

**Stormwater Attenuation and Source  
Reduction Strategy for the  
Pettaquamscutt River:  
Revised: Final Plan**

**Town of South Kingstown**  
South Kingstown, Rhode Island

July 2014  
Revised December 2016



317 Iron Horse Way  
Providence, Rhode Island

**DRAFT**

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# 1 Background and Purpose

The Pettaquamscutt River, also known as the Narrow River, is located in southern Rhode Island passing through North Kingstown and forms the boundary between the towns of South Kingstown (Town) and Narragansett (project location is depicted in *Figure 1*, see end of report). The river's watershed is approximately ten (10) miles long, covering a total area of approximately fourteen (14) square miles.

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## 1.1 Background

This project report investigates stormwater attenuation strategies for parts of the Pettaquamscutt River Watershed in the Town of South Kingstown (hereinafter the "Town"). (A description of the Pettaquamscutt River—also known as the Narrow River—is provided in *Section 2.1* of this report.)

Due to its recognition as an important estuary, the Pettaquamscutt River has been the focus of many studies and environmental plans over the years such as the Coastal Resource Management Council's (CRMC) *Narrow River Special Area Management Plan (SAMP)* (CRMC, 1987), the *Narrow River Stormwater Study (Tritown Study)* (ASA et al 1991), and the *Narrow River Stormwater Abatement Study* (F&O, 2006). The SAMP focuses on policy changes in the municipalities within the river's watershed while the Tritown Study investigated approaches to implement those policies and reduce pollutants through potential best management practices (BMPs) such as structural stormwater management.

Loadings of pathogens to the Pettaquamscutt River have prevented it from meeting its designated use and have resulted in its inclusion on the State's 303(d) list. The 303(d) list is prepared every two years by the Rhode Island Department of Environmental Management (RIDEM) Office of Water Resources in compliance with the federal Clean Water Act and includes all waterbodies that do not meet *Rhode Island Water Quality Standards* based on the most recent assessment of water quality conditions. A fecal coliform total maximum daily load (TMDL), entitled *Fecal Coliform TMDL for the Pettaquamscutt (Narrow) River Watershed, Rhode Island* (hereinafter "Pettaquamscutt TMDL"), has been developed for this river and was approved on April 29, 2002. The TMDL identifies wet-weather as a significant source of fecal coliform:

Storm water runoff is the largest wet weather source of bacteria to the Pettaquamscutt River and its tributaries. Storm sewers magnify the problem by rapidly collecting, concentrating and directly routing polluted runoff to receiving waters.  
(p. 75, RIDEM, 2001)

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## 1.2 Purpose and Objectives

The purpose of this project is to assist South Kingstown in developing stormwater controls for the twelve Town outfalls within the boundaries of the Pettaquamscutt River Watershed and to help the Town comply with the requirements of the *General Permit Rhode Island Pollutant Discharge Elimination System Storm Water Discharge from Small Municipal Separate Storm Sewer Systems and from Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s* (Stormwater Phase II GP). Because the Pettaquamscutt TMDL identifies the stormwater from the Town's storm sewer outfalls as a significant contributor to the impairment of the river, South Kingstown must address stormwater discharges to the river as part of its

stormwater management program. Compliance with the Stormwater Phase II GP will be accomplished by developing a plan that will serve as an addendum to the Town's storm water management program plan (SWMPP). Specific parts of the final plan that address compliance with the Stormwater Phase II GP are listed in *Table 1*, below.

**Table 1**  
**Stormwater Phase II GP Compliance Requirements and**  
**Sections of the**  
**Stormwater Attenuation and Source Reduction Strategy for the**  
**Pettaquamscutt River: Final Plan**

<b>Compliance Requirements</b>	<b>Final Plan Reference</b>
Map Drainage Area Contributing to Existing Stormwater Outfalls	<ul style="list-style-type: none"> <li>• <i>Appendix A</i> “Conceptual BMP Layout Plans – With Aerials”</li> <li>• <i>Appendix B</i> “Conceptual BMP Layout Plans – With As-Built Sewer Plans”</li> </ul>
Conduct Existing Drainage Area Survey and Feasibility Analysis	<ul style="list-style-type: none"> <li>• <i>Section 3</i> “Existing Conditions”</li> <li>• <i>Section 4</i> “Alternatives Analysis”</li> <li>• <i>Section 5</i> “Analysis of Hydrology and Hydraulics</li> <li>• <i>Section 6</i> “Selection of Preferred Alternatives...”</li> </ul>
Calculate Groundwater Recharge Goals by Catchment	<ul style="list-style-type: none"> <li>• <i>Section 3.4</i> “Groundwater Recharge Goal”</li> </ul>
Conduct Source Reduction Survey	<ul style="list-style-type: none"> <li>• <i>Section 7</i> “Source Reduction Survey”</li> </ul>
Develop Conceptual (10%) Designs for Each Catchment	<ul style="list-style-type: none"> <li>• <i>Appendix A</i> “Conceptual BMP Layout Plans – With Aerials”</li> <li>• <i>Appendix B</i> “Conceptual BMP Layout Plans – With As-Built Sewer Plans”</li> </ul>
Develop a Stormwater Attenuation and Source Reduction Strategy	<ul style="list-style-type: none"> <li>• <i>Section 9</i> “Stormwater Attenuation and Source Reduction Strategy”</li> </ul>

Following acceptance of this final plan by the Town, we will provide the Town with bidding and construction administration services for construction of selected BMPs.

### **1.3 Consideration of Walmsley Lane**

During the initiation meeting for this project (February 7, 2013), representatives of RIDEM requested consideration of the outfalls near Walmsley Lane. Participants of the February 7 meeting also reviewed a map of outfalls, catch basins and piping; land use; and available land, which was provided by the Town. It was noted that several outfalls discharge to wooded areas and result in overland flow. This is essentially a preferred condition as it allows stormwater to attenuate naturally. Therefore, participants agreed that such outfalls could probably be considered lower priority for retrofit.

We have reviewed the six outfalls of Walmsley Lane. Based on outfall mapping provided by the Town, we determined that the outfalls of this road discharge to overland and are, therefore, lower priority than the other outfalls in the study area. The outfalls of Walmsley Lane have not been further considered in

this document. Below, *Figure 2 Walmsley Lane Stormwater Infrastructure* shows the outfalls of concern in relationship to the Pettaquamscutt River.

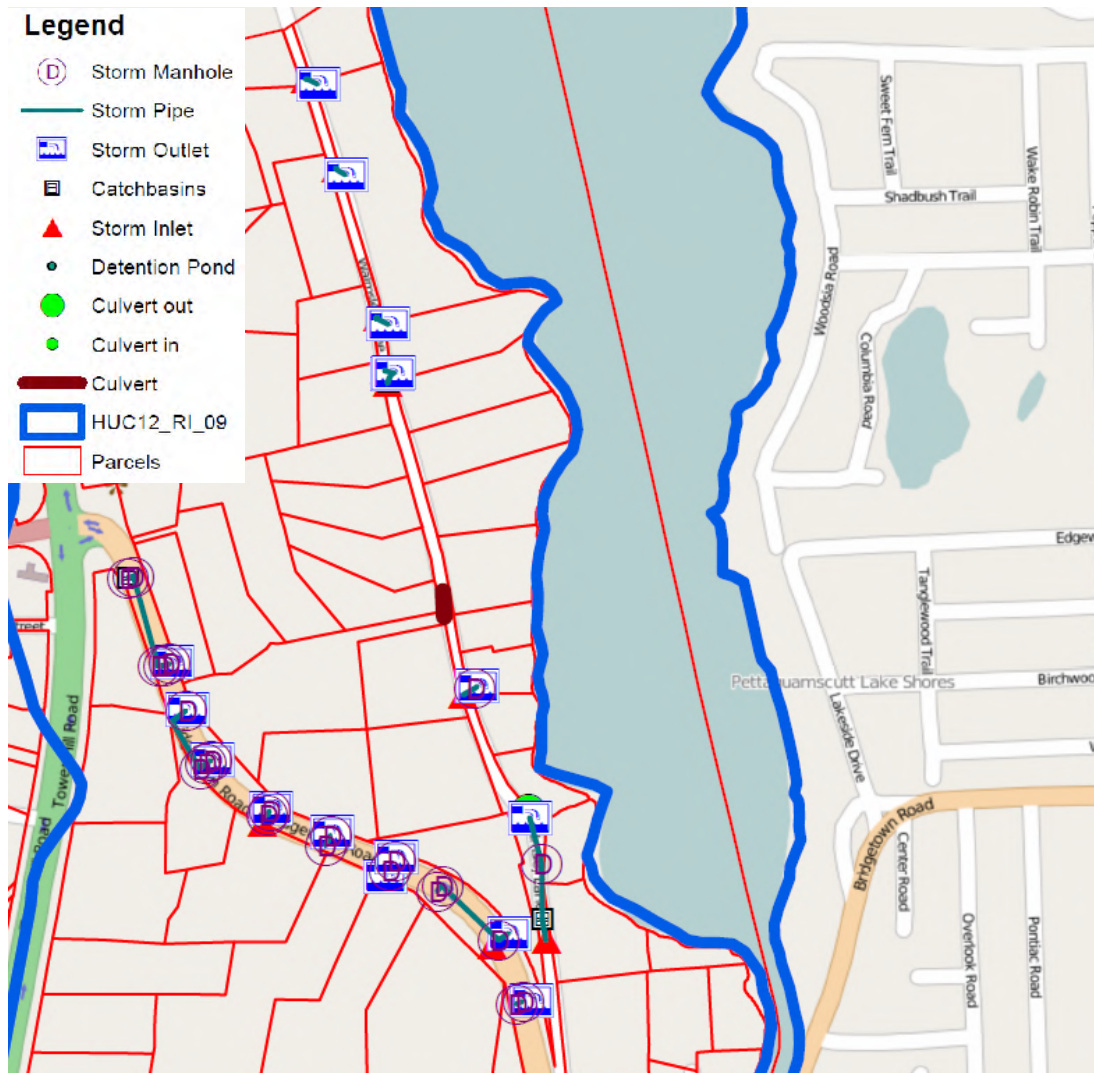


Figure 2— Walmsley Lane Stormwater Infrastructure

## 2 Review of the Pettaquamscutt (Narrow) River TMDL

This section of our report provides a waterbody description and has been adapted from the Pettaquamscutt TMDL. It is required for compliance with the Stormwater Phase II GP.

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## 2.1 Waterbody Description

The Pettaquamscutt River is a 5.9 miles river that runs approximately parallel to the Narragansett Bay in Narragansett, RI. The river is a tidal inlet estuary as it experiences tidal flushing from its outlet to the Bay. Much of the area surrounding the river is comprised of wildlife habitat and recreational area; however, approximately 35% of the watershed is developed (RIDEM, 2001).

Although ten streams discharge to the Pettaquamscutt River, a large portion of the inflow to the river comes from groundwater seepage. The three most significant tributaries to the river include Gilbert Stuart Stream, Mumford Brook and Crooked Brook.

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## 2.2 Impairments of Concern

The Pettaquamscutt River is a Category 4A water on the State of Rhode Island's 2012 303(d) List of Impaired Waters. Water quality has been a concern in the Pettaquamscutt River for decades. Water sampling has confirmed elevated fecal coliform levels over the past 40 years with the highest concentrations in the Pettaquamscutt Cove in the southern portion of the Pettaquamscutt River. The highest concentrations of fecal coliform have been observed after rainfall events and in the warm summer months (RIDEM, 2001).

Mumford Brook is the second largest tributary to the Pettaquamscutt River. This particular waterway originates at the outfall to a groundwater fed pond near Tower Hill Road in South Kingstown. The 0.8 kilometer tributary runs through hardwood wetland and a phragmites dominated swamp and discharges to the southern end of the Pettaquamscutt Cove. The watershed for Mumford Brook is predominantly medium-density residential. Bacteria concentrations in the brook have proven to consistently be approximately two orders of magnitude higher or more than other tributaries to the Pettaquamscutt River (RIDEM, 2001).

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## 2.3 Sources of Impairment as Described in the TMDL

Stormwater runoff and wildlife fecal matter have been identified as the primary bacterial pollution sources in the Pettaquamscutt River. Runoff from the three major tributaries discussed above along with large waterfowl populations in the Pettaquamscutt River (specifically in Pettaquamscutt Cove) have been linked to elevated fecal coliform concentrations within the waterbody (RIDEM, 2001).

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## 2.4 Waterbody-Specific TMDL Recommendations

The Pettaquamscutt TMDL has identified the three major tributaries emptying into the Pettaquamscutt River as principal pathways for fecal coliform. These tributaries are the Narrow River, Gilbert Stuart River and the Mumford Brook. The TMDL recommends measures to mitigate fecal coliform and achieve the required water quality improvements. Structural and nonstructural BMPs designed to treat

flows and pollutant loadings at the stormwater outfalls are also recommended by the Pettaquamscutt TMDL for much of the impact areas within the watershed.

More specifically, the TMDL document presents reductions in fecal coliform levels necessary to ensure that both parts of the fecal coliform standard are met for the Narrow River, Gilbert Stuart River and Mumford Brook. These reductions represent overall reduction goals that are applicable to the composite of all point and nonpoint sources contributing to the water quality impairments.

