp, HSG A
0.750		62.00% Pervious Area
0.460		38.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.2	50	0.5000	0.37		**Sheet Flow, Lawn** Grass: Dense n= 0.240 P2= 3.30"
0.1	69	0.5000	14.35		**Shallow Concentrated Flow, Driveway** Paved Kv= 20.3 fps
0.3	197	0.6000	11.94	11.94	**Channel Flow, Gutter** Area= 1.0 sf Perim= 20.2' r= 0.05' n= 0.013 Asphalt, smooth
2.6	316	Total			

Subcatchment 1S: Inflow WSD



Summary for Pond 1P: Sed-Oil Separation Chamber

Inflow Area =	1.210 ac, 38.00% Impervious, Inflow Depth = 1.25"	for 10 yr storm event	
Inflow =	1.80 cfs @ 12.05 hrs, Volume=	0.126 af	
Outflow =	1.79 cfs @ 12.05 hrs, Volume=	0.126 af,	Atten= 1%, Lag= 0.0 min
Primary =	1.79 cfs @ 12.05 hrs, Volume=	0.126 af	

Routing by Dyn-Stor-Ind method, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs / 3
Peak Elev= 32.19' @ 12.99 hrs Surf.Area= 60 sf Storage= 66 cf

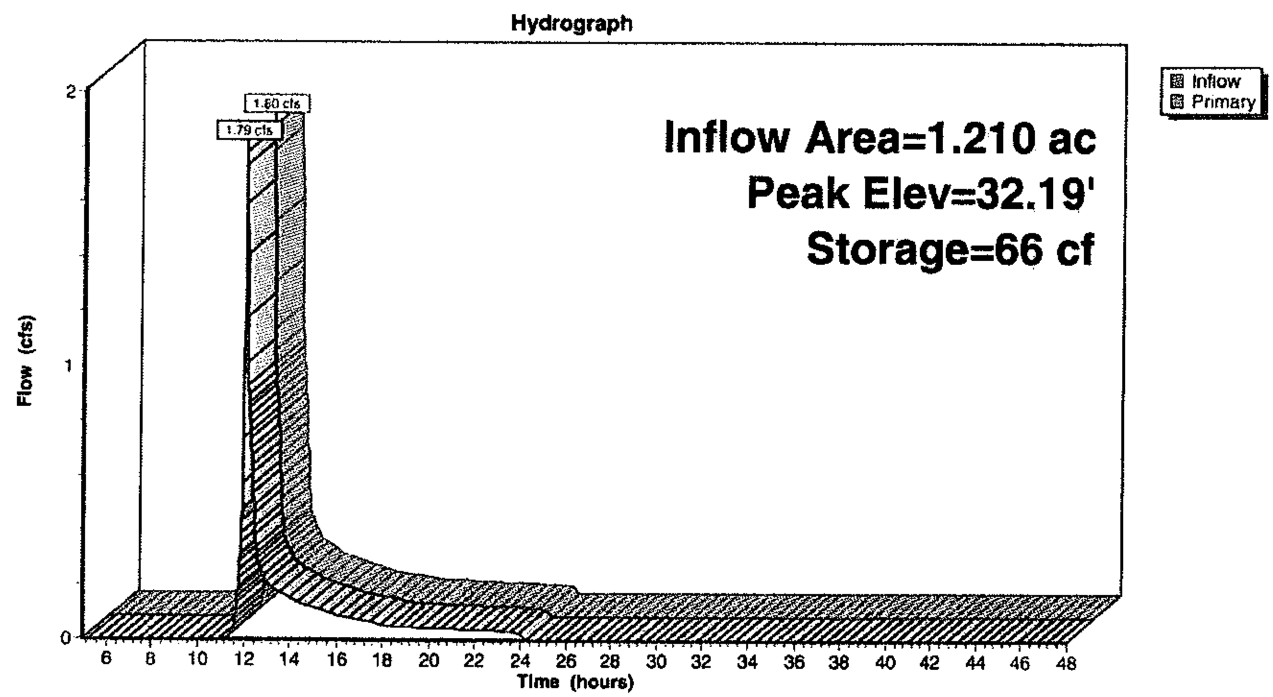
Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 2.5 min (874.7 - 872.2)

Volume	Invert	Avail.Storage	Storage Description
#1	31.10'	180 cf	**6.00'W x 10.00'L x 3.00'H Prismatoid**

Device	Routing	Invert	Outlet Devices
#1	Primary	31.00'	**18.0" Vert. Orifice/Grate X 3.00** C= 0.600

Primary OutFlow Max=1.86 cfs @ 12.05 hrs HW=31.35' TW=31.16' (Dynamic Tailwater)
1=Orifice/Grate (Orifice Controls 1.86 cfs @ 2.01 fps)

Pond 1P: Sed-Oil Separation Chamber



Summary for Pond 3P: Infiltration System

Inflow Area = 1.210 ac, 38.00% Impervious, Inflow Depth = 1.25" for 10 yr storm event
Inflow = 1.79 cfs @ 12.05 hrs, Volume= 0.126 af
Outflow = 0.21 cfs @ 12.99 hrs, Volume= 0.126 af, Atten= 88%, Lag= 56.5 min
Discarded = 0.21 cfs @ 12.99 hrs, Volume= 0.126 af
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs / 3
Peak Elev= 32.19' @ 12.99 hrs Surf.Area= 2,492 sf Storage= 1,694 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 78.8 min (953.5 - 874.7)

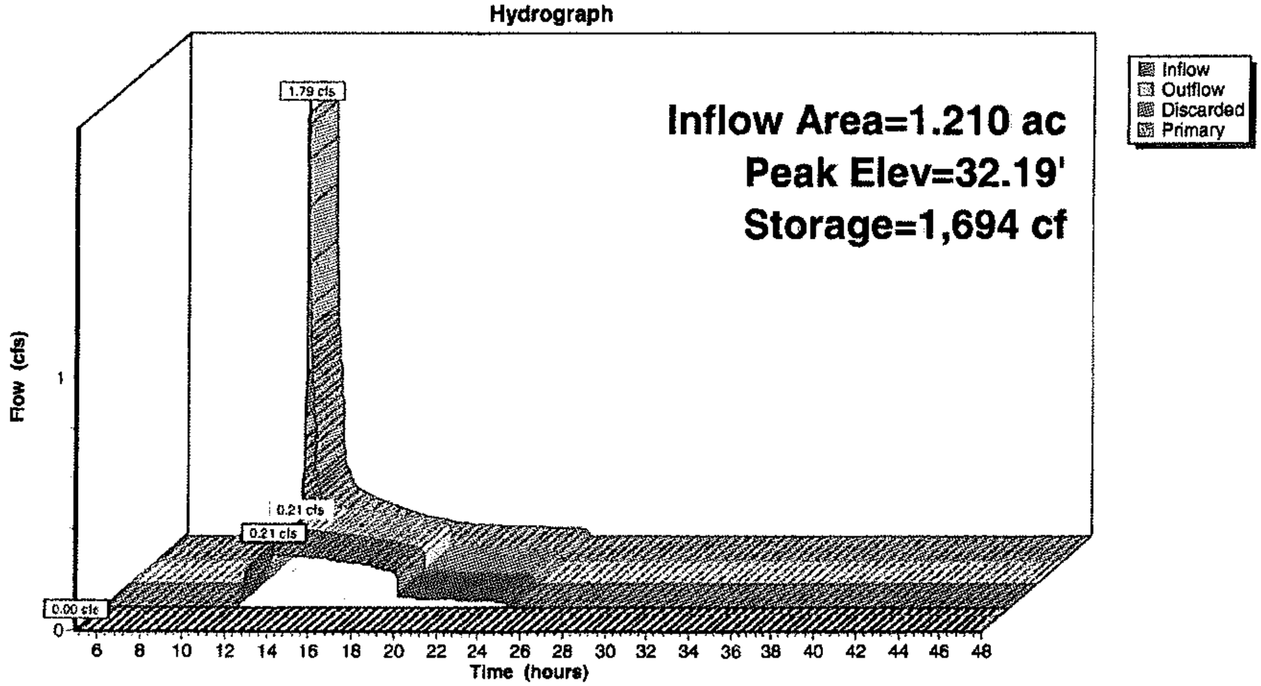
Volume	Invert	Avail.Storage	Storage Description
#1	30.50'	1,270 cf	**7.00'W x 178.00'L x 3.50'H Prismatoid** 4,361 cf Overall - 514 cf Embedded = 3,847 cf x 33.0% Voids
#2	31.00'	315 cf	**18.0" D x 178.0'L Pipe Storage** Inside #1 514 cf Overall - 2.5" Wall Thickness = 315 cf
#3	31.00'	38 cf	**4.00'D x 3.00'H Vertical Cone/Cylinder** -Impervious
#4	30.50'	1,270 cf	**7.00'W x 178.00'L x 3.50'H Prismatoid** 4,361 cf Overall - 514 cf Embedded = 3,847 cf x 33.0% Voids
#5	31.00'	315 cf	**18.0" D x 178.0'L Pipe Storage** Inside #4 514 cf Overall - 2.5" Wall Thickness = 315 cf
#6	31.00'	38 cf	**4.00'D x 3.00'H Vertical Cone/Cylinder** -Impervious
		3,244 cf	Total Available Storage