The TMDL report identifies stormwater runoff as the largest wet weather source of bacteria to the Narrow River and its tributaries, as further described below:

“Stormwater runoff is the largest wet weather source of bacteria to the Narrow River and its tributaries. Storm sewers magnify the problem by rapidly collecting, concentrating and directly routing polluted runoff to receiving waters. Storm sewer outfalls discharging to Segments 2, 3 and 4 represent the only point sources of fecal coliform to the Narrow River. They supply the majority of the fecal coliform load to the middle portion of the river during wet weather. The twelve largest storm sewer outfalls (shown on TMDL Figure 3.4), representing an estimated ninety-three (93) percent of the total fecal coliform load from outfalls to the Narrow River, are listed in TMDL Table 5.7. Consistent with the goals of this TMDL, these outfalls are targeted for water quality best management practices to mitigate pollutant loadings to the greatest extent practicable. The largest outfalls should receive priority for BMP implementation; however, special consideration should be given to those outfalls discharging to, or immediately upstream of, Segments 3 and 4. These two segments are shallow and narrow with relatively little dilution volume available to absorb the impact of pollutant loadings. Consequently, significant loading reductions in these reaches would lead to substantive in-stream water quality improvements during wet weather. Ultimately all direct discharge outfalls that contribute to the impairment of the Narrow River should be addressed as necessary to meet water quality goals”.

None of the twelve outfalls identified as the largest storm sewer outfalls in the above excerpt from the Narrow River TMDL are located on the South Kingstown side of the river. Of relevance to this plan, are the two final points. First consideration should be given to prioritizing discharges to Segments 3 and 4 (Upper and Lower River respectively) since this is where reduced bacteria loadings are expected to have the greatest impact on receiving water quality. Secondly, though none of the twelve largest stormwater sources are located in South Kingstown, ultimately all direct stormwater outfalls that contribute to the impairment should be addressed as necessary to meet water quality goals. *Figure 3* (at the end of this report) has been borrowed from the Fecal Coliform TMDL for the Pettaquamscutt (Narrow) River Watershed prepared by RIDEM to show the Narrow River Segments. All or portions of Segments 2, 3, 4 and 5 fall within the boundaries of the Town of South Kingstown. These relevant Segments are Lower Pond, Upper River, Lower River and Pettaquamscutt Cove respectively.

### 3 Existing Conditions

*Section 3* discusses the following items related to the development of base mapping and collection of existing-conditions data:

- Data sources and methods used to develop base mapping.
- Description of the South Kingstown areas of the Pettaquamscutt River Watershed by drainage catchment.

Base mapping is shown as part the conceptual BMP drawing sets found in *Appendix A* (base mapping on aerial photographs) and *Appendix B* (base mapping showing as-built sewer plans). The base mapping presented includes drainage areas and catchments, inclusive of topography, parcel data and aerial photography.

## 3.1 Stormwater Drainage System and Mapping

### 3.1.1 Data Sources

*Table 1* indicates the data sources we used to compile base mapping for the study area.

**Table 2**  
**Data Sources Used to Develop Base Mapping for the Project Study Area**

<b>Elevations and contours, including severe slopes</b>	South Kingstown GIS data
<b>Soil types including hydrologic soil groups</b>	RIGIS – 2012 USDA/NRCS Soil Survey Geographic Database
<b>Infiltration rates based on soil type</b>	RIGIS – 2012 USDA/NRCS Soil Survey Geographic Database
<b>Depth to groundwater</b>	RIGIS – 2012 USDA/NRCS Soil Survey Geographic Database Town record drawings for sewer construction
<b>Surface waters</b>	South Kingstown GIS data
<b>Wetlands and Natural Heritage Areas</b>	RIGIS
<b>Rock outcroppings or shallow bedrock</b>	Town record drawings for sewer construction
<b>Buried utilities</b>	South Kingstown data
<b>Public wells and wellhead protection areas within 400 feet of proposed BMP sites</b>	RIGIS - Wellhead protection areas
<b>Properties served by private wells within 100 feet of proposed BMP sites</b>	South Kingstown data (properties without public water)
<b>Properties served by onsite wastewater treatment systems</b>	South Kingstown data
<b>Identification of rights of way, easements, publicly owned and undeveloped properties within the drainage area.</b>	South Kingstown GIS data
<b>Description of downstream reach impacted by the stormwater outfalls</b>	RIGIS – Rivers and Streams RI Integrated Water Quality and Assessment Report
<b>Impervious area to each outfall</b>	RIGIS
<b>Land Use Data</b>	RIGIS

### 3.1.2 Methods

Drainage areas were delineated utilizing existing Town topographic mapping with 2-foot contours and 1992 record drawings also provided by the Town. Additional sources of data for base mapping and delineation include soil types and hydrologic soil groups from RIGIS, parcel data from RIGIS and impervious area from RIGIS.

Drainage areas were delineated based on the slope of 2-foot contours, observed pitches of roads and ROWs, and aerial photography.

Drainage areas were further divided into catchments in such a manner as to take into account the siting of multiple possible stormwater controls. Subsequent to a site visit conducted on April 3, 2013, catchments were refined to account for slight topographic characteristics that were not clear from the Town's 1992 record drawings.

### 3.1.3 Description by Catchment

A map of the delineated stormwater catchment areas is provided in *Appendix A*. The map shows 17 areas, numbered 1 - 17 one for each discharge from the project study area. The 17 discharges include twelve outfalls, one leaching catch basin and four areas of overland flow. The catchments are further broken down into a total of 30 catchments to account for hydrologic separation within the catchments that may affect siting of BMPs. The catchments are named using the number of their catchment followed by a letter indicating direction (e.g., 1W1E2W2EW, E, SW, NW, etc.).

**Table 3  
Discharges and Related Catchments in the  
Project Study Area**

<b>Outfall or Discharge</b>	<b>Catchments</b>
<b>Segment 4</b>	
Outfall 1	1W, 1E
Leaching Catch Basin 1	2W, 2E
Overland Flow	3W, 3E
Outfall 2	4S, 4N
Outfall 3	5SW, 5NW, 5SE, 5NE
Outfall 4	6SW, 6NW, 6E
<b>Segment 3</b>	
Outfall 5	7W, 7E
Outfall 6	8W, 8E
Outfall 7	9W, 9E
Outfall 8	10E, 10E
Outfall 9	11
<b>Mumford Brook</b>	
Outfall 10	12
<b>Segment 5</b>	

<b>Outfall or Discharge</b>	<b>Catchments</b>
Presumed Outfall 11	13
Overland Flow	14
Overland Flow	15
Overland Flow	16
Outfall 12	17

The following is a narrative description of each outfall catchment.

### ***Catchment 1***

Catchment 1 has been broken down into two catchments, catchment 1W and catchment 1E, which consist of approximately 43.28 and 0.37 acres, respectively. Both catchments drain to an outfall at the end of Lafayette Avenue via a series of catch basins and a short swale along the west portion of Middlebridge Road. Catchment 1W is generally represented by pervious forested land, which slopes toward Pettaquamscutt River, with a small percentage of densely populated residential lots along Middlebridge Road and its side streets to the west. Catchment 1E is bounded by the crown of Middlebridge Road and consists of the right-of-way (ROW) on Middlebridge. Catchment 1E is approximately 70% impervious due to its location along the roadway and its limited size.

### ***Catchment 2***

Catchment 2 consists of catchment 2W and Catchment 2E of 16.45 and 0.37 acres, respectively, divided along the crown of Middlebridge Road. Catchment 2W drains to a catch basin on the west side of Middlebridge road which is then piped to a leaching catch basin on the east side of the road. Catchment 2E drains directly to the leaching catch basin on the east side of Middlebridge Road. Again, catchment 2W is mainly characterized by forested vegetation and a narrow band of residential development along Middlebridge Road. Catchment 2E is bounded by the crown of Middlebridge Road and the ROW.

### ***Catchment 3***

Collectively, catchment 3W and Catchment 3E drain overland to the Pettaquamscutt River. We have separated these catchments because Catchment 3E may be an ideal location for the siting of a stormwater retrofit control. Stormwater from another drainage area could be piped into a potential linear bioretention basin along the ROW on the west side of Middlebridge Road. 3W is approximately 33.38 acres of forested vegetation with the inclusive of a few homes along Middlebridge and well-tended lawns for homes sited on Torry Road. Catchment 3E consists of a narrow strip of ROW along Middlebridge Road at its intersection with Torry Road.

### ***Catchment 4***

Catchment 4S and Catchment 4N flank Torry Road, Catchment 4S to the south and Catchment 4N to the north. Both catchments are steeply sloped toward the Pettaquamscutt River and are separated by the crown of the roadway. Currently, there are two heavily sedimented stormwater swales on either side of the road, which are transported through culverts to catch basins and eventually are discharged to the Pettaquamscutt River via an outfall directly east of Torry Road. Catchment 4S is in the vicinity of 14.45 acres while 4N is 3.78 acres.

### ***Catchment 5***

Catchment 5 has been delineated into four catchments based upon the locations of and the drainage paths to four separate catch basins. Catchment 5SW is 6.84 acres and includes a small stream that outlets to a catch basin at the intersection of Berglund Avenue and Middlebridge Road. Catchment 5NW is 12.85 acres and is bounded by the crown of Berglund Avenue and Middlebridge Road. Catchment 5SE and Catchment 5NE are on the east side of Middlebridge and are bounded by the crown of road and the limit of the ROW and consist of 0.04 and 0.06 acres, respectively. The roadway frontage of Catchment 5SW is undeveloped and wooded. Catch basins within Catchment 5 outlet to the stormwater swale within the ROW of Catchment 6NW, which ultimately discharge to the outfall at the end of Mitchell Avenue.

#### ***Catchment 6***

Catchment 6 is delineated into three catchments. Catchment 6SW has very little roadway frontage on Middlebridge Road and is 9.19 acres. Catchment 6NW consists of 23.31 acres whose roadway frontage is undeveloped; however, an unmaintained stormwater swale is located here and Catchment 6E consists of a 4.72-acre region of densely developed residential land along the east of Middlebridge road which drains to the road rather than to the Pettaquamscutt River. The outfall for Catchment 6 is at the end of Mitchell Avenue within the Pettaquamscutt River Fishing Access point.

#### ***Catchment 7***

Catchment 7W is sited along the west side of Middlebridge Road and primarily characterized by forested vegetation. The stormwater swale which was described as an attribute in Catchment 6NW continues into Catchment 7W along the west side of Middlebridge Road. Catchment 7E is bounded by the crown of Middlebridge Road and a highpoint between the road and the river inclusive of several residential lots. Catchment 7W is 26.25 acres while 7E is 3.82. Catchment 7 discharges to an outfall just north of John Street.

#### ***Catchment 8***

Catchment 8W and Catchment 8E are located on either side of Middlebridge Road. Catchment 8W is located to the west and Catchment 8E is located to the east. These two catchments are divided along the crown of Middlebridge Road and are made up of 34.01 acres of forested vegetation and 0.92 acres of a densely populated residential neighborhood respectively. Catchment 8E has a high point along the rooftops of homes located on the east side of Middlebridge. The roadway frontage of catchment 8W is undeveloped but work in the ROW may be limited by an existing stone wall. Catchment 8W is steeply sloped toward Middlebridge Road and the outfall for Catchment 8 is located just south of the most southerly entrance to Riverside Avenue.

#### ***Catchment 9***

Catchment 9 discharges to an outfall at the most southerly bend of Riverside Avenue. Catchment 9W is located on the west side of Middlebridge Road and consists of 25.20 acres of heavily wooded land and Catchment 9E is situated on the east side of Middlebridge Road encompassing 4.49 acres of houses along both Middlebridge Road and Riverside Avenue. Catchment 9W and Catchment 9E are divided along the crown of Middlebridge Road.

#### ***Catchment 10***

Catchment 10W and Catchment 10E are similarly separated by the crown of Middlebridge Road, Catchment 10W is located on the west side of the road and Catchment 10E is located on the east side.

Catchment 10W is 43.10 acres of primarily forested vegetation while Catchment 10E is 2.11 acres of a densely populated residential development. Both Catchments discharge directly east of Shadbush Trail to an outfall located on the Pettaquamscutt River.

#### ***Catchment 11***

Catchment 11 has not been further divided and is bounded by Catchment 10W, two high points in Riverside Avenue and a high point along the ROW on the east side of Riverside. Catchment 11 includes 4.48 acres of residential buildings.

#### ***Catchment 12***

Catchment 12 is spatially separated from the other 11 catchments and is located to the south. Catchment 12 discharges to an outfall at the southern end of Narragansett Avenue East with catchbasins along Narragansett Avenue East. This catchment is 11.80 acres in size and incorporates residential and institutional buildings, as well as open and forested land.

#### ***Catchment 13***

Catchment 13 is similarly spatially separated from Catchments 1 through 11 and is located slightly northwest of Catchment 12. The catchment is characterized by a series of catchbasins along Hillside Drive that presumably discharges to an outfall (outfall 11) that would be located east of Hillside Drive. The catchment is 7.40 acres in size and incorporates both medium density and medium high-high density residential land.

#### ***Catchment 14***

Catchment 14 is located to the south of catchment 13 and primarily encompasses the area of Crest Avenue. This catchment has no formal drainage and flows from northeast to southwest and discharges via overland flow to a ravine which ultimately drains to the river. The catchment is 6.58 acres in size and is characterized by mostly medium high-high residential land use.

#### ***Catchment 15***

Catchment 15 is located adjacent to, and slightly northwest of, Catchment 14. This catchment accepts drainage from both Summit Avenue and Holland Drive. There are no formal drainage features on either street and water ultimately discharges to the same ravine as Catchment 14 via overland flow. This catchment is 15.18 acres in size and is characterized by both medium density and medium high-high density residential land use.

#### ***Catchment 16***

Catchment 16 is located adjacent to, and slightly northwest of, Catchment 15. This catchment is primarily the area draining to Seaview Avenue. Similar to Catchments 14 and 15, there is no formal drainage infrastructure located along this street. Stormwater flows northeast to southwest along the roadway and discharges to the ravine located at the southwestern end of the street via overland flow before being discharged to the Pettaquamscutt River. The drainage area is 2.58 acres in size and is characterized by mostly medium density residential and some forested land uses.

#### ***Catchment 17***

Catchment 17 is located adjacent to and slightly east of Catchment 12. This catchment drains the northeast portion of Kimberley Drive. Currently, there is a catch basin and outfall located at the cul-de-

sac at the end of Kimberley Drive. The drainage area is 9.2 acres, 22% of which is considered impervious. Land use in the catchment is primarily composed of medium density residential.

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## 3.2 Town's Process for Drainage System Mapping Updates

The Stormwater Phase II GP requires that MS4 operators with service areas that include one or more stormwater TMDL provide a process for updating drainage system mapping as needed. The Town of South Kingstown has already mapped its outfalls and catch basins on a townwide basis. This mapping included the study area of this report. If previously unknown outfalls are found or installed, the Town will define their drainage areas using available topographical information such as USGS maps and RIGIS data.

### 3.2.1 Identify Remaining Discharges

As previously noted, the Town has completed the outfall mapping requirement as part of the Stormwater Phase II GP. Where possible, this mapping has included other forms of discharge (e.g., leaching catch basins and overland flow). The Town expects that all municipally owned stormwater outfalls and other major points of discharge to the Pettaquamscutt River have been identified; however, it is possible that unidentified discharges exist. If new discharges are identified or installed, the Town will work to identify, survey, and document any previously unidentified discharges with drainage system ownership data as available.

### 3.2.2 Process for Defining Catchments

The Town has previously mapped Town-owned drainage system features such as outfalls and catch basins for compliance with Stormwater Phase II GP. Catchment and Catchment areas have also been mapped in the Town-owned areas of the Pettaquamscutt River Watershed. While the Town has defined catchments to the extent practicable with available data, it is possible that unidentified system features exist or that refinement of catchment areas may be needed at some point in the future. If needed, the Town will define newly identified drainage areas using available topographical information such as USGS maps and RIGIS data.

### 3.2.3 Process for Identifying Interconnections

The Town inspects its catch basins annually and cleans them on a predictive schedule basis. In accordance with the Stormwater Phase II GP, the Town's inspections include a process for identification of interconnections. To date, no interconnections have been identified; however, if future investigatory work (e.g., catch basin inspections) reveals previously unidentified interconnections, the Town will add such interconnections to its drainage system data.

### 3.3 Estimated Pollutant Loadings

Pollutant loadings for bacteria were calculated for each Catchment utilizing the following equation from the *Rhode Island Stormwater Design and Installation Manual* (RIDEM, 2010):

$$L = 1.03 \times 10^{-3}[(P)(P_j)(R_v)](C')(A)$$

Where:

L = billion colonies

P = rainfall depth (inches)

P<sub>j</sub> = rainfall correction factor

R<sub>v</sub> = runoff coefficient expressing the fraction of rainfall converted to runoff

$$[R_v = 0.05 + 0.009(\% \text{ impervious})]$$

C' = flow-weighted mean bacteria concentration (#col/100ml)

A = contributing drainage area of development site (acres)

1.03 x 10<sup>-3</sup> is a conversion factor

Note: The mean bacteria concentrations in the table below (C') were calculated as weighted averages of the percentage of land classified as either residential or undeveloped within each watershed multiplied by the event mean bacteria concentrations for residential (7,000 col/100ml) and undeveloped land (300 col/100ml). 10

**Table 4**  
**Pollutant Loadings by Catchment**

Catchment	Contributing Area (acres)	Percent Impervious	Mean Bacteria Concentration (col/100 ml)	Loading (billion colonies)
<b>Segment 4</b>				
Catchment 1W	48.2	6.38	1.45 x 10 <sup>3</sup>	3.41 x 10 <sup>2</sup>
Catchment 1E	0.264	71.5	7.00 x 10 <sup>3</sup>	5.82 x 10 <sup>1</sup>
Catchment 2W	16.5	6.60	3.05 x 10 <sup>3</sup>	2.50 x 10 <sup>2</sup>
Catchment 2E	0.373	88.6	6.04 x 10 <sup>3</sup>	8.67 x 10 <sup>1</sup>
Catchment 3W	33.4	4.10	1.83 x 10 <sup>3</sup>	2.41 x 10 <sup>2</sup>
Catchment 3E	0.163	94.9	300	2.00 x 10 <sup>0</sup>
Catchment 4S	14.5	12.0	2.89 x 10 <sup>3</sup>	3.00 x 10 <sup>2</sup>
Catchment 4N	3.79	33.5	5.05 x 10 <sup>3</sup>	3.06 x 10 <sup>2</sup>
Catchment 5SW	6.85	14.3	4.85 x 10 <sup>3</sup>	2.70 x 10 <sup>2</sup>
Catchment 5NW	12.9	7.34	2.75 x 10 <sup>3</sup>	1.87 x 10 <sup>2</sup>
Catchment 5SE	0.0414	100	7.00 x 10 <sup>3</sup>	1.25 x 10 <sup>1</sup>
Catchment 5NE	0.0683	100	7.00 x 10 <sup>3</sup>	2.06 x 10 <sup>1</sup>
<b>Segment 3</b>				
Catchment 6SW	9.19	9.14	2.39 x 10 <sup>3</sup>	1.32 x 10 <sup>2</sup>
Catchment 6NW	23.3	3.83	1.60 x 10 <sup>3</sup>	1.43 x 10 <sup>2</sup>
Catchment 6E	4.72	47.5	6.94 x 10 <sup>3</sup>	7.11 x 10 <sup>2</sup>

Catchment	Contributing Area (acres)	Percent Impervious	Mean Bacteria Concentration (col/100 ml)	Loading (billion colonies)
Catchment 7W	26.3	3.10	686	6.39 x 10 <sup>1</sup>
Catchment 7E	3.82	44.0	6.96 x 10 <sup>3</sup>	5.39 x 10 <sup>2</sup>
Catchment 8W	34.0	3.12	907	1.09 x 10 <sup>2</sup>
Catchment 8E	0.923	69.0	7.00 x 10 <sup>3</sup>	1.97 x 10 <sup>2</sup>
Catchment 9W	25.2	7.88	2.08 x 10 <sup>3</sup>	2.88 x 10 <sup>2</sup>
Catchment 9E	4.49	45.3	7.00 x 10 <sup>3</sup>	6.54 x 10 <sup>2</sup>
Catchment 10W	43.1	7.11	1.53 x 10 <sup>3</sup>	3.42 x 10 <sup>2</sup>
Catchment 10E	2.12	44.7	7.00 x 10 <sup>3</sup>	3.05 x 10 <sup>2</sup>
Catchment 11	4.49	42.0	7.00 x 10 <sup>3</sup>	6.11 x 10 <sup>2</sup>
<b>Mumford Brook</b>				
Catchment 12	21.80	26.8	4.16 x 10 <sup>3</sup>	6.50 x 10 <sup>2</sup>
<b>Segment 5</b>				
Catchment 13	7.40	34.6	6.95 x 10 <sup>3</sup>	8.43 x 10 <sup>2</sup>
Catchment 14	6.67	29.6	6.88 x 10 <sup>3</sup>	6.50 x 10 <sup>2</sup>
Catchment 15	15.2	22.1	6.94 x 10 <sup>3</sup>	1.19 x 10 <sup>3</sup>
Catchment 16	2.58	39.5	6.01 x 10 <sup>3</sup>	2.86 x 10 <sup>2</sup>
Catchment 17	9.20	22.9	3.91 x 10 <sup>3</sup>	4.19 x 10 <sup>2</sup>

### 3.4 Groundwater Recharge Goal

Groundwater recharge goals were calculated for each of the 17 catchments discussed in *Section 3.1.3* using the following equation from the *Rhode Island Stormwater Design and Installation Manual* (RIDEM, 2010):

$$GRV = (1'' * F * A) / 12$$

Where:

GRV = groundwater recharge volume (acre-feet)

F = recharge factor, see below

A = impervious area of catchment for each outfall (acres)

The recharge goal is calculated and considered in order to aid in protecting stream base flows, water table levels and adjacent wetland areas when designing stormwater retrofit opportunities. Table 8 summarizes calculated recharge goals side by side with the Water Quality Volume (WQv) for all 17 catchments. Since the WQv is often larger than the calculated recharge goal retrofit opportunities will be assessed on their ability to treat 100% of the calculated WQv. Where site constraints prevent treatment of the entire WQv the recharge goal will also be considered when selecting and prioritizing BMP opportunities.

The following table summarizes the groundwater recharge goals (GRV) for each of the 25 Catchments described in the above sections.

**Table 5  
Groundwater Recharge Goal by Catchment**

Watershed No.	Soil Group	Area of Impervious Surface by Soil Group (Acres)	Recharge Factor for Soil Group (F)	Groundwater Recharge Volume by Soil Group (Acre-Feet)
<b>Segment 4</b>				
<b>Catchment 1W</b>	A	2.21	0.60	0.11
	B	0.73	0.35	0.02
	C	0.14	0.25	0.00
		<b>3.08</b>		<b>0.13</b>
<b>Catchment 1E</b>	A	0.17	0.60	0.01
	B	0.02	0.35	0.00
		<b>0.19</b>		<b>0.01</b>
<b>Catchment 2W</b>	A	0.35	0.60	0.02
	B	0.73	0.35	0.02
		<b>1.09</b>		<b>0.04</b>
<b>Catchment 2E</b>	A	0.03	0.60	0.00
	B	0.30	0.35	0.01
		<b>0.33</b>		<b>0.01</b>
<b>Catchment 3W</b>	A	0.35	0.60	0.02
	B	1.02	0.35	0.03
		<b>1.37</b>		<b>0.05</b>
<b>Catchment 3E</b>	B	0.15	0.35	0.00
		<b>0.15</b>		<b>0.00</b>
<b>Catchment 4S</b>	B	1.73	0.35	0.05
	C	0.01	0.25	0.00
		<b>1.74</b>		<b>0.05</b>
<b>Catchment 4N</b>	B	1.26	0.35	0.04
	C	0.01	0.25	0.00

Watershed No.	Soil Group	Area of Impervious Surface by Soil Group (Acres)	Recharge Factor for Soil Group (F)	Groundwater Recharge Volume by Soil Group (Acre-Feet)
		<b>1.27</b>		<b>0.04</b>
<b>Catchment 5SW</b>	A	0.06	0.60	0.00
	B	0.85	0.35	0.02
	C	0.07	0.25	0.00
		<b>0.98</b>		<b>0.03</b>
<b>Catchment 5NW</b>	A	0.17	0.60	0.01
	B	0.38	0.35	0.01
	C	0.40	0.25	0.01
		<b>0.94</b>		<b>0.03</b>
<b>Catchment 5SE</b>	A	0.04	0.60	0.00
		<b>0.04</b>		<b>0.00</b>
<b>Catchment 5NE</b>	A	0.07	0.60	0.00
		<b>0.07</b>		<b>0.00</b>
<b>Segment 4</b>				
<b>Catchment 6SW</b>	A	0.27	0.60	0.01
	B	0.28	0.35	0.01
	C	0.29	0.25	0.01
		<b>0.84</b>		<b>0.03</b>
<b>Catchment 6NW</b>	A	0.39	0.60	0.02
	B	0.06	0.35	0.00
	C	0.44	0.25	0.01
		<b>0.89</b>		<b>0.03</b>
<b>Catchment 6E</b>	A	2.24	0.60	0.11
		<b>2.24</b>		<b>0.11</b>
<b>Catchment 7W</b>	A	0.36	0.60	0.02
	B	0.23	0.35	0.02
	C	0.23	0.25	0.00

Watershed No.	Soil Group	Area of Impervious Surface by Soil Group (Acres)	Recharge Factor for Soil Group (F)	Groundwater Recharge Volume by Soil Group (Acre-Feet)
		<b>0.81</b>		<b>0.04</b>
Catchment 7E	A	1.68	0.60	0.08
		<b>1.68</b>		<b>0.08</b>
Catchment 8W	A	0.41	0.60	0.02
	B	0.56	0.35	0.02
	C	0.10	0.25	0.00
		<b>1.06</b>		<b>0.04</b>
Catchment 8E	A	0.64	0.60	0.03
		<b>0.64</b>		<b>0.03</b>
Catchment 9W	A	0.26	0.60	0.01
	B	0.70	0.35	0.02
	C	1.03	0.25	0.02
		<b>1.99</b>		<b>0.05</b>
Catchment 9E	A	2.04	0.60	0.10
		<b>2.04</b>		<b>0.10</b>
Catchment 10W	A	0.57	0.60	0.03
	B	1.20	0.35	0.04
	C	1.29	0.25	0.03
		<b>3.07</b>		<b>0.09</b>
Catchment 10E	A	0.94	0.60	0.05
		<b>0.94</b>		<b>0.05</b>
Catchment 11	A	1.88	0.60	0.09
	B	0.00	0.35	0.00
		<b>1.88</b>		<b>0.09</b>

Watershed No.	Soil Group	Area of Impervious Surface by Soil Group (Acres)	Recharge Factor for Soil Group (F)	Groundwater Recharge Volume by Soil Group (Acre-Feet)
<b>Mumford Brook</b>				
<b>Catchment 12</b>	B	2.67	.35	0.08
	C	1.30	.25	0.03
	Variable	1.29	.1	0.01
		<b>5.26</b>		<b>0.12</b>
<b>Segment 5</b>				
<b>Catchment 13</b>	B	0.15	.35	0.00
	C	2.41	.25	0.05
		<b>2.56</b>		<b>0.05</b>
<b>Catchment 14</b>	B	1.51	.35	0.04
	C	0.44	.25	0.01
		<b>1.95</b>		<b>0.05</b>
<b>Catchment 15</b>	B	0.12	.35	0.00
	C	3.24	.25	0.07
		<b>3.36</b>		<b>0.07</b>
<b>Catchment 16</b>	C	1.02		0.02
		<b>1.02</b>		<b>0.02</b>
<b>Catchment 17</b>	B	2.11	.35	0.06
	Variable	0.00	.10	0.00
		<b>2.11</b>		<b>0.06</b>

### 3.5 Land Use

The project study area contains a stormwater sewer system that includes ten Town-owned outfalls. Residential parcels vary in density from medium density (i.e., 1/4 to 1 acre lots) to medium-high density (i.e., 1/8 to 1/4 acre lots). There is a significant amount of open space in the study area primarily classified by RIGIS as deciduous forest.