Device	Routing	Invert	Outlet Devices
#1	Discarded	30.50'	**2.410 in/hr Exfiltration over Wetted area**
#2	Primary	32.25'	**10.0" Round Culvert** L= 9.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 32.25' / 31.00' S= 0.1389 '/' Cc= 0.900 n= 0.015
#3	Primary	32.25'	**10.0" Round Culvert** L= 5.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 32.25' / 31.00' S= 0.2500 '/' Cc= 0.900 n= 0.015

Discarded OutFlow Max=0.21 cfs @ 12.99 hrs HW=32.19' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.21 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=30.50' (Free Discharge)
├─**2=Culvert** (Controls 0.00 cfs)
└─**3=Culvert** (Controls 0.00 cfs)

Pond 3P: Infiltration System



100 YEAR STORM

Time span=5.00-48.00 hrs, dt=0.02 hrs, 2151 points x 3
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: Inflow WSD Runoff Area=1.210 ac 38.00% Impervious Runoff Depth=3.99"
Flow Length=316' Tc=2.6 min CN=61 Runoff=6.34 cfs 0.402 af

Pond 1P: Sed-Oil Separation Chamber Peak Elev=33.50' Storage=144 cf Inflow=6.34 cfs 0.402 af
Outflow=6.24 cfs 0.402 af

Pond 3P: Infiltration System Peak Elev=33.47' Storage=2,791 cf Inflow=6.24 cfs 0.402 af
Discarded=0.26 cfs 0.217 af Primary=4.69 cfs 0.185 af Outflow=4.96 cfs 0.402 af

Summary for Subcatchment 1S: Inflow WSD

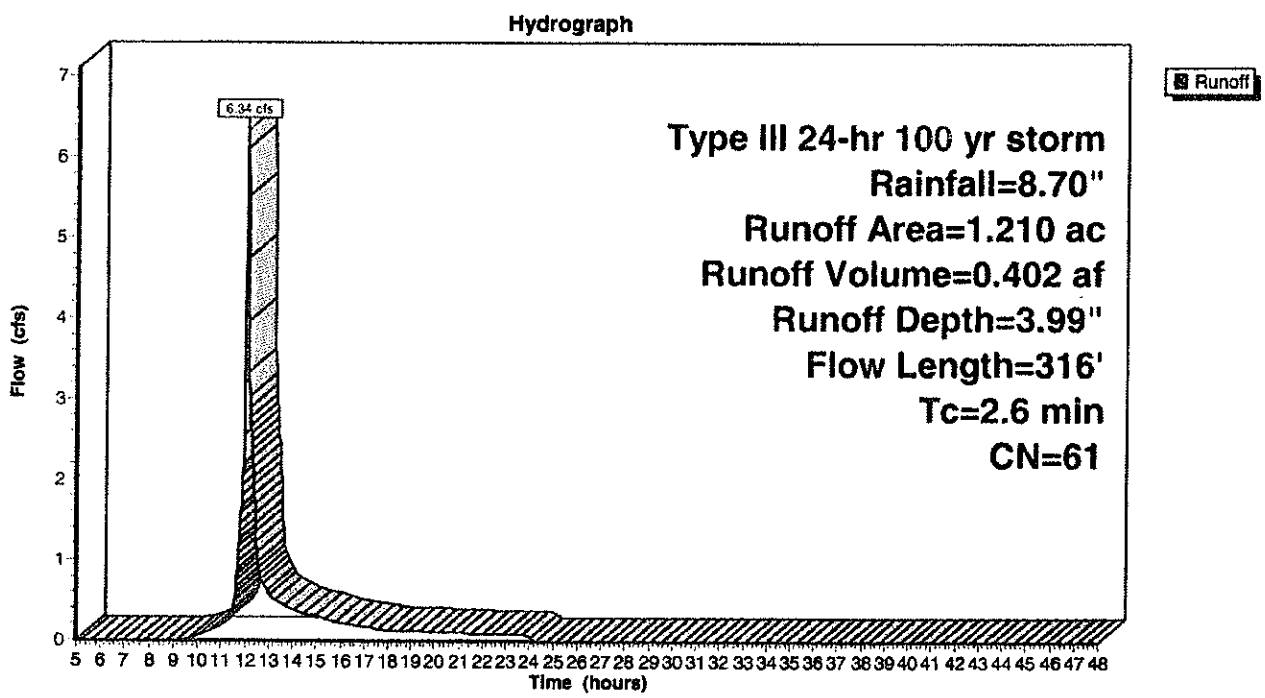
Runoff = 6.34 cfs @ 12.04 hrs, Volume= 0.402 af, Depth= 3.99"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs
Type III 24-hr 100 yr storm Rainfall=8.70"

Area (ac)	CN	Description
1.210	61	1/4 acre lots, 38% imp, HSG A
0.750		62.00% Pervious Area
0.460		38.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.2	50	0.5000	0.37		**Sheet Flow, Lawn** Grass: Dense n= 0.240 P2= 3.30"
0.1	69	0.5000	14.35		**Shallow Concentrated Flow, Driveway** Paved Kv= 20.3 fps
0.3	197	0.6000	11.94	11.94	**Channel Flow, Gutter** Area= 1.0 sf Perim= 20.2' r= 0.05' n= 0.013 Asphalt, smooth
2.6	316	Total			

Subcatchment 1S: Inflow WSD



Summary for Pond 1P: Sed-Oil Separation Chamber

Inflow Area = 1.210 ac, 38.00% Impervious, Inflow Depth = 3.99" for 100 yr storm event
Inflow = 6.34 cfs @ 12.04 hrs, Volume= 0.402 af
Outflow = 6.24 cfs @ 12.04 hrs, Volume= 0.402 af, Atten= 2%, Lag= 0.0 min
Primary = 6.24 cfs @ 12.04 hrs, Volume= 0.402 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs / 3
Peak Elev= 33.50' @ 12.09 hrs Surf.Area= 60 sf Storage= 144 cf

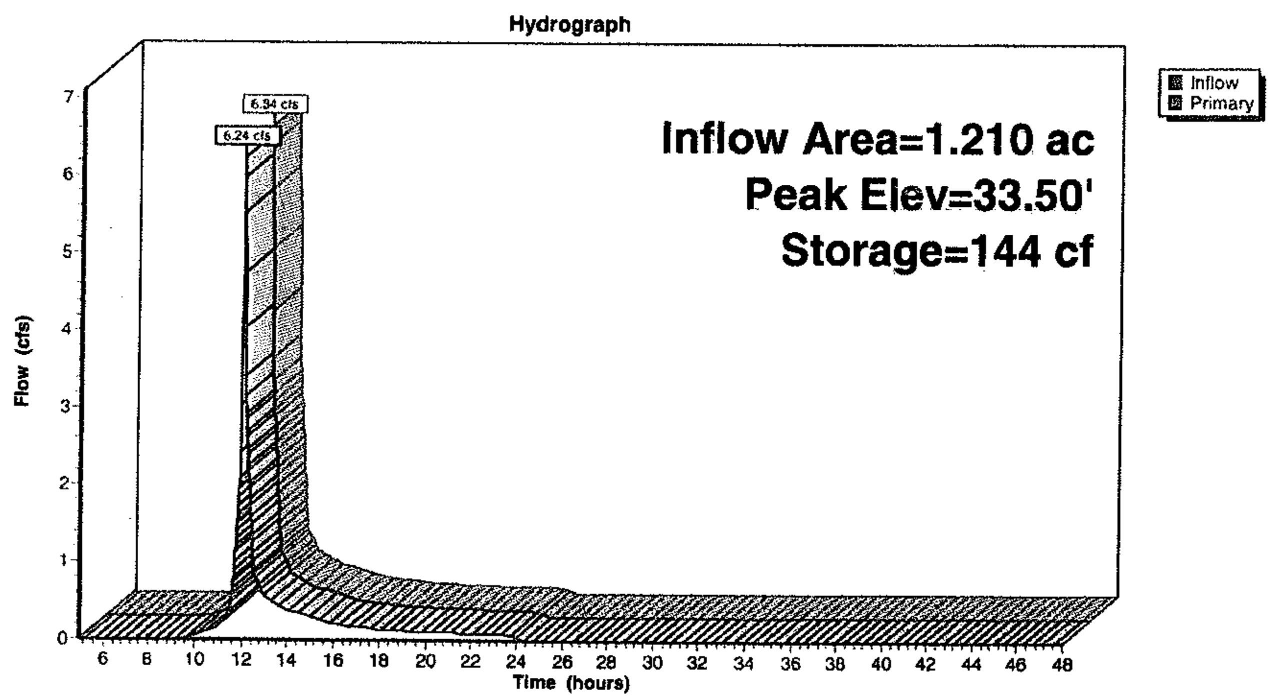
Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 2.0 min (838.5 - 836.5)

Volume	Invert	Avail.Storage	Storage Description
#1	31.10'	180 cf	**6.00'W x 10.00'L x 3.00'H Prismatoid**

Device	Routing	Invert	Outlet Devices
#1	Primary	31.00'	**18.0" Vert. Orifice/Grate X 3.00** C= 0.600

Primary OutFlow Max=6.14 cfs @ 12.04 hrs HW=33.31' TW=33.25' (Dynamic Tailwater)
└—**1=Orifice/Grate** (Orifice Controls 6.14 cfs @ 1.16 fps)

Pond 1P: Sed-Oil Separation Chamber



Summary for Pond 3P: Infiltration System

Inflow Area = 1.210 ac, 38.00% Impervious, Inflow Depth = 3.99" for 100 yr storm event
Inflow = 6.24 cfs @ 12.04 hrs, Volume= 0.402 af
Outflow = 4.96 cfs @ 12.10 hrs, Volume= 0.402 af, Atten= 21%, Lag= 3.1 min
Discarded = 0.26 cfs @ 12.10 hrs, Volume= 0.217 af
Primary = 4.69 cfs @ 12.10 hrs, Volume= 0.185 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-48.00 hrs, dt= 0.02 hrs / 3
Peak Elev= 33.47' @ 12.10 hrs Surf.Area= 2,492 sf Storage= 2,791 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 55.8 min (894.4 - 838.5)

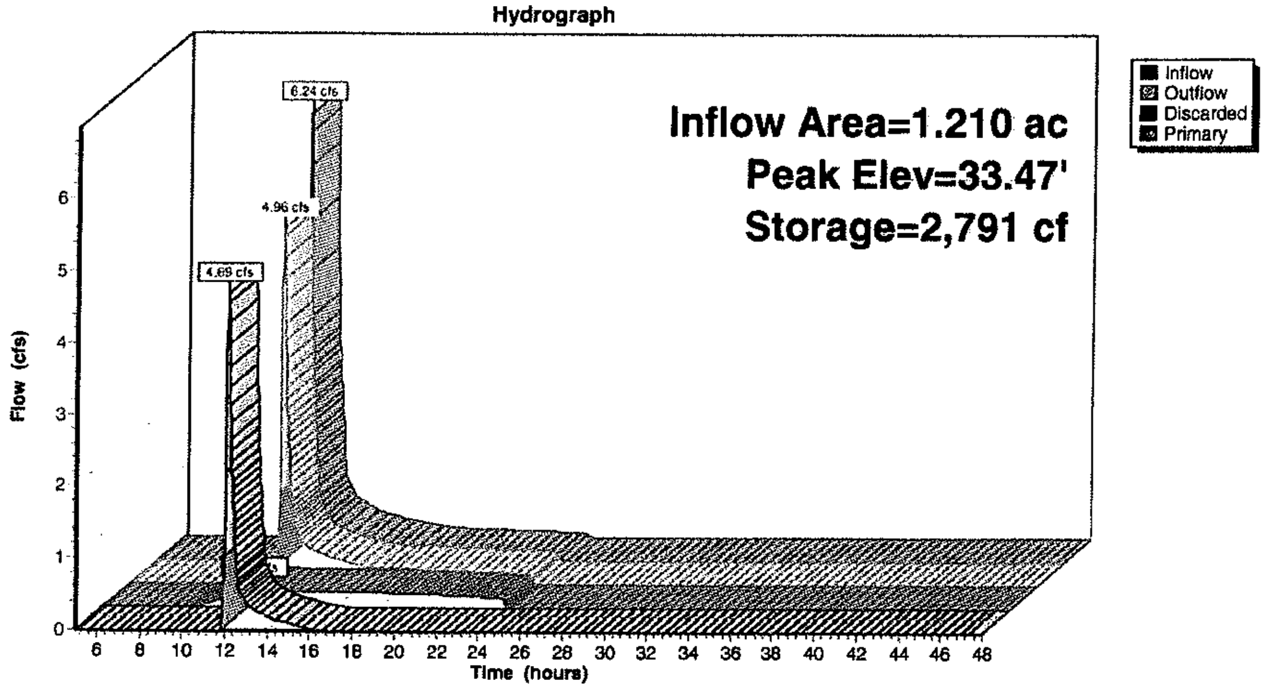
Volume	Invert	Avail.Storage	Storage Description
#1	30.50'	1,270 cf	**7.00'W x 178.00'L x 3.50'H Prismatoid** 4,361 cf Overall - 514 cf Embedded = 3,847 cf x 33.0% Voids
#2	31.00'	315 cf	**18.0" D x 178.0'L Pipe Storage** Inside #1 514 cf Overall - 2.5" Wall Thickness = 315 cf
#3	31.00'	38 cf	**4.00'D x 3.00'H Vertical Cone/Cylinder** -Impervious
#4	30.50'	1,270 cf	**7.00'W x 178.00'L x 3.50'H Prismatoid** 4,361 cf Overall - 514 cf Embedded = 3,847 cf x 33.0% Voids
#5	31.00'	315 cf	**18.0" D x 178.0'L Pipe Storage** Inside #4 514 cf Overall - 2.5" Wall Thickness = 315 cf
#6	31.00'	38 cf	**4.00'D x 3.00'H Vertical Cone/Cylinder** -Impervious
		3,244 cf	Total Available Storage

Device	Routing	Invert	Outlet Devices
#1	Discarded	30.50'	**2.410 in/hr Exfiltration over Wetted area**
#2	Primary	32.25'	**10.0" Round Culvert** L= 9.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 32.25' / 31.00' S= 0.1389 '/' Cc= 0.900 n= 0.015
#3	Primary	32.25'	**10.0" Round Culvert** L= 5.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 32.25' / 31.00' S= 0.2500 '/' Cc= 0.900 n= 0.015

Discarded OutFlow Max=0.26 cfs @ 12.10 hrs HW=33.46' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.26 cfs)