### 3.6 Environmental Constraints

#### 3.6.1 Wetlands, Habitat and Cultural Resources

There are three historical candidate sites located within the project. Two of these areas, which are identified in RIGIS's database, are shown in *Figure 4*. The third area is not available in any publically available mapping due to the sensitivity of the resource area. The most northerly historic candidate location is Pettaquamscutt Rock. The more southerly historic candidate location is labeled as Kymbolde in RIGIS's database. Emergent and forested wetlands and uplands are also shown in *Figure 4*.

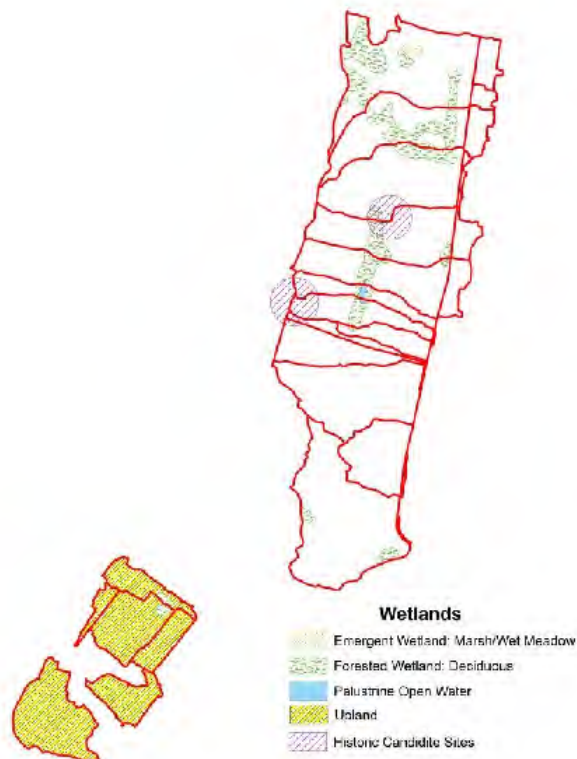


Figure 4—Wetland, Habitat and Cultural

### 3.6.2 Soils and Groundwater

The 17 drainage areas and 30 Catchments shown in *Appendix A* and *Appendix B* are underlain by soils of the hydrologic soil groups (HSG) A, B, and C. The majority of the watershed is underlain by HSG type B and C soils. There are pockets of HSG A soils along the east side of Middlebridge Road nearest to Pettaquamscutt River.

*Figure 5* and *Figure 6*, below, display hydrologic soil types and depth to groundwater where known within the project area. The red outlines are Catchment delineations. Enlarged soils mapping for each Catchment have been included in *Appendix C*.

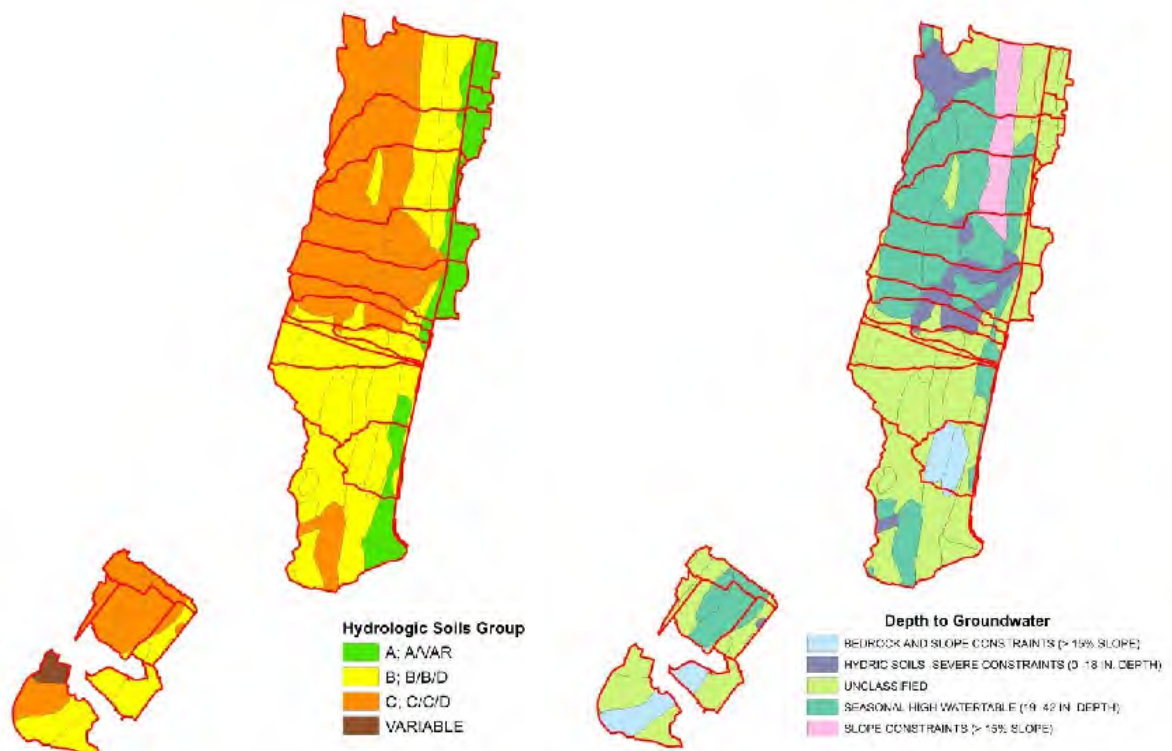


Figure 5—Hydrologic Soil Group

Figure 6—Depth to Groundwater

### 3.6.3 Topography

The topography of the study area slopes from west to east, finally terminating at the Pettaquamscutt River. In general, the land is sloped greatly between Tower Hill Road and Middlebridge Road and gently sloped from Middlebridge Road extending to the Pettaquamscutt River. Narragansett Avenue East generally slopes from West to East as well. Two-foot contours are included as part of the base mapping and can be viewed in *Appendix A* and *Appendix B*.

## 4 Alternatives Analysis

### 4.1 Design Criteria

Installation of structural BMPs requires adherence to certain design standards, regulatory standards, management of existing structures, and management of hydrologic feasibility. For purposes of engineering BMPs, these issues can be translated into design criteria, which can be used to narrow BMP alternatives. This section discusses the design criteria for our alternatives analysis.

We considered the following issues as part of selecting BMPs for analysis: and design criteria as part of selecting BMP alternatives:

#### *Pathogen Reduction, Nutrient Reduction and Groundwater Recharge*

The primary goal of this project is to reduce pathogens in stormwater runoff to the Pettaquamscutt River. Generally, stormwater BMPs accomplish such reduction through filtering mechanisms or more ideally infiltration to groundwater, which provides both filtering and a groundwater recharge benefit. Where possible vegetative treatment, such as may be incorporated through bioretention, should be included to achieve nutrient reduction, which is a goal for CRMC under the Narrow River SAMP. We also consider groundwater recharge as a secondary goal since it is a requirement of the *Rhode Island Stormwater Design and Installation Standards Manual* (RISDISM).

#### *Avoid Disturbance of Subsurface Utilities and Interference with Existing Uses*

The study area is largely developed for residential use with subsurface utilities (e.g., sewer, water, and natural gas), which should be left undisturbed to the extent practicable. Installation of BMPs should only occur on publically owned lands.

#### *Stormwater Collection and Discharge*

For a BMP to be cost-beneficial it must be practicable to collect runoff for treatment. After treatment, there must be a practicable method of water discharge. Infiltration requires certain separation to groundwater and must avoid bedrock or impermeable subsurface layers. Filtration requires discharge to surface water or reconnection to a drainage system.

#### *Other Issues of Regulatory Feasibility*

BMPs must be designed and maintained in accordance with the RISDISM.

We also consider additional issues of feasibility such as cost of implementation, operation and maintenance issues. The following summarizes key design criteria:

- Maximize water quality treatment capacity with infiltration and vegetative treatment.
- Reduced BMP footprint to maximize treatment benefit and minimize disturbance of existing uses.
- Treat runoff and pollution as close to the source as possible
- Avoid BMP installation beyond the public rights-of-way.

- Limit potential disturbance of sewer, water, gas and, electric utility lines.
- Hydrologic feasibility of collecting flow at proposed BMP inflows.
- Maintain appropriate separation of BMP discharge to groundwater and bedrock.
- Feasibility of connecting BMP discharges to existing storm drain network.
- Permitting and design standards in the RISDISM.
- Ensure appropriate slope for installation of proposed retrofits.
- Implementation costs.
- Operation and maintenance.

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## 4.2 Candidate Alternatives

### 4.2.1 Treatment BMPs

Candidate BMPs are discussed and analyzed in the following sections. The BMPs that are considered below were selected for their feasibility and their capacity to remove pathogens. The following sections briefly discuss each BMP alternative that was considered as a candidate for this study.

#### 4.2.1.1 Bioretention Basins

Bioretention basins are constructed depressions that treat stormwater runoff and attenuate peak flows (*Figure 7*). Water is directed into the basin where it filters through multiple layers of soils and gravel that in combination offer physical, chemical, and biological treatment.

Bioretention is typically composed of several elements. A grass buffer strip is used to slow runoff, remove TSS and direct water into the basin. Basins are typically vegetated with various plant species, appropriately selected for either upland or wetland environments, to remove excess nutrients and further process the water.

The upper most layer of a bioretention media is typically an organic layer composed of compost, loam, or mulch. This helps capture bacteria, particulates and other pollutants that adhere to particulates. A layer of highly pervious engineered soil media underlies the organic layer. The engineered soil supports the vegetative growth above and allows for nutrient uptake via filtration and absorption and facilitates absorption of nutrients, hydrocarbons, and heavy metals.

The layer beneath the engineered soil consists of a sand bed that further filters pollutants. The sand layer is underlain by pea gravel and sometimes an underdrain to allow for treatment and discharge of treated effluent. In cases where there are HSG type A and B soils in situ, bioretention basins are usually designed to infiltrate; however, if depth to groundwater is shallow or there are poor hydrologic soils, an underdrain system may be used.

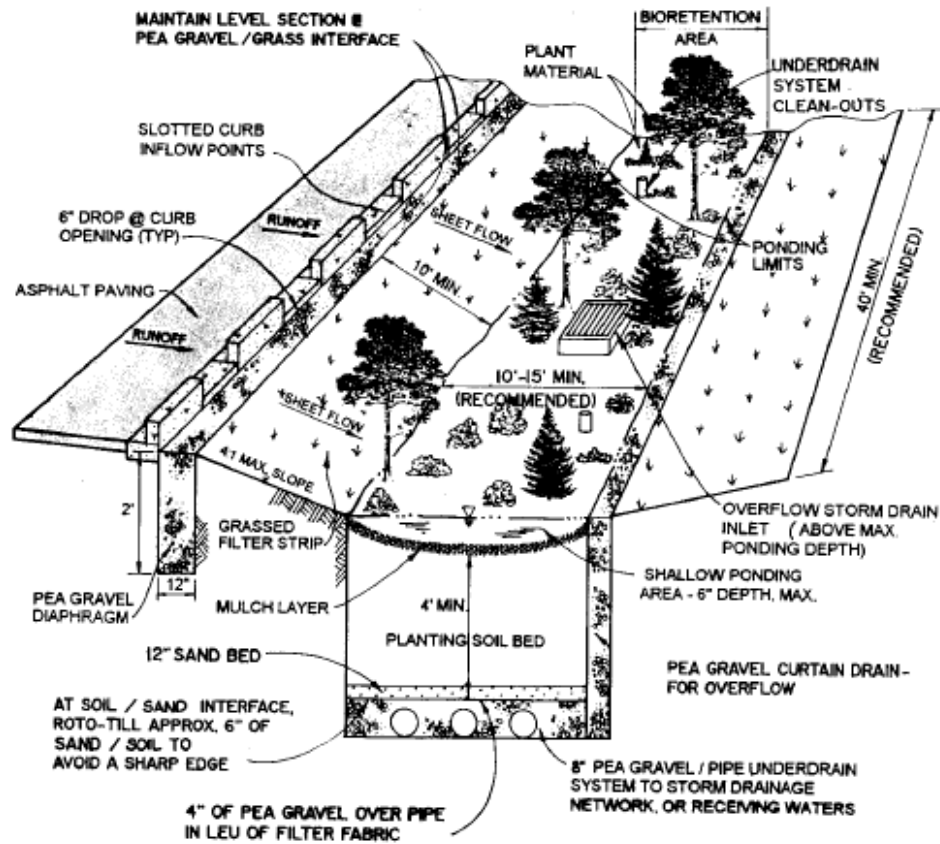


Figure 7—Schematic of a Bioretention System (GSMM , 2001)

Infiltrating bioretention basins work most effectively in hydrologic soil types A and B that have a clay content of less than 20%. Typically, a filter strip or sediment forebay is required as pretreatment for 25% of the water quality volume. A planting plan is required to ensure proper vegetation type and density for the local climate.