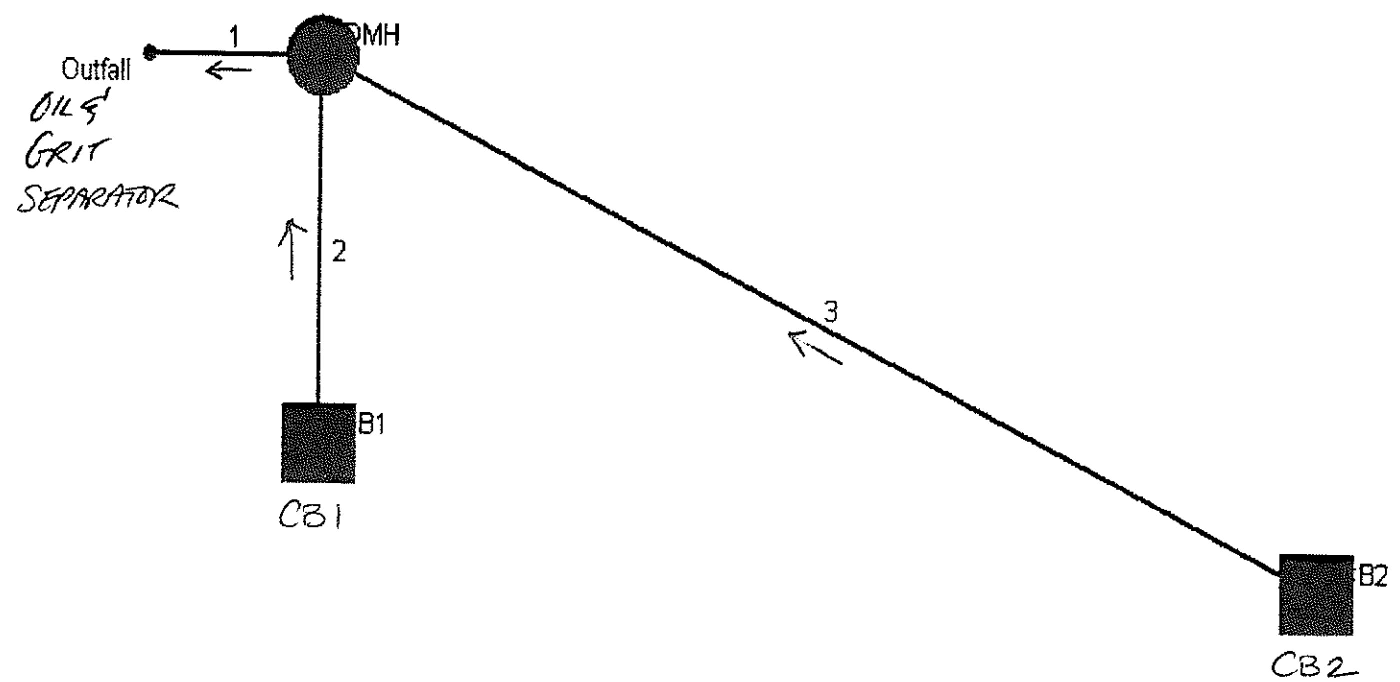
Primary OutFlow Max=4.68 cfs @ 12.10 hrs HW=33.46' (Free Discharge)
├─**2=Culvert** (Inlet Controls 2.34 cfs @ 4.29 fps)
└─**3=Culvert** (Inlet Controls 2.34 cfs @ 4.29 fps)

Pond 3P: Infiltration System



c. Drainage Pipe Sizing Calculations

Hydraflow Plan View



Project file: Asylum-1.stm	IDF file: Kent.IDF	No. Lines: 3	11-04-2011

Hydraflow Summary Report

Line No.	Line ID	Flow rate (cfs)	Line size (in)	Line length (ft)	Invert EL Dn (ft)	Invert EL Up (ft)	Line slope (%)	HGL down (ft)	HGL up (ft)	Minor loss (ft)	Dns line No.
1	DMH1TO OG	4.50	12 c	5.0	31.60	31.60	0.000	32.60*	32.71*	0.51	End
2	CB1 TO DMH1	1.91	12 c	10.0	31.60	31.69	0.900	33.22*	33.25*	0.09	1
3	CB2 TO DMH1	2.89	12 c	32.0	31.60	32.63	3.219	33.22	33.43	0.29	1

Project File: Asylum-1.stm	IDF File: Kent.IDF	Total No. Lines: 3	Run Date: 11-04-2011

NOTES: c = circular; e = elliptical; b = box; Return period = 100 Yrs.; * Indicates surcharge condition.

Hydraflow Inlet Report

Line No	Inlet ID	Q = CIA (cfs)	Q carry (cfs)	Q capt (cfs)	Q byp (cfs)	Junc type	Curb Inlet		Grate Inlet			Gutter							Inlet			Byp line No
							Ht (in)	L (ft)	area (sqft)	L (ft)	W (ft)	So (ft/ft)	W (ft)	Sw (ft/ft)	Sx (ft/ft)	n	depth (ft)	spread (ft)	depth (ft)	spread (ft)	Dep (in)	
1	DMH	0.00	0.00	0.00	0.00	MH	0.0	0.00	0.00	0.00	0.00	Sag	0.00	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.0	Off
2	CB1	1.91	0.00	1.91	0.00	Grate	0.0	0.00	2.20	4.00	2.00	Sag	5.00	0.010	0.010	0.000	0.18	18.46	0.18	18.46	0.0	Off
3	CB2	2.89	0.00	2.89	0.00	Grate	0.0	0.00	2.20	4.00	2.00	Sag	5.00	0.010	0.010	0.000	0.24	24.35	0.24	24.35	0.0	Off

Project File: Asylum-1.stm | I-D-F File: Kent.IDF | Total number of lines: 3 | Run Date: 11-04-2011

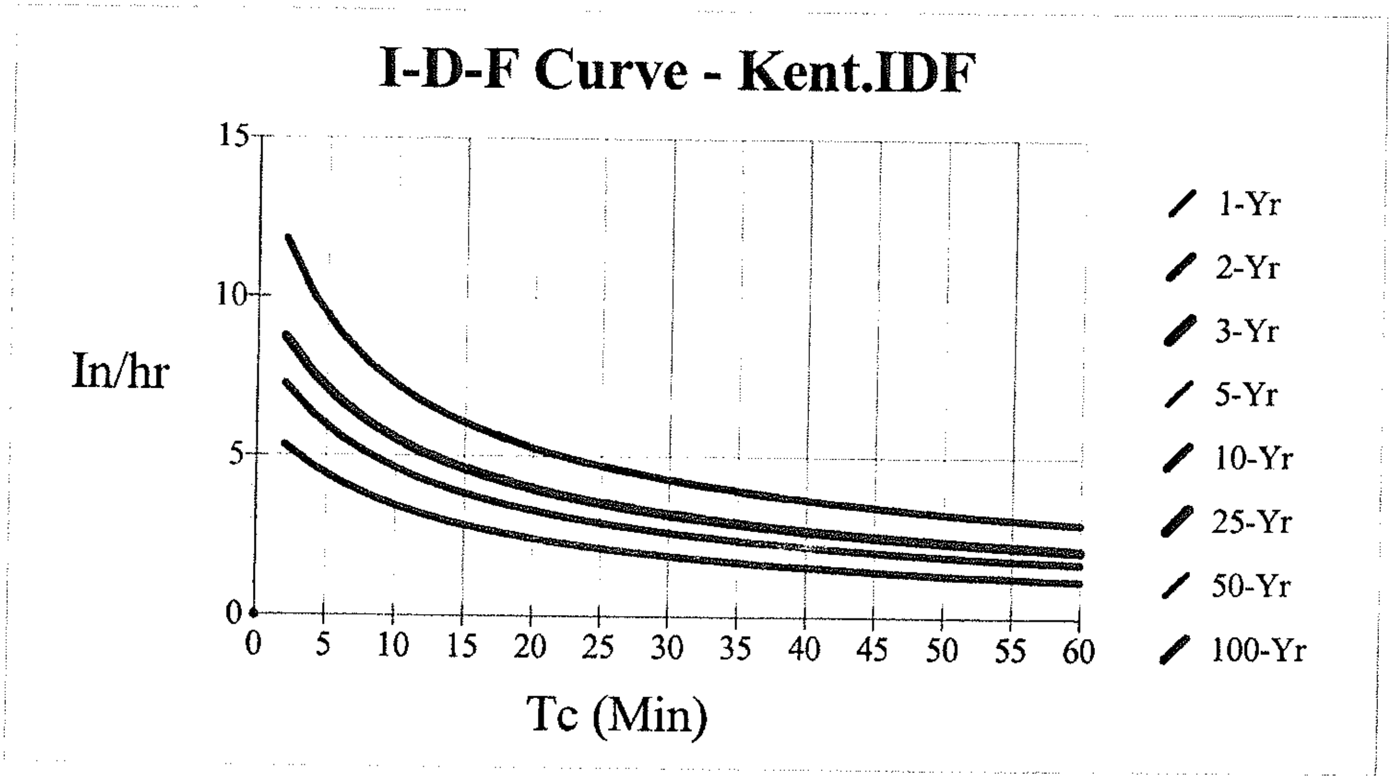
NOTES: Inlet N-Values = 0.016 ; Intensity = 36.31 / (Inlet time + 4.40) ^ 0.60; Return period = 100 Yrs. ; * Indicates Known Q added

Hydraflow Hydraulic Grade Line Computations

Line	Size	Q	Downstream								Len	Upstream								Check		JL coeff	Minor loss
	(in)	(cfs)	Invert elev (ft)	HGL elev (ft)	Depth (ft)	Area (sqft)	Vel (ft/s)	Vel head (ft)	EGL elev (ft)	Sf (%)	(ft)	Invert elev (ft)	HGL elev (ft)	Depth (ft)	Area (sqft)	Vel (ft/s)	Vel head (ft)	EGL elev (ft)	Sf (%)	Ave Sf (%)	Enrgy loss (ft)	(K)	(ft)
1	12	4.50	31.60	32.60	1.00	0.79	5.72	0.51	33.11	2.119	5.0	31.60	32.71	1.00	0.79	5.72	0.51	33.22	2.122	2.120	0.106	1.00	0.51
2	12	1.91	31.60	33.22	1.00	0.79	2.43	0.09	33.31	0.382	10.0	31.69	33.25	1.00	0.79	2.43	0.09	33.35	0.382	0.382	0.038	1.00	0.09
3	12	2.89	31.60	33.22	1.00	0.79	3.68	0.21	33.43	0.876	32.0	32.63	33.43	0.80	0.67	4.31	0.29	33.71	0.926	0.901	0.288	1.00	0.29

Project File: Asylum-1.stm	IDF File: Kent.IDF	Total number of lines: 3	Run Date: 11-04-2011

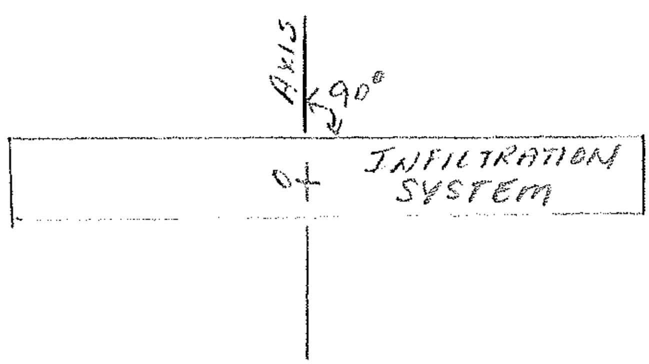
NOTES: Initial tailwater elevation = 32.6 (ft) , * Normal depth assumed., ** Critical depth assumed., i Under inlet control.


I-D-F Curve - Kent.IDF
15
10
5
0
In/hr
0 5 10 15 20 25 30 35 40 45 50 55 60
Tc (Min)
1-Yr
2-Yr
3-Yr
5-Yr
10-Yr
25-Yr
50-Yr
100-Yr

d. Mounding Analysis

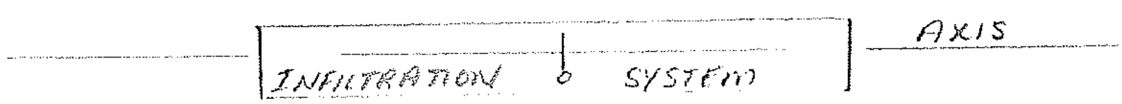
RECHARGE RATE	=	3.55 FT/DAY
TRANSMISSIVITY	=	566 SQ.FT/DAY
SPECIFIC YIELD	=	.25
BEGINNING TIME	=	1 DAYS
FINAL TIME	=	1 DAYS
TIME INCREMENT	=	1 DAYS
TIME OF CUT OFF	=	1 DAYS
BEGINNING DISTANCE	=	0 FT
FINAL DISTANCE	=	100 FT
DISTANCE INCREMENT	=	10 FT
DEPTH	=	2.5 FT
WIDTH	=	14 FT
LENGTH	=	178 FT
ANGLE	=	90 DEGREES

TIME (DAYS)	DISTANCE (FT)	HEIGHT (FT)
1.000	0.000	2.105
1.000	10.000	1.851
1.000	20.000	1.493
1.000	30.000	1.188
1.000	40.000	0.933
1.000	50.000	0.721
1.000	60.000	0.550
1.000	70.000	0.413
1.000	80.000	0.305
1.000	90.000	0.222
1.000	100.000	0.159



RECHARGE RATE = 3.55 FT/DAY
TRANSMISSIVITY = 566 SQ.FT/DAY
SPECIFIC YIELD = .25
BEGINNING TIME = 1 DAYS
FINAL TIME = 1 DAYS
TIME INCREMENT = 1 DAYS
TIME OF CUT OFF = 1 DAYS
BEGINNING DISTANCE = 0 FT
FINAL DISTANCE = 100 FT
DISTANCE INCREMENT = 10 FT
DEPTH = 2.5 FT
WIDTH = 14 FT
LENGTH = 178 FT
ANGLE = 0 DEGREES

TIME (DAYS)	DISTANCE (FT)	HEIGHT (FT)
1.000	0.000	2.105
1.000	10.000	2.098
1.000	20.000	2.078
1.000	30.000	2.042
1.000	40.000	1.988
1.000	50.000	1.910
1.000	60.000	1.800
1.000	70.000	1.646
1.000	80.000	1.421
1.000	90.000	1.055
1.000	100.000	0.726



WATER-RESOURCES ENGINEERING

THIRD EDITION

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Table 4-1 Approximate average porosity, specific yield, and permeability of various materials

Material	Porosity, %	Specific yield, %	Permeability K_s gpd/ft^2	Permeability K_s m/day	Intrinsic permeability, darcys
Clay	45	3	0.01	0.0004	0.0005
Sand	35	25	1000	41	50
Gravel	25	22	100000	4100	5000
Gravel and sand	20	16	10000	410	500
Sandstone	15	8	100	4.1	5
Limestone, shale	5	2	1	0.041	0.05
Quartzite, granite	1	0.5	0.01	0.0004	0.0005

may yield almost all the water it contains. The most important aquifers economically are deposits of sand and gravel, which have a fairly high specific yield.

4-4 The water table The static level of water in wells penetrating the zone of saturation (Fig. 4-1) is called the *water table*. The water table is often described as a subdued replica of the surface topography. It is commonly higher under the hills than under valleys, and a contour map of the water table in an area may look much like the surface topography. The water table is the surface of a water body which is constantly adjusting itself toward an equilibrium condition. If there were no recharge to or outflow from the groundwater in a basin, the water table would eventually become horizontal. Few basins have uniform recharge conditions at the surface. Some areas receive more rain than others. Some portions of the basin have more permeable soil. Thus, when intermittent recharge does occur, mounds and ridges form in the water table under the areas of greatest recharge. Subsequent recharge creates additional mounds, perhaps at other points in the basin, and the flow pattern is further changed. Superimpose upon this fairly simple picture variations in permeability of the aquifers, impermeable strata, and the influence of lakes, streams, and wells, and one obtains a picture of a water table constantly adjusting toward equilibrium. Because of the low flow rates in most aquifers this equilibrium is rarely attained before additional disturbances occur.

When water occurs in cracks, fissures, and caverns, the situation is somewhat different. Flow in large openings is usually turbulent, and adjustments take place fairly rapidly. Water is usually found at about the same level anywhere within a system of interconnected openings. Water levels may vary considerably, however, between entirely separate openings in the same formation (Fig. 4-3). Wells driven into such formations will yield little water unless they intersect one of the fissures or caverns.