Bioretention maintenance is relatively intensive in comparison to the other candidate BMPs. Sediment must be cleaned out of the sediment forebay when:

- It reaches a depth of 12 inches.
- Drawdown within the forebay exceeds 36 hours.

Sediment must be removed from the bioretention area when:

- It accumulates to a depth of 1 inch or more.
- Filtering capacity diminishes such that water ponds for more than 48 hours after a storm event.

The vegetation within the bioretention area must be pruned and trimmed so that the vegetation does not exceed 18 inches. Trash and debris must be removed from the bioretention basin and sediment forebay during every inspection. During the first six months after implementation, inspection should occur after at least the first two precipitation events during which more than an inch of rain falls. Thereafter, inspections should occur once annually and after every storm event greater than or equal to the 1-year, 24-hour Type III precipitation event.

It is important to note that bioretention features are designed to dewater within 48 hours. This limits the opportunity for mosquitoes to breed and mature. Mosquito larvae need several days to mature according to RIDEM (<http://www.dem.ri.gov/programs/agriculture/mosquito.php>). As long as bioretention features dewater properly and are properly inspected and maintained they should not become mosquito breeding areas.

#### 4.2.1.2 *Bioswales and Linear Bioretention*

Bioswales are vegetated channels that collect, convey, filter and infiltrate stormwater. Another common name for bioswales is “linear bioretention.” Bioswales both decrease peak runoff rates and treat stormwater by filtering and removing pollutants and other harmful constituents. A photograph of a bioswale with check dam is shown in *Figure 8*.



Water collects in the bioswale trench that acts as storage before the water is infiltrated. As water moves through the bioswale, the vegetation reduces the velocity, delays peak runoff, and filters suspended particles. As the water infiltrates to the ground, microbes in the soil provide organic digestion of harmful nutrient pollutants.

If the *in-situ* soil does not support infiltration, an underdrain can be installed so that the treated water is collected and carried offsite. If the BMP installation site is very steep, check dams can be installed within the bioswale to further reduce velocity and allow pooling at various steps within the bioswale.

Bioswales are very similar to bioretention basins in that they both reduce peak flow rates and filter sediment and pollutants out of storm water. Bioswales also have the same maintenance requirements to bioretention basins. See *Section 4.2.1.1* for maintenance requirements.

### 4.2.1.3 Subsurface Infiltration

Subsurface infiltration structures are underground systems that infiltrate captured runoff into groundwater through *in situ* soils. There are three common types of subsurface infiltration BMPs that are constructed with combinations of crushed stone, natural soils and a manufactured system.

- Infiltration pits/trench—perforated, stone-filled, pre-cast concrete or plastic barrel structures that are buried so that entering water is encouraged to infiltrate into the soil; or lined trenches that are filled with stone that encourage entering water to infiltrate into the adjacent soil.
- Infiltration chambers—high-density polyethylene (HDPE) arched chambers that sit below the ground surface over a bed of stone. The chambers have open or perforated bottoms to encourage infiltration. These chambers are typically connected to storm drain system or stand-alone catch basins.
- Modular storage units—cellular blocks or “crates” that are stacked below grade to provide storage for runoff while encouraging infiltration to the surrounding soils.

All infiltrating systems must be underlain by appropriate soils as per the design standards of the infiltration product. Generally soils of hydrologic soil group A and B are accepted. Infiltration to groundwater in all subsurface infiltration systems should be designed to infiltrate in no more than 48 hours.

As per the RISDISM, a pretreatment device must be provided to ensure the long-term integrity of the infiltration system that is, at minimum, 25% of the water quality volume. This can be done by implementing a grass channel, filter strip, sediment fore bay, deep sump catch basin with upper sand layer or washed pea gravel, or a proprietary device.

#### **Infiltration Pits/Trenches**

Infiltration trenches are very adaptable and the availability of many practical configurations makes them ideal for small urban drainage areas (*Figure 9*). They are most effective and have a longer life cycle when some form of pretreatment is included in their design. Pretreatment may include techniques like vegetated filter strips or grass swales. Maintenance practices include removing debris and sediment from the stone and replacing the stone if it becomes clogged.

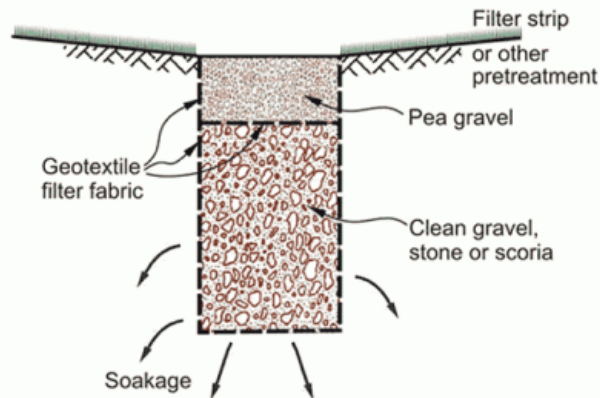


Figure 9—Schematic of an Infiltration Trench (RiverSides 2009)

### Infiltration Chambers

Infiltration chambers allow for storage of runoff and release of stored runoff to the groundwater at a predefined rate. Infiltration chambers are good for areas where there is not sufficient surface space for other structural BMPs as they can be placed under roadways and can be connected to existing storm drain systems or can be implemented in areas without existing storm drain networks. Maintenance for infiltration chambers is limited and involves regular maintenance of connected catch basins and monitoring of inspection ports. If during inspection port observation, water is observed in the infiltration chambers after the allowed infiltration period (usually 48 hours) after a storm event, the chambers and underlying stone may need replacement. A variety of infiltration chamber products are available such as Cultec (*Figure 10*), Stormtech, and Stormceptor.



Figure 10—Schematic of Infiltration Chambers (Cultec, 2007)

### Modular Storage Units

There are a variety of modular stormwater storage unit products available. Most are made of stackable plastic crates that are wrapped in filter fabric and surrounded by stone or gravel. The modular units can be placed under traditional pavement where runoff enters the system through catch basins, or they can be placed under permeable surfaces (e.g. porous pavement, grass, gravel, etc.) where runoff enters the modular units directly from above. The modular storage systems serve as runoff storage (most systems are more than 95% void space) and encourage infiltration to the surrounding soils.

Modular storage units are suitable for application in many locations. They do not take up a large amount of surface area on the ground and can be installed underneath many different terrains. Maintenance requirements for most modular storage systems are minimal and include checking the system through the maintenance ports. If during inspection port observation, water is observed in modular storage system after the allowed infiltration period (usually 48 hours) after a storm event, the system may need replacement. A variety of modular storage products are available such as StormTank, RainStore (*Figure 11*), and RainTank.

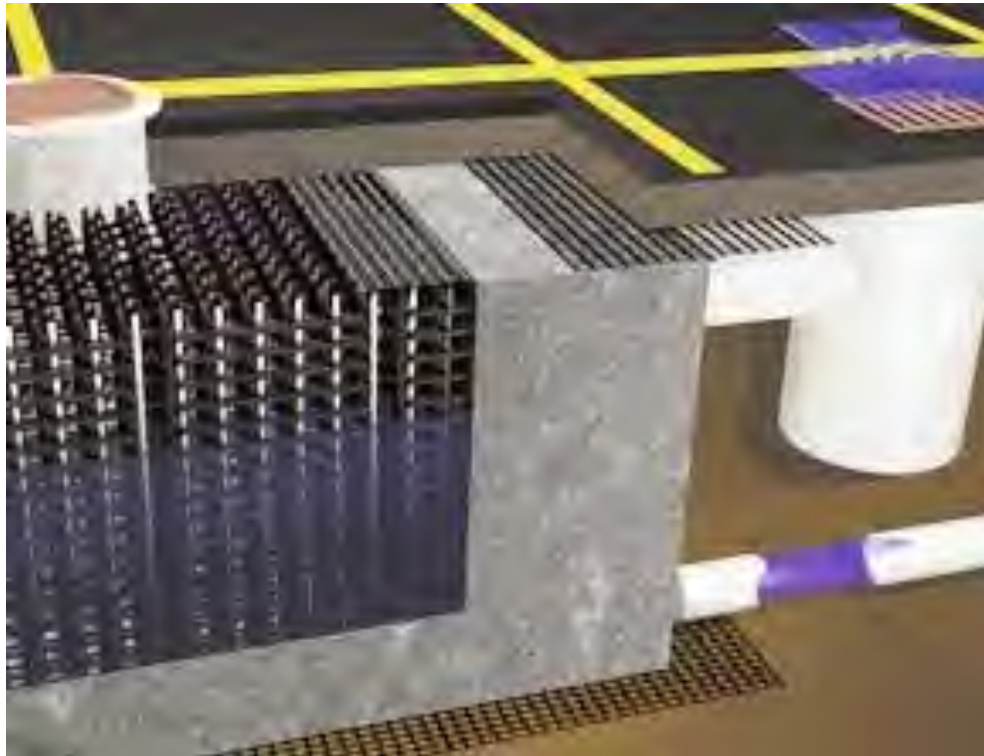


Figure 11—Schematic of a Modular Storage System (Invisible Structures , 2011)

#### 4.2.1.4 Disconnected Catch Basins

Conventionally, storm sewer networks employ catch basins to collect surface water runoff, skim floatables and settle larger sediment particles and convey runoff to drain pipes. Disconnected catch basins with proprietary infiltration units (referred to as disconnected catch basins) perform all these

functions except that there is not a connection to a pipe network (with the exception of an overflow pipe) and instead, infiltrate collected runoff through galleys, flow diffusers or proprietary infiltration units (e.g. infiltration chambers). Disconnected catch basins are commonly sized to capture the water quality volume. Once the disconnected catch basins fill, larger volumes simply bypass the system. Disconnected catch basins may also be designed as off-line BMPs.

Disconnected catch basins can be installed in any location where the soils are suited for infiltration. Maintenance procedures are very similar to that of traditional in-line catch basins and cleaning and inspection. Depending on the type of proprietary infiltration unit, maintenance requirements may differ.

#### 4.2.1.5 Qualifying Pervious Areas for Dead End Streets

The RISDISM defines qualifying pervious area (QPA) as “generally flat, natural or landscaped vegetated areas that are fully stabilized and where discharge from imperious areas may be directed via sheet flow.” QPA can be used as a low impact development (LID) practice if it meets the necessary design standards. These design standards primarily include, but are not limited to:

- QPA must not be underlain by D soils.
- QPA must not be underlain by compacted soils.
- QPA must not be underlain by bedrock.
- QPA must not be underlain by contaminated soils.
- QPA must have a seasonal high groundwater elevation of at least 18 inches below the land surface.
- QPA must have a slope less than or equal to 5.0%.
- QPA must be an area where vehicle operation is prohibited.
- QPA width may not be narrower than the width of the contributing drainage area.
- QPA must be greater than 6,000 square feet.
- QPA shall not be in a location where there is history of groundwater seepage and/or basement flooding.

A QPA can be considered a BMP in that it is a method of reducing direct discharge and pollutant loadings by recharging stormwater to the groundwater. QPA can enhance pollutant removal and can either act as a standalone BMP, or can be a polishing step for treatment. Erosion prevention techniques are usually implemented with QPAs in order to increase the lifespan of the QPA and promote sheet flow. Maintenance for QPA includes at least annual inspection to remove deposited sediment and address any ponding, erosion or diminishing vegetation.

This technical memorandum proposes application of QPAs for water quality treatment retrofit. Below is a proposed list of site conditions and modifications to proper function of QPA retrofits.

- Use a level spreader to encourage sheet flow onto the QPA.
- Install QPAs in HSG type A or B soil only.

- Till and vegetate the QPA to ensure vegetative cover in good condition with excellent infiltrative capacity.

QPAs of a given surface area should generally be considered to provide treatment of the water quality volume from an equally sized area of impervious surface.

## 4.2.2 Qualitative Assessment

*Table 6* summarizes the candidate stormwater BMPs and selection factors for implementation. Our assessment focuses on differentiating criteria for the project study area including vegetative treatment capacity, typical depth to groundwater required, relative cost of installation, land area per unit treatment, and operation and maintenance requirements. *Section 4.2.1* of this technical memorandum provides a more detailed discussion of each of the controls.

Information used to compile *Table 6* was gathered from a literature review including the RISDISM. “Cost of installation” is based on professional experience on similar projects and literature reviews. Operation and maintenance requirements are primarily based on the RISDISM, best professional judgment and experience with implementing stormwater controls.