4-5 Artesian aquifers The discussion thus far has dealt with aquifers in which the upper surface of the water is unconfined. Sometimes an aquifer is confined by strata of low permeability (Fig. 4-4). Such *artesian aquifers* are analogous to

Second edition

FUNDAMENTALS OF HYDRAULIC ENGINEERING SYSTEMS

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The derivation of Equations (7.11) and (7.12) assumes that the aquifer is homogeneous and isotropic and that it extends over an area larger than the area that the radius of influence can reach. In practice, however, the equations have been widely used to provide good estimations of permeability coefficients for a variety of aquifer conditions, in spite of these restrictive conditions.

Table 7.2 gives an indication of the numerical values for the coefficient of permeability for some natural soil formations.

TABLE 7.2 Magnitude of Coefficient of Permeability of Some Natural Soil Formations

Soils	*K(m/sec)*
Clays	$< 10^{-9}$
Sandy clays	$10^{-9} - 10^{-8}$
Peat	$10^{-9} - 10^{-7}$
Silt	$10^{-8} - 10^{-7}$
Very fine sands	$10^{-6} - 10^{-5}$
Fine sands	$10^{-5} - 10^{-4}$
Coarse sands	$10^{-4} - 10^{-2}$
Sand with gravels	$10^{-3} - 10^{-2}$
Gravels	$> 10^{-2}$

Example 7.2

A well 20 cm in diameter penetrates 30 m deep into the undisturbed water table of an unconfined aquifer. After a long period of pumping at the constant rate of 0.1 m^3/sec, the drawdown at distances of 20 m and 50 m from the well are observed to be 4 m and 2.5 m, respectively. Determine the coefficient of permeability of the aquifer. What is the drawdown at the pumped well?

Solution

Conditions given are $Q = 0.1$ m^3/sec, $r_1 = 20$ m, $r_2 = 50$ m; hence, $h_1 =$ 30.0 m − 4 m = 26 m, and $h_2 = 30.0$ m − 2.5 m = 27.5 m, in reference to Figures 7.4 and 7.5. Substituting these values into Equation (7.11), we have

$$K = \frac{0.1}{\pi(27.5^2 - 26^2)} \ln\left(\frac{50}{20}\right) = \frac{0.00114}{\pi} = 0.000363 \text{ m/sec}$$

The drawdown at the pumped well can be calculated by using the same equation with the calculated value of the coefficient of permeability and the well diameter.

e. Reference Data

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2b.—Runoff curve numbers for cultivated agricultural lands[1]

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Treatment[2]	Hydrologic condition[3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Crop residue cover* applies only if residue is on at least 5% of the surface throughout the year.

[3]Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 2-2d.—Runoff curve numbers for arid and semiarid rangelands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition[2]	A[3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[1]Average runoff condition, and $I_a = 0.2S$. For range in humid regions, use table 2-2c.

[2]*Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.

[3]Curve numbers for group A have been developed only for desert shrub.

TABLE 10-2.02E

RECOMMENDED RUNOFF COEFFICIENTS (C) FOR RATIONAL METHOD

(BY OVERALL CHARACTER OF AREA)

DESCRIPTION OF AREA	RUNOFF COEFFICIENTS
BUSINESS	
DOWNTOWN	
NEIGHBORHOOD	0.70 to 0.95
RESIDENTIAL	0.50 to 0.70
SINGLE-FAMILY	
MULTI-FAMILY, DETACHED	0.30 to 0.50
MULTI-FAMILY, ATTACHED	0.40 to 0.60
RESIDENTIAL (SUBURBAN)	0.60 to 0.75
APARTMENT	0.25 to 0.40
INDUSTRIAL	0.50 to 0.70
LIGHT	
HEAVY	0.50 to 0.80
PARKS, CEMETERIES	0.60 to 0.90
PLAYGROUNDS	0.10 to 0.25
RAILROAD YARD	0.20 to 0.35
UNIMPROVED	0.20 to 0.35
WOODLAND	0.10 to 0.30
CULTIVATED	0.15 to 0.25
SWAMP, MARSH	0.40 to 0.60
	0.10

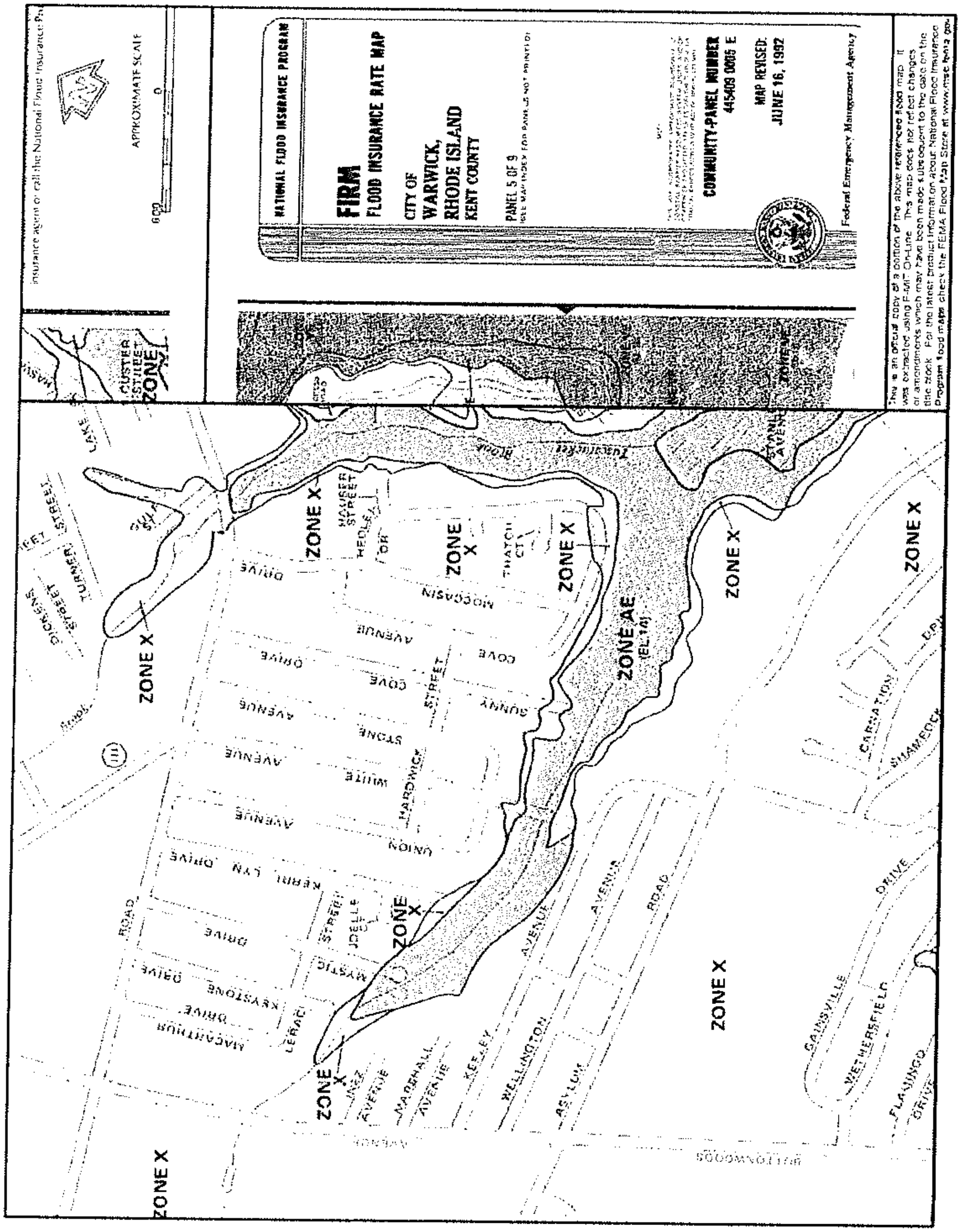
TABLE 10-2.02F

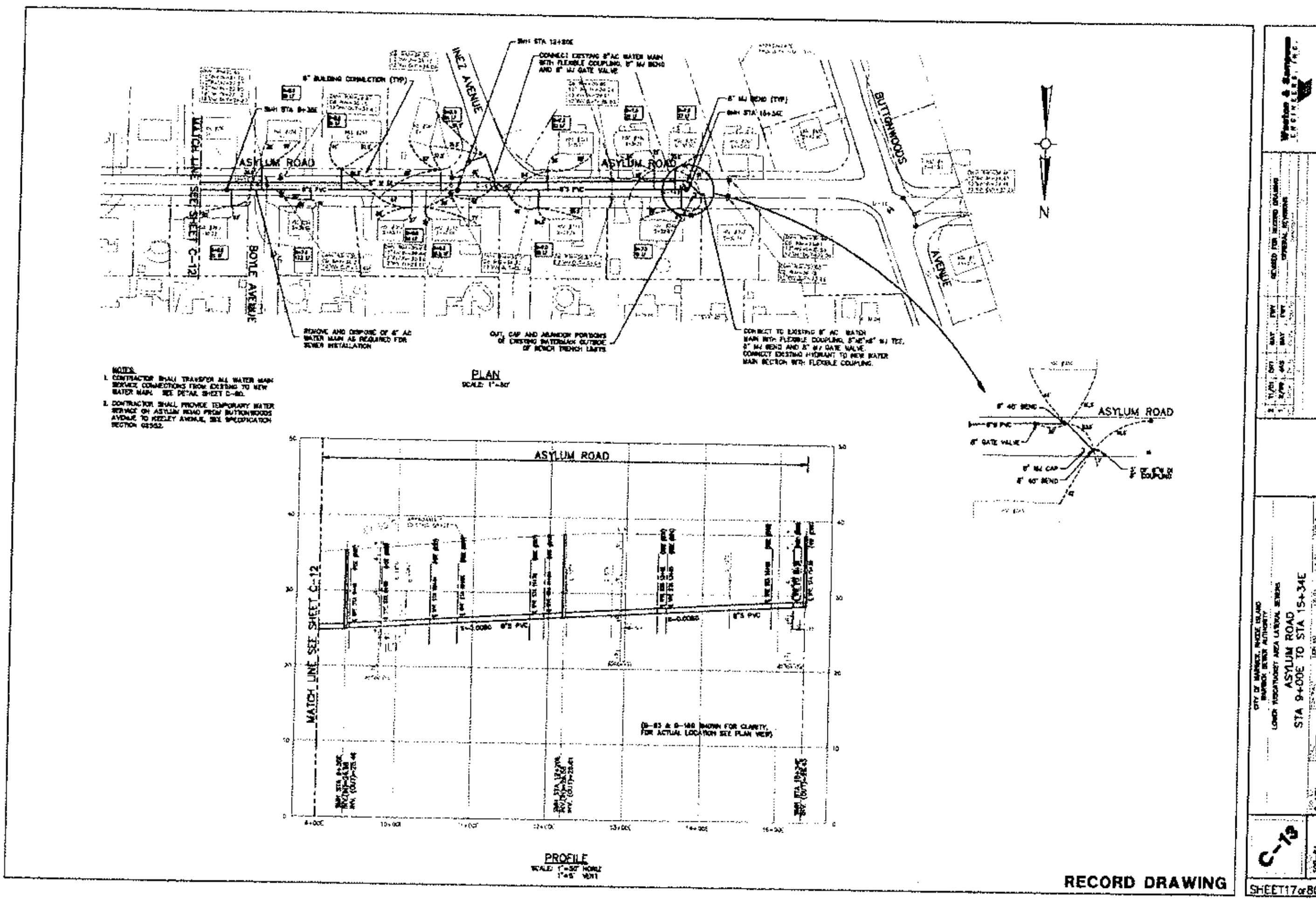
RECOMMENDED RUNOFF COEFFICIENTS (C) FOR RATIONAL METHOD

(FOR SURFACE TYPE)

CHARACTER OF SURFACE	RUNOFF COEFFICIENTS
PAVEMENT	
ASPHALTIC AND CONCRETE	
BRICK	0.70 to 0.95
ROOFS	0.70 to 0.85
LAWNS, SANDY SOIL	0.75 to 0.95
FLAT, 2 PERCENT	
AVERAGE, 2 TO 7 PERCENT	0.05 to 0.10
STEEP, 7 PERCENT	0.10 to 0.15
LAWNS, HEAVY SOIL	0.15 to 0.20
FLAT, 2 PERCENT	
AVERAGE, 2 TO 7 PERCENT	0.13 to 0.17
STEEP, 7 PERCENT	0.18 to 0.22
	0.25 to 0.35

Reference: WPCF Manual of Practice No. 9, Design and Construction of Sanitary and Storm Sewers


NATIONAL FLOOD INSURANCE PROGRAM
FIRM
FLOOD INSURANCE RATE MAP
CITY OF
WARWICK,
RHODE ISLAND
KENT COUNTY
PANEL 5 OF 9
COMMUNITY-PANEL NUMBER
445409 0005 E
MAP REVISED:
JUNE 16, 1992
Federal Emergency Management Agency
ZONE X
ZONE AE
(EL 10)


ASYLUM ROAD
INEZ AVENUE
BUTTONWOODS AVENUE
BOYLE AVENUE
MATCH LINE SEE SHEET C-12
N
PLAN
PROFILE
RECORD DRAWING
ASYLUM ROAD
STA 9+00E TO STA 15+34E
C-13
SHEET 17 of 80

f. Soil Data

State of Rhode Island and Providence Plantations
Department of Environmental Management
Office of Water Resources

Site Evaluation Form
Part A - Soil Profile Description

Application Number ____________

Property Owner: CITY OF WARWICK (1624.23)
Property Location: BOYLE AVENUE (PAPER STREET) NORTH OF ASYLUM, WARWICK
Date of Test Hole: 4/14/2011
Soil Evaluator: JON VERNAVA License Number: D4011
Weather: SUNNY Shaded: Yes ☐ No ☒ Time: 1:30 PM

TH 3 Horizon	Depth	Horizon Boundaries Dist	Topo	Soil Colors Matrix	Re-Dox Features	Re-Dox Description Ab. S. Con.	Texture	Structure	Consistence	Soil Category
HTM	0-6	—	—							
Ap	6-12	a	s	10YR 4/2	—	—	fsl	1fgr	vfr	3
Bw	12-21	c	w	10YR 6/8	—	—	sl	1msbk	vfr	3
C1	21-84	a	s	2.5Y 6/4	—	—	cos/lcos	0sg	l	1
C2	84-96			2.5Y 7/2	—	—	ls	0m	fr	6
				Occassional gravelly stratifications within C1 horizon.						

TH ___ Horizon	Depth	Horizon Boundaries Dist	Topo	Soil Colors Matrix	Re-Dox Features	Re-Dox Description Ab. S. Con.	Texture	Structure	Consistence	Soil Category

Soil Class: C - outwash
Total Depth of each Test Hole: 96"
Depth to Groundwater Seepage: None at 96"
Depth to Impervious or Limiting Layer: None
Estimated Seasonal High Water Table: > 84"
Comments:

Part B

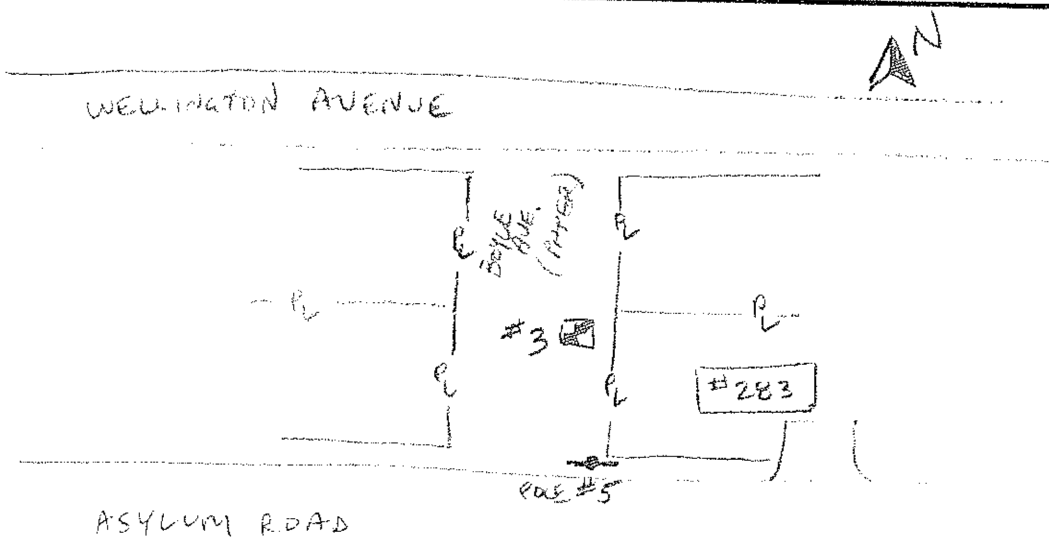
Site Evaluation - to be completed by Class II or III Designer or Soil Evaluator