**Table 6**  
**Stormwater Controls Considered For Implementation**

<b>Stormwater Controls</b>	<b>Vegetative Treatment Capacity</b>	<b>Typical Depth to Groundwater Required</b>	<b>Relative Cost of Installation</b>	<b>Land Area per Unit Treatment</b>	<b>Operation and Maintenance Requirements</b>
Bioretention Basins (infiltrating)	•	3 feet	Medium	Medium	Medium
Bioswales (infiltrating)	•	3 feet	Medium	Medium	Medium
Subsurface Infiltration		6 – 8 feet	High	Minimal	Low
Disconnected Catch Basins		6 – 8 feet	Low	Minimal	Low to Medium
QPA	•	< 1 foot	Low	Large	Low

Table 7 identifies the general benefits and limitations associated with the stormwater controls considered.

**Table 7  
Benefits and Disadvantages of Stormwater Controls by Type**

<b>Stormwater Control</b>	<b>Benefits</b>	<b>Disadvantages</b>
Bioretention	<ul style="list-style-type: none"> <li>• Provides groundwater recharge</li> <li>• Capable of treating multiple pollutants of concern</li> <li>• Provides vegetative treatment</li> <li>• Reduces peak flow velocity</li> </ul>	<ul style="list-style-type: none"> <li>• May result in standing water for 24 hours after a storm</li> <li>• More intensive maintenance needs than other candidate BMPs</li> </ul>
Bioswales		
Subsurface Infiltration	<ul style="list-style-type: none"> <li>• Provides groundwater recharge</li> <li>• Appropriate for installation directly adjacent to parking lots or other impervious surfaces</li> <li>• Appropriate in locations where surface space is not available for BMP installation</li> </ul>	<ul style="list-style-type: none"> <li>• Relatively expensive</li> <li>• Although maintenance is minimal, if clogging occurs the entire system may need to be replaced</li> </ul>
Disconnected Catch Basins	<ul style="list-style-type: none"> <li>• Provides groundwater recharge</li> <li>• Low cost per unit of treatment</li> <li>• Especially suitable retrofit for roads and parking lots</li> <li>• Relatively easy to repair/replace</li> </ul>	<ul style="list-style-type: none"> <li>• Susceptible to clogging by sediment</li> </ul>
QPA	<ul style="list-style-type: none"> <li>• Provides groundwater recharge</li> <li>• Low cost per unit of treatment</li> <li>• Provides vegetative treatment</li> </ul>	<ul style="list-style-type: none"> <li>• Susceptible to erosion</li> </ul>

Previous analysis of the study area indicates shallow depth to ground water, typically less than six feet. This essentially prohibits the use of disconnected catch basins and subsurface infiltration. QPAs generally require too great a land footprint to be practicable for the available areas in public ownership; however, in some cases QPAs may be appropriate at road ends that discharge to publically owned open spaces (e.g., east side of the study area near the river). Further analysis will focus on linear bioretention in roadways and QPAs in public owned areas at the end of streets where rights-of-way do not provide good opportunity for linear bioretention.

## **5 Analysis of Hydrology and Hydraulics**

For the purposes of this report, water quality volumes (WQVs) have been calculated for each of the 30 Catchments and are summarized below alongside groundwater recharge goals for comparison and context. We will conduct a full hydrologic and hydraulic assessment following the conceptual design

process and selection of BMPs for detailed design. The RISDISM provides the following equation for calculating WQV:

$$WQV = (1'') (i) / 12$$

WQV = water quality volume (acre-feet)

i = impervious area (acres)

Table 8 summarizes GRVs from Section 3.4 as well as WQVs. These calculations will be used to size conceptual BMPs in a later part of the design study.

**Table 8**  
**Groundwater Recharge Volume and Water Quality Volume by**  
**Catchment for the**  
**Pettaquamscutt River Study Area**

Catchment	Catchment and Hydrological Soil Group Areas	Groundwater Recharge Volume for Each Soil Group Area (Acre-Feet)	Water Quality Volume (Acre-Feet)
<b>Segment 4</b>			
Catchment 1W	A	1.11 x 10 <sup>-1</sup>	1.84 x 10 <sup>-1</sup>
	B	2.13 x 10 <sup>-2</sup>	6.08 x 10 <sup>-2</sup>
	C	2.92 x 10 <sup>-3</sup>	1.17 x 10 <sup>-2</sup>
	Combined	<b>1.35 x 10<sup>-1</sup></b>	<b>2.57 x 10<sup>-1</sup></b>
Catchment 1E	A	8.50 x 10 <sup>-3</sup>	1.42 x 10 <sup>-2</sup>
	B	5.83 x 10 <sup>-4</sup>	1.67 x 10 <sup>-3</sup>
	Combined	<b>9.08 x 10<sup>-3</sup></b>	<b>1.58 x 10<sup>-2</sup></b>
Catchment 2W	A	1.75 x 10 <sup>-2</sup>	2.92 x 10 <sup>-2</sup>
	B	2.13 x 10 <sup>-2</sup>	6.08 x 10 <sup>-2</sup>
	Combined	<b>3.88 x 10<sup>-2</sup></b>	<b>9.08 x 10<sup>-2</sup></b>
Catchment 2E	A	1.50 x 10 <sup>-3</sup>	2.50 x 10 <sup>-3</sup>
	B	8.75 x 10 <sup>-3</sup>	2.50 x 10 <sup>-2</sup>
	Combined	<b>1.03 x 10<sup>-2</sup></b>	<b>2.75 x 10<sup>-2</sup></b>
Catchment 3W	A	1.75 x 10 <sup>-2</sup>	2.92 x 10 <sup>-2</sup>
	B	2.98 x 10 <sup>-2</sup>	8.50 x 10 <sup>-2</sup>
	Combined	<b>4.73 x 10<sup>-2</sup></b>	<b>1.14 x 10<sup>-1</sup></b>
Catchment 3E	B	4.38 x 10 <sup>-3</sup>	1.25 x 10 <sup>-2</sup>
	Combined	<b>4.38 x 10<sup>-3</sup></b>	<b>1.25 x 10<sup>-2</sup></b>
Catchment 4S	B	5.05 x 10 <sup>-2</sup>	1.44 x 10 <sup>-1</sup>
	C	2.08 x 10 <sup>-4</sup>	8.33 x 10 <sup>-4</sup>
	Combined	<b>5.07 x 10<sup>-2</sup></b>	<b>1.45 x 10<sup>-1</sup></b>
Catchment 4N	B	3.68 x 10 <sup>-2</sup>	1.05 x 10 <sup>-1</sup>
	C	2.08 x 10 <sup>-4</sup>	8.33 x 10 <sup>-4</sup>

Catchment	Catchment and Hydrological Soil Group Areas	Groundwater Recharge Volume for Each Soil Group Area (Acre-Feet)	Water Quality Volume (Acre-Feet)
	Combined	<b>3.70 x 10<sup>-2</sup></b>	<b>1.06 x 10<sup>-1</sup></b>
Catchment 5SW	A	3.00 x 10 <sup>-3</sup>	5.00 x 10 <sup>-3</sup>
	B	2.48 x 10 <sup>-2</sup>	7.08 x 10 <sup>-2</sup>
	C	1.46 x 10 <sup>-3</sup>	5.83 x 10 <sup>-3</sup>
	Combined	<b>2.93 x 10<sup>-2</sup></b>	<b>8.17 x 10<sup>-2</sup></b>
Catchment 5NW	A	8.50 x 10 <sup>-3</sup>	1.42 x 10 <sup>-2</sup>
	B	1.11 x 10 <sup>-2</sup>	3.17 x 10 <sup>-2</sup>
	C	8.33 x 10 <sup>-3</sup>	3.33 x 10 <sup>-2</sup>
	Combined	<b>2.79 x 10<sup>-2</sup></b>	<b>7.83 x 10<sup>-2</sup></b>
Catchment 5SE	A	2.00 x 10 <sup>-3</sup>	3.33 x 10 <sup>-3</sup>
	Combined	<b>2.00 x 10<sup>-3</sup></b>	<b>3.33 x 10<sup>-3</sup></b>
Catchment 5NE	A	3.50 x 10 <sup>-3</sup>	5.83 x 10 <sup>-3</sup>
	Combined	<b>3.50 x 10<sup>-3</sup></b>	<b>5.83 x 10<sup>-3</sup></b>
<b>Segment 3</b>			
Catchment 6SW	A	1.35 x 10 <sup>-2</sup>	2.25 x 10 <sup>-2</sup>
	B	8.17 x 10 <sup>-3</sup>	2.33 x 10 <sup>-2</sup>
	C	6.04 x 10 <sup>-3</sup>	2.42 x 10 <sup>-2</sup>
	Combined	<b>2.77 x 10<sup>-2</sup></b>	<b>7.00 x 10<sup>-2</sup></b>
Catchment 6NW	A	1.95 x 10 <sup>-2</sup>	3.25 x 10 <sup>-2</sup>
	B	1.75 x 10 <sup>-3</sup>	5.00 x 10 <sup>-3</sup>
	C	9.17 x 10 <sup>-3</sup>	3.67 x 10 <sup>-2</sup>
	Combined	<b>3.04 x 10<sup>-2</sup></b>	<b>7.42 x 10<sup>-2</sup></b>
Catchment 6E	A	1.12 x 10 <sup>-1</sup>	1.87 x 10 <sup>-1</sup>
	Combined	<b>1.12 x 10<sup>-1</sup></b>	<b>1.87 x 10<sup>-1</sup></b>
Catchment 7W	A	1.80 x 10 <sup>-2</sup>	3.00 x 10 <sup>-2</sup>
	B	6.71 x 10 <sup>-3</sup>	1.92 x 10 <sup>-2</sup>
	C	4.79 x 10 <sup>-3</sup>	1.92 x 10 <sup>-2</sup>
	Combined	<b>2.95 x 10<sup>-2</sup></b>	<b>6.75 x 10<sup>-2</sup></b>
Catchment 7E	A	8.40 x 10 <sup>-2</sup>	1.40 x 10 <sup>-1</sup>
	Combined	<b>8.40 x 10<sup>-2</sup></b>	<b>1.40 x 10<sup>-1</sup></b>
Catchment 8W	A	2.05 x 10 <sup>-2</sup>	3.42 x 10 <sup>-2</sup>
	B	1.63 x 10 <sup>-2</sup>	4.67 x 10 <sup>-2</sup>
	C	2.08 x 10 <sup>-3</sup>	8.33 x 10 <sup>-2</sup>
	Combined	<b>3.89 x 10<sup>-2</sup></b>	<b>8.83 x 10<sup>-2</sup></b>
Catchment 8E	A	3.20 x 10 <sup>-2</sup>	5.33 x 10 <sup>-2</sup>
	Combined	<b>3.20 x 10<sup>-2</sup></b>	<b>5.33 x 10<sup>-2</sup></b>
Catchment 9W	A	1.30 x 10 <sup>-2</sup>	2.17 x 10 <sup>-2</sup>

Catchment	Catchment and Hydrological Soil Group Areas	Groundwater Recharge Volume for Each Soil Group Area (Acre-Feet)	Water Quality Volume (Acre-Feet)
	B	$2.04 \times 10^{-2}$	$5.83 \times 10^{-2}$
	C	$2.15 \times 10^{-2}$	$8.58 \times 10^{-2}$
	Combined	<b><math>5.49 \times 10^{-2}</math></b>	<b><math>1.66 \times 10^{-1}</math></b>
Catchment 9E	A	$1.02 \times 10^{-1}$	$1.70 \times 10^{-1}$
	Combined	<b><math>1.02 \times 10^{-1}</math></b>	<b><math>1.70 \times 10^{-1}</math></b>
Catchment 10W	A	$2.85 \times 10^{-2}$	$4.75 \times 10^{-2}$
	B	$3.50 \times 10^{-2}$	$1.00 \times 10^{-1}$
	C	$2.69 \times 10^{-2}$	$1.08 \times 10^{-1}$
	Combined	<b><math>9.04 \times 10^{-2}</math></b>	<b><math>2.56 \times 10^{-1}</math></b>
Catchment 10E	A	$4.70 \times 10^{-2}$	$7.83 \times 10^{-2}$
	Combined	<b><math>4.70 \times 10^{-2}</math></b>	<b><math>7.83 \times 10^{-2}</math></b>
Catchment 11	A	$9.40 \times 10^{-2}$	$1.57 \times 10^{-1}$
	B	$0.00 \times 10^{-1}$	$0.00 \times 10^{-1}$
	Combined	<b><math>9.40 \times 10^{-1}</math></b>	<b><math>1.57 \times 10^{-1}</math></b>
<b>Mumford Brook</b>			
Catchment 12	B	$7.79 \times 10^{-2}$	$2.22 \times 10^{-1}$
	C	$2.72 \times 10^{-2}$	$1.09 \times 10^{-1}$
	Variable	$1.08 \times 10^{-2}$	$1.08 \times 10^{-1}$
	Combined	<b><math>1.16 \times 10^{-1}</math></b>	<b><math>4.39 \times 10^{-1}</math></b>
<b>Segment 5</b>			
Catchment 13	B	$4.25 \times 10^{-3}$	$1.21 \times 10^{-2}$
	C	$5.03 \times 10^{-2}$	$2.01 \times 10^{-1}$
	Combined	<b><math>5.45 \times 10^{-2}</math></b>	<b><math>2.13 \times 10^{-1}</math></b>
Catchment 14	B	$4.40 \times 10^{-2}$	$1.26 \times 10^{-1}$
	C	$9.17 \times 10^{-3}$	$3.67 \times 10^{-2}$
	Combined	<b><math>5.32 \times 10^{-2}</math></b>	<b><math>1.62 \times 10^{-1}</math></b>
Catchment 15	B	$1.21 \times 10^{-1}$	$1.01 \times 10^{-2}$
	C	$3.24 \times 10^{-0}$	$2.70 \times 10^{-1}$
	Combined	<b><math>3.36 \times 10^{-0}</math></b>	<b><math>2.80 \times 10^{-1}</math></b>
Catchment 16	B	$2.13 \times 10^{-2}$	$8.50 \times 10^{-2}$
	Combined	<b><math>2.13 \times 10^{-2}</math></b>	<b><math>8.50 \times 10^{-2}</math></b>
Catchment 17	B	$6.14 \times 10^{-2}$	$1.75 \times 10^{-1}$
	Variable	$8.33 \times 10^{-7}$	$8.33 \times 10^{-6}$
	Combined	<b><math>6.14 \times 10^{-2}</math></b>	<b><math>1.75 \times 10^{-1}</math></b>

## 6 Selection of Preferred Alternatives for Each Catchment Based on Design Criteria

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### 6.1 Collection of Field Data

An initial site visit was conducted on April 3, 2013 to refine hydrologic delineations and identify suitable locations for proposed linear bioretention basins. *Appendix A* and *Appendix B* have been included at the end of this report to show base mapping of existing conditions and indicate seemingly appropriate BMP locations.