Please use the area below to locate:

1. Test holes
2. Approximate direction of due north
3. Offsets from test holes to fixed points such as street, utility pole, or other permanent, marked object

Key:

- Approximate location of test holes
- x% → Estimated gradient and direction of slope
- N Approximate direction of due north



1. Relief and Slope: 4 FEET 0 - 3%
2. Presence of any watercourse, wetlands or surface water bodies, within 200 feet of test holes: YES☐ NO☒ If yes, locate on above sketch.
3. Presence of existing or proposed private drinking water wells within 200 feet of test holes: YES☐ NO☒ If yes, locate on above sketch.
4. Public drinking water wells within 500 feet of test holes: YES☐ NO☒ If yes, locate on above sketch.
5. Is site within the watershed of a public drinking water reservoir or other critical area defined in SD 19.00? YES☐ NO☒
6. Has soil been excavated from or fill deposited on site? YES☐ NO☒ If yes, locate on above sketch.
7. Site's potential for flooding or ponding: NONE☒ SLIGHT☐ MODERATE☐ SEVERE☐
8. Landscape position: SUMMIT
9. Vegetation: GRASSLAND / HARDWOODS
10. Indicate approximate location of property lines and roadways.
11. Additional comments, site constraints or additional information regarding site:

Certification

The undersigned hereby certifies that all information on this application and accompanying forms, submittals and sketches are true and accurate and that I have been authorized by the owner(s) to conduct these necessary field investigations and submit this request.

Part A prepared by:

Signature License #

Part B prepared by:

Signature License #

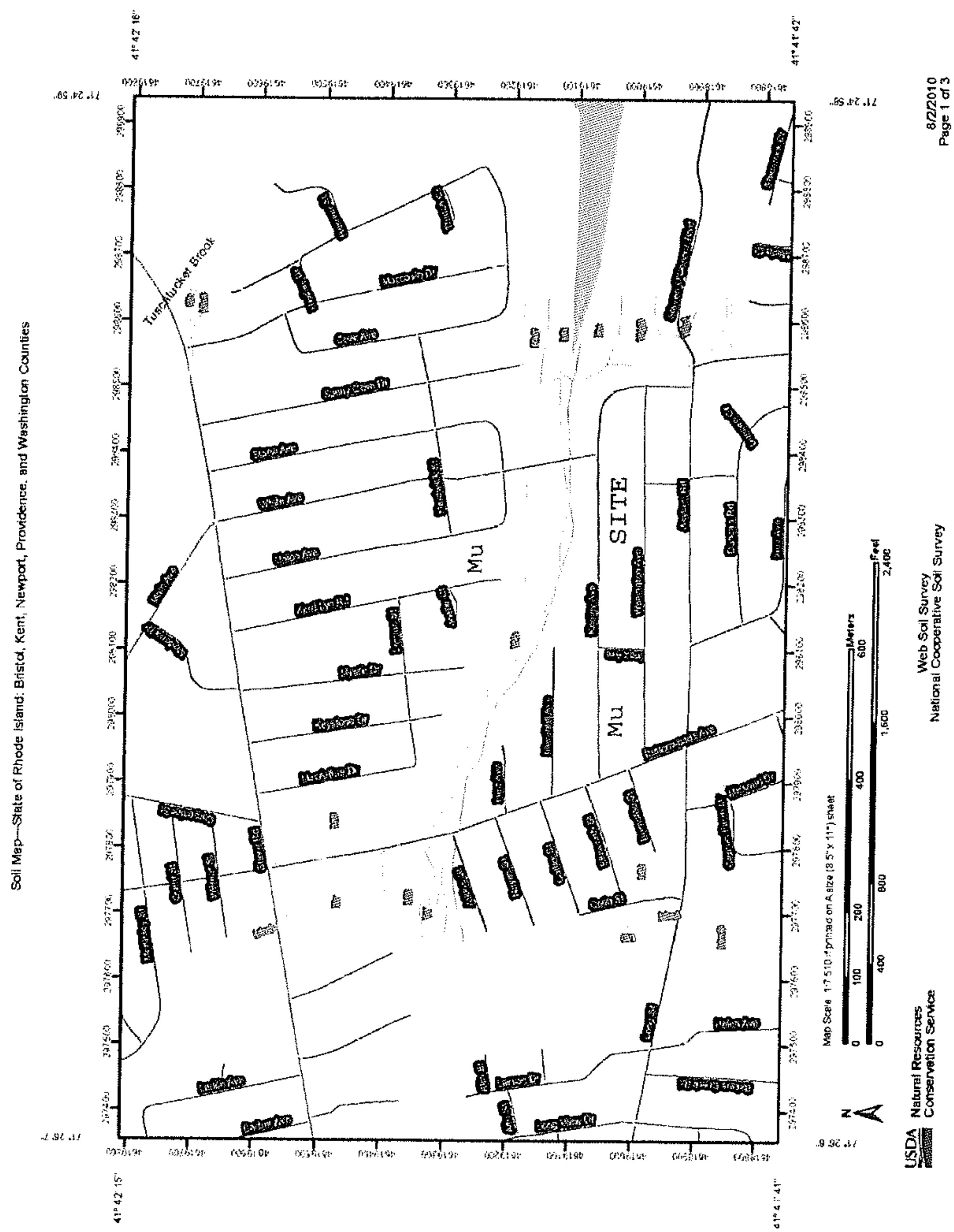
FOR OFFICE USE ONLY

Decision: Approved ☐ Disclaimed ☐

Comments:

Signature Authorized Agent Date

revised 5/8/01


Soil Map—State of Rhode Island: Bristol, Kent, Newport, Providence, and Washington Counties
Tuscatucket Brook
SITE
Mu
Mu
Web Soil Survey
National Cooperative Soil Survey
8/2/2010
Page 1 of 3
USDA Natural Resources Conservation Service

Soil Map–State of Rhode Island: Bristol, Kent, Newport, Providence, and Washington Counties

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:7,510 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 19N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: State of Rhode Island: Bristol, Kent, Newport, Providence, and Washington Counties
Survey Area Data: Version 6, Oct 14, 2009

Date(s) aerial images were photographed: 8/14/2003

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Soil Map–State of Rhode Island: Bristol, Kent, Newport, Providence, and Washington Counties

Map Unit Legend

State of Rhode Island: Bristol, Kent, Newport, Providence, and Washington Counties (RI600)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Dc	Deerfield loamy fine sand	1.8	0.9%
HkC	Hinckley gravelly sandy loam, rolling	1.7	0.8%
Mk	Matunuck mucky peat	1.7	0.8%
MmA	Merrimac sandy loam, 0 to 3 percent slopes	5.2	2.5%
MmB	Merrimac sandy loam, 3 to 8 percent slopes	1.0	0.5%
MU	Merrimac-Urban land complex	172.4	81.5%
Sb	Scarboro mucky sandy loam	0.0	0.0%
UD	Udorthents-Urban land complex	3.4	1.6%
Ur	Urban land	5.5	2.6%
W	Water	0.2	0.1%
Wa	Walpole sandy loam	14.2	6.7%
WgA	Windsor loamy sand, 0 to 3 percent slopes	1.0	0.5%
WgB	Windsor loamy sand, 3 to 8 percent slopes	3.5	1.7%
Totals for Area of Interest		**211.6**	**100.0%**

g. USGS Topographic Map and Site Photographs

USGS Topographic Map

Photograph #1: Looking North from Asylum Road.

Photograph #2: Looking south from Wellington Avenue.