Test pits were conducted by Fuss & O'Neill on May 20 and 29, 2013. Test pit locations were chosen to best represent the array of possible BMP siting locations identified during the initial site visit. Seven test pits were excavated to a depth of 72 inches unless bedrock and/or groundwater was encountered in which excavation was halted. Test pits were excavated to dimensions of approximately eight feet by four feet.

While *Appendices A* and *B* include callouts in the location of preformed test pits as well as general information collected during the May 20<sup>th</sup> and 29<sup>th</sup> site visits, *Table 9* provides similar information within the body of this report.

It is important to note that archeological artifacts may be discovered during QPA and bioretention pre-design activities. As such, QPAs and bioretention BMPs may not be possible in all proposed locations should archeological artifacts be discovered.

**Table 9**  
**Data Collected from Test Pits Conducted on May 20, 2013 and May 29, 2013**

<b>Test Pit Number</b>	<b>Location</b>	<b>Depth</b>	<b>Infiltration Rate</b>	<b>Depth to SHGT<sup>4</sup></b>
TP-1	Torry Road	68"	No test performed due to bedrock encountered at 68" and the observation of standing water after infiltration complete	68"
TP-2	South of the Torry Road/Middlebridge Road intersection	74"	6"/Hour	>74" <sup>1</sup>
TP-3	South of the Kingstown Avenue/Middlebridge Road intersection	32"	No test performed due to groundwater	32"
TP-4	North of the River Avenue/Middlebridge Road intersection	66"	No test performed due to groundwater	52"
TP-5	North of the John Street/Middlebridge Road intersection	66"	No test performed due to groundwater	58"
TP-6	Not Conducted due to conflict with underground utilities	NA <sup>2</sup>	NA <sup>2</sup>	NA <sup>1</sup>
TP-7	At the intersection of Shadbush Trail and Riverside Drive	66"	8"/Hour	38"
TP-8	At the intersection of Pine Court and Middlebridge Road	72"	1"/Hour	>72" <sup>1</sup>
TP-9	Along Middlebridge Road between Pine Court and Torry Road	72"	Not selected for infiltration test	>72" <sup>1</sup>

Notes

<sup>1</sup> Neither mottling or groundwater encountered.

<sup>2</sup> NA means not applicable.

<sup>3</sup> Three locations selected for representative infiltration tests,

<sup>4</sup> SHGT – seasonal high groundwater table.

At three of the test pit locations infiltration tests were conducted. Infiltration tests were not conducted at the other locations due to the presence of bedrock or groundwater. Infiltration rates ranged from less than one half inch to eight inches per hour. Test pit locations, applicable depths to groundwater and bedrock, as well as infiltration rates where measured, are called out on the maps in *Appendix A* and *Appendix B*.

## 6.2 Conceptual Layouts and Typical Cross-Sections of Selected Alternatives

A conceptual layout of potential locations for linear bioretention was developed based upon existing data such as location of buried utilities, catchment delineations, and a site visit conducted to evaluate the feasibility of BMP placements within the public rights-of-way in the project area.

At a minimum, proposed linear bioretention basins have been sited in locations where an eight-foot width is available for construction. The significance of this eight-foot minimum allows for a basin with the following dimensions:

- A depth of one foot.
- Bottom width of two feet.
- Side slopes with a horizontal to vertical ration of 3:1.

Generally, as shown in *Figure 12*, we recommend a soil-media depth of 36 inches. If the presence of bedrock does not limit excavation and depth to groundwater is found to be sufficient to allow for imported soil media to be placed with the bottom of filter bed at or above groundwater, then linear bioretention basins will be designed as such. The RISDISM states that the *top* of filter bed material must be at least three feet above the seasonal high groundwater table. However, the RISDISM also allows for reduction of treatment media depth on a case-by-case basis:

“The depth of bioretention systems may be reduced to 12” on a case-by-case basis as demonstrated by the designer that 24” to 48” range is not feasible, such as sites with high groundwater or shallow depth to bedrock or clay soils, or in retrofit situations where pre-existing site constraints exist.”

(RIDEM, 2010)

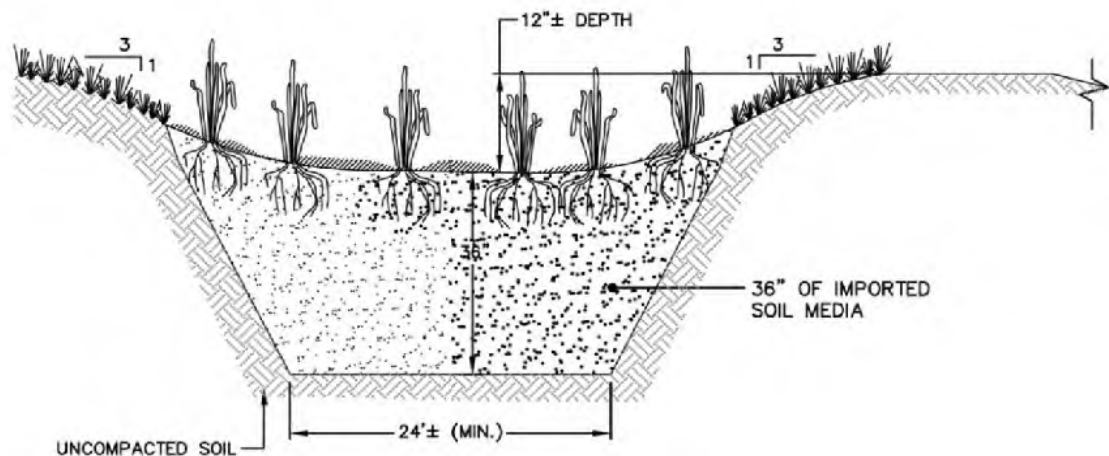


Figure 12—Conceptual Schematic of Linear Bioretention for the Study Area

## 6.3 Order-of-Magnitude Costs

Order of magnitude costs were developed for the construction of generalized linear bioretention basins in units of dollars per linear foot of basin and dollars per cubic foot of water storage (both above ground and within the basin's imported soil media). *Appendix D* includes these Order of Magnitude Opinion of Costs which are based upon 2013 dollars, and should be considered accurate to minus 30% or plus 50%. *Tables 10* and *11* summarize these costs.

**Table 10**  
**Order-of-Magnitude Construction Costs per**  
**Linear Foot of Bioretention**

<b>Cost Per Linear Foot of Bioretention</b>	
Total Cost Per Linear Foot (Rounded To Nearest \$1,000)	\$80.00
Upper Cost Range Limit (+50%)	\$110.00
Lower Cost Range Limit (-30%)	\$50.00

**Table 11**  
**Order-of-Magnitude Construction Costs for**  
**Linear Bioretention per Cubic Foot of Water Storage**

<b>Cost Per Cubic Foot of Water Storage</b>	
Total Cost Per Cubic Foot of Water Storage (Rounded To Nearest \$1,000)	\$14.00
Upper Cost Range Limit (+50%)	\$17.00
Lower Cost Range Limit (-30%)	\$4.90

A budgetary level opinion of cost will be developed for construction purposes once the Town has selected locations of BMPs to be developed through final design.

Costs of construction per linear foot of basin and per cubic foot of water storage were calculated by dividing the total estimated cost of construction for one example basin, Bioretention Basin 1 located in Catchment 1W, and then divided by the length and storage capacity of this basin respectively. A non-exhaustive list of the assumptions made when developing these opinions of cost, include the following:

- Clearing and grubbing will be limited to brush and not trees.
- Excavation will only occur within unpaved roadway shoulder.
- Imported soil media will be installed to a depth of three feet.
- The depth, bottom width, and side slope definitions described in *section 6.2* will be adhered to.
- \$15,000 was added to the cost of a linear bioretention system proposed within Catchment 12 to accommodate the construction of an overflow structure.

Economies of scale are not reflected in our order of magnitude opinions-of-cost; however, it would be logical to assume that larger individual systems will be more cost beneficial than multiple smaller systems. Therefore, we recommend selection of larger systems where practicable.

## 6.4 Pollution Reduction Benefit of Bioswales

Potential bacteria load reductions for bioswale areas were calculated based on estimated load reductions attributed to filter systems as presented in Appendix H of the RISDISM. Table H-3 of the RISDISM states that bioretention filters have a medium pollutant removal efficiency of 70% for bacteria; however, this efficiency is applicable only to those water quality BMPs meeting Minimum Standard 3. Minimum Standard 3 requires that 75% of the water quality volume for of any retrofitted catchment be treated by an approved BMP.

Due to the limitations of publically owned land in of the study area (primarily within roadway right-of-ways), treatment of the entire water quality volume appears to be unattainable for many of the catchments in the study area . Therefore the pollutant removal efficiency for bioretention basins within each of these catchments has been reduced according to the percentage of the water quality volume treated. Calculations are provided in *Appendix E*. Simply put, we anticipate that the greatest bacteria reductions can be achieved where linear bioretention treatment capacity most closely approximates the WQV. *Table 12* below breaks down the cost of linear bioretention per catchment based upon several parameters.

Land use was an important variable in the calculation of existing pollutant loadings to individual Catchments. *Figure 13* below identifies general categories of land use within the project area. Generally speaking, town, state and federally owned properties within the project area are limited to roadways and their associated right-of-ways.

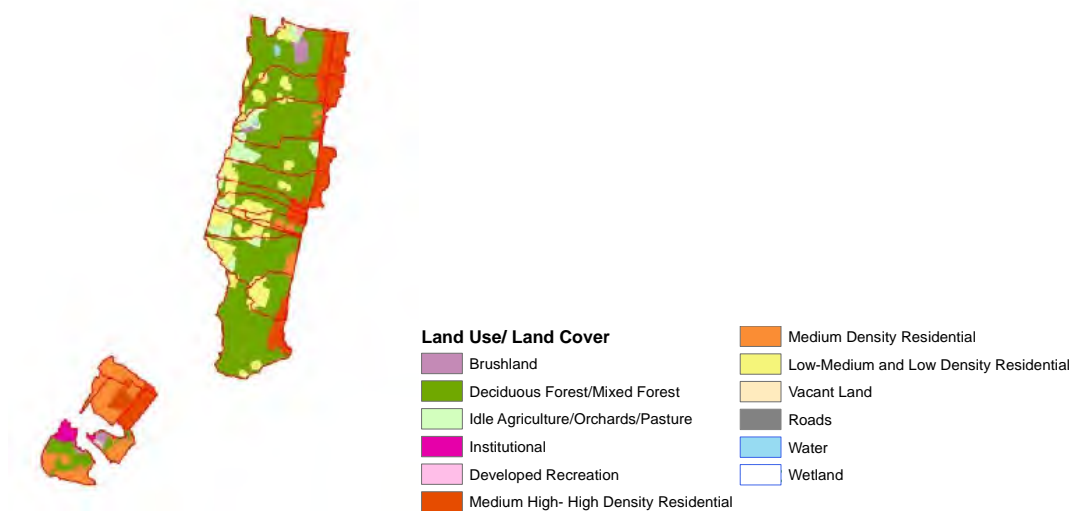


Figure 13 —Land Use

**Table 12**  
**Anticipated Load Reduction of Linear Bioretention and Cost per Unit of Pollution Reduction**

Catchment	Number of Individual Systems	Total Potential Length of Bioretention (feet)	Order-of-Magnitude Cost	Anticipated Load Reduction (billion colonies)	Cost per Unit Reduction (\$/billion colonies reduced)
<b>Segment 4</b>					
Catchment 1W	1	150	\$12,000	21.48	\$559
Catchment 1E	1	95	\$7,600	39.53	\$192
Catchment 2W	3	530	\$42,400	164.55	\$258
Catchment 2E	3	430	\$34,400	60.70	\$567
Catchment 3W	2	580	\$46,400	1.41	\$33,008
Catchment 3E	0	0	\$0	0.00	NA
Catchment 4S	1	750	\$60,000	174.73	\$343
Catchment 4N	1	225	\$18,000	72.73	\$247
Catchment 5SW	0	0	\$0	0.00	NA
Catchment 5NW	0	0	\$0	0.00	NA
Catchment 5SE	0	0	\$0	0.00	NA
Catchment 5NE	1	125	\$10,000	0.62	\$16,157
<b>Segment 3</b>					
Catchment 6SW	0	0	\$0	0.00	NA
Catchment 6NW	2	770	\$61,600	100.13	\$615
Catchment 6E	1	135	\$10,800	59.68	\$181
Catchment 7W	4	490	\$39,200	44.69	\$877
Catchment 7E	3	325	\$26,000	139.50	\$186
Catchment 8W	3	465	\$37,200	64.31	\$578
Catchment 8E	1	80	\$6,400	33.08	\$193
Catchment 9W	4	460	\$36,800	90.69	\$406
Catchment 9E	3	235	\$18,800	100.63	\$187
Catchment 10W	4	355	\$28,400	55.67	\$510
Catchment 10E	2	80	\$6,400	34.15	\$187
Catchment 11	5	320	\$25,600	141.15	\$181
<b>Mumford Brook</b>					
Catchment 12	1	105	\$8,400	27.14	\$310

<b>Segment 5<sup>1</sup></b>					
<b>Catchment 13</b>	1	54 <sup>2</sup>	\$43,600	413.45	\$105
<b>Catchment 14</b>	1	60 <sup>2</sup>	\$15,200	141.13	\$108
<b>Catchment 15</b>	1	50 <sup>2</sup>	\$28,800	291.84	\$99
<b>Catchment 16</b>	1	30 <sup>2</sup>	\$18,800	151.87	\$124
<b>Catchment 17</b>	1	110 <sup>2</sup>	\$71,040	407.41	\$174
<b>TOTAL</b>	51	6705	\$725,800	2832.27	\$256

<sup>1</sup> cost estimate derived from linear bioretention cell equivalent

<sup>2</sup> length along longest axis of proposed bioretention cell

Table 13 breaks down costs of linear bioretention basins within each Catchment by road.

**Table 13**  
**Cost of Linear Bioretention in Catchments by Road**

<b>Subcatchment</b>	<b>Roads Planned for Installation</b>	<b>Order-of-Magnitude Cost</b>
<b>Segment 4</b>		
<b>Catchment 1W</b>	Middlebridge Road	\$12,000
<b>Catchment 1E</b>	Middlebridge Road	\$7,600
<b>Catchment 2W</b>	Middlebridge Road	\$5,600
	Pine Court	\$36,800
<b>Catchment 2E</b>	Middlebridge Road	\$34,400
<b>Catchment 3W</b>	Middlebridge Road	\$46,400
<b>Catchment 3E</b>	NA	\$0
<b>Catchment 4S</b>	Torry Road	\$60,000
<b>Catchment 4N</b>	Torry Road	\$18,000
<b>Catchment 5SW</b>	NA	\$0
<b>Catchment 5NW</b>	NA	\$0
<b>Catchment 5SE</b>	NA	\$0
<b>Catchment 5NE</b>	Middlebridge Road	\$10,000

<b>Segment 3</b>		
<b>Catchment 6SW</b>	NA	\$0
<b>Catchment 6NW</b>	Middlebridge Road	\$61,600
<b>Catchment 6E</b>	Middlebridge Road	\$10,800
<b>Catchment 7W</b>	Middlebridge Road	\$39,200
<b>Catchment 7E</b>	Middlebridge Road	\$26,000
<b>Catchment 8W</b>	Middlebridge Road	\$37,200
<b>Catchment 8E</b>	Middlebridge Road	\$6,400
<b>Catchment 9W</b>	Middlebridge Road	\$36,800
<b>Catchment 9E</b>	Riverside Drive	\$18,800
<b>Catchment 10W</b>	Middlebridge Road	\$28,400
<b>Catchment 10E</b>	Riverside Drive	\$6,400
<b>Catchment 11</b>	Middlebridge Road	\$12,800
	Riverside Drive	\$12,800
<b>Mumford Brook</b>		
<b>Catchment 12</b>	Narragansett Avenue East	\$20,400
<b>Segment 5</b>		
<b>Catchment 13</b>	Hillside Road	\$43,600.00
<b>Catchment 14</b>	Crest Avenue	\$15,200.00
<b>Catchment 15</b>	Summit Ave./Holland Drive	\$28,800.00
<b>Catchment 16</b>	Seaview Avenue	\$18,800.00
<b>Catchment 17</b>	Kimberley Drive	\$71,040.00
<b>TOTAL</b>		\$725,840.00

## 7 Source Reduction Survey

We conducted a source reduction survey of the South Kingstown portion of the Pettaquamscutt River Watershed, which focused on sources of bacteria. This section discusses our survey methods, findings, conclusions, and recommendations.

### 7.1 Methods

A source reduction survey was conducted for the study area that focused on the source of bacteria identified in the Pettaquamscutt TMDL on April 3, 2013. We collected photographs and compiled field notes which will be included in the final report for this project. Additionally, any public comments received from the informational public meeting yet to be held will also be included in the final report for this project. Survey included the following:

- Review of available databases such as RIGIS to identify potential sources.
- Review of the 2011 RIDEM Multispectral Orthophotography of Rhode Island to identify potential sources.
- Windshield survey of watershed to identify potential sources.
- Review of current maintenance practices to identify modifications that would reduce bacteria loadings.

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## 7.2 Findings

Below are our findings for the Pettaquamscutt River Source Reduction Survey.

### *Distinct sources of bacteria in the watershed*

No distinct sources of bacteria were observed in the project area during the site investigation on April 3, 2013.

### *Activities in the watershed that contribute to bacteria loadings*

No specific activities which contribute to bacteria loadings were observed in the project area during the site investigation on April 3, 2013.

### *Maintenance practices that can be modified to better address bacteria loadings*

Several catch basins were more than 50% filled with sediment and leaf debris at the time of the windshield survey on April 3, 2013. These included the following:

- Catch basin at the corner of Lafayette Avenue and Middlebridge Road
- Leaching catch basin north of Pine Street on Middlebridge Road
- Double catch basin on Middlebridge Road across from Cook Avenue
- Two catch basins at the intersection of Sherman Court and Middlebridge Road.

Roadside stormwater swales were also observed to have significant sediment, driveway culverts were found to be significantly clogged with leaf litter and the swales themselves showed a decline in water storage volume due to the collection of leaf litter.

### *Recommended actions in the watershed*

Recommended actions in the portion of the Pettaquamscutt River watershed located in South Kingstown include modifying maintenance practices relevant to cleaning stormwater infrastructure (i.e. catch basins and stormwater swales) more frequently.

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### 7.3 Source Reduction Survey Conclusions and Recommendations

It is recommended that the Town of South Kingstown continue their current inspection program of Town-owned catch basins, swales and other stormwater structures annually in the study area. These structures should be cleaned as needed based on inspection results.

Sedimentation from stormwater swales will need to be removed to reclaim volumetric capacity.

While no distinct sources of bacteria pollution were observed at the time of investigation there are several potential sources of bacteria pollution that may still be contributing to bacteria loading in the study area. Dog waste, waterfowl waste, leaking septic systems and leaking sewer lines can all contribute to bacteria loading. These potential sources should be kept in mind during implementation and if observed, additional measures may be needed to reduce bacteria loading.

## 8 Revisions to the Six Minimum Measures in South Kingstown's SWMPP

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### 8.1 Public Education and Outreach

Certain actions by the general public may have a direct and adverse effect on water quality (e.g., illicit dumping, illicit discharging, improper management of pet wastes, etc.). This SWMPP revision includes implementation of several general measures to address the pollutants of concern for the impaired waters identified above.

The Town's Storm Water Management Program Plan (SWMPP) provides detailed information on the public education and outreach measures that the Town has implemented. The Town will continue to work with the University of Rhode Island Cooperative Extension, Nonpoint Education for Municipal Officials (NEMO) as well as neighborhood associations and other local groups to incorporate public education and outreach materials into the Town's stormwater program. The Town has disseminated fact sheets to inform residents of recycling, electronic waste disposal, and BMPs for stormwater runoff quality (pet waste clean-up, use of fertilizers, car washing), employing NEMO-developed materials as appropriate. Materials have been posted on the Town stormwater webpage at:

<http://www.southkingstownri.com/town-government/municipal-departments/public-services/stormwater-management-soil-erosion-program>.

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### 8.2 Public Involvement and Participation

Studies show that stewardship messages alter behavior most effectively when delivered by peers. Public participation (i.e., volunteerism) will encourage behavior that will lead to better water quality in the river.

Individuals who help to deliver these messages tend to internalize them, which also results in behavior change.

The Town intends to maintain public involvement through Engineering, Planning, and Public Works Departments. Through coordination with local civic groups the Town will continue to maintain public participation and coordination on storm water management activities related to public participation, education, and outreach.

Several examples of public participation activities are listed in the Town's SWMPP. DEM, RIDOT, and URI are developing watershed protection programs through the Storm Water Outreach Program. Implementation of these programs will be tailored for use by the Town.

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### 8.3 Illicit Discharge Detection and Elimination

As previously noted, the Town has completed the required high- and low-groundwater dry-weather IDDE surveys and has reported the results to the RIPDES permitting program in the immediate future. Through dry-weather surveys, each outfall is inspected and sampled (if flowing), with flowing outfalls which discharge to the Pettaquamscutt River tested for the presence of bacteria. The Town has in place a stormwater management ordinance (chapter 20-1 through 20-49), which includes a provision prohibiting illicit discharges to the MS4. A copy of this ordinance was provided to DEM previously and is available on the web at:

<http://library.municode.com/index.aspx?clientId=14928&stateId=39&stateName=Rhode%20Island>.

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### 8.4 Construction Control

As zoned, the study area has largely been developed to capacity, and while new construction is unlikely, limited redevelopment within this area may occur in the future. The Town has completed the required elements pursuant to the construction control minimum measure, and the Town's SWMPP describes the construction site runoff control measures.

In addition to the Stormwater Management ordinance and a Construction Stormwater Control Ordinance (chapter 20-50 through chapter 20-74), the Town has in place a soil erosion and sediment control ordinance, which includes appropriate provisions for the installation and maintenance of construction-phase controls in accordance with the *Rhode Island Soil Erosion and Sediment Control Handbook*. The ordinance is available on the web at:

<http://library.municode.com/index.aspx?clientId=14928&stateId=39&stateName=Rhode%20Island>.

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### 8.5 Post Construction Control

The Town of South Kingstown's post-construction storm water management program is described in the SWMPP. The Town has not currently adopted a post-construction ordinance; however, the Town is working toward completing one.

At a minimum, applicants for development and redevelopment projects will be required to meet the standards set forth in the *2010 Rhode Island Stormwater Design and Installation Standards Manual* (including the recharge/runoff volume reduction standard). It is currently the policy of the Town to require upgrades for compliance with TMDL standards when redevelopment is proposed.

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## 8.6 Pollution Prevention and Good Housekeeping

The Town has completed the elements required pursuant to the pollution prevention/good housekeeping minimum measure. This includes implementation of regular catch basin cleaning. Any required repairs or modifications to storm water collection and conveyance systems identified through inspections are undertaken by the Town DPW, which will continue to perform such corrective measures as required. As noted in the RIPDES MS4 Annual Reports, the Town conducts street sweeping of its roads at least annually, including more frequent cleanings in certain areas (i.e., downtown streets). Inspections of facilities owned and operated by the Town are conducted on a regular basis; to date these inspections have been appropriate and effective in preventing pollution from potential sources from entering the municipal drainage systems.

In accordance with *Section 7*, it is recommended that the Town of South Kingstown continue their current inspection program of Town owned catch basins, swales and other stormwater structures annually in the study area. These structures should be cleaned as needed based on inspection results. Sedimentation from stormwater swales will need to be removed to reclaim volumetric capacity.

## 9 Implementation Strategy

This section contains a recommended implementation strategy including:

- Priorities and timelines.
- Recommendations and measurable goals for implementation.
- Funding options.
- Program evaluation and revisions to the stormwater management program.

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### 9.1 Priorities and Timeline

Continued implementation of the Stormwater Phase II GP will occur throughout the implementation period as needed or as scheduled for compliance purposes. The Town will develop a post-construction stormwater ordinance and introduce this for adoption as soon as practicable within the next year.

We recommend implementation of structural BMPs using the timeline shown in *Table 14*. *Table 14* is structured to front load the installation of BMPs with most favorable cost-benefit ratios by year of installation. We assume a five-year implementation period based on Town funding of approximately \$75,000 annually.

**Table 14**  
**Implementation Timeline Based on Cost-Benefit**

Catchment	Number of Individual Systems	Total Potential Length of Bioretention (feet)	Order-of-Magnitude Cost	Anticipated Load Reduction (billion colonies)	Cost per Unit Reduction (\$/billion colonies reduced)	Proposed Year of Installation and Cost
Catchment 6E	1	135	\$10,800	59.68	\$181	Year 1 \$87,600
Catchment 11	5	320	\$25,600	141.15	\$181	
Catchment 7E	3	325	\$26,000	139.50	\$186	
Catchment 9E	3	235	\$18,800	100.63	\$187	
Catchment 10E	2	80	\$6,400	34.15	\$187	
Catchment 1E	1	95	\$7,600	39.53	\$192	Year 2 \$74,400
Catchment 8E	1	80	\$6,400	33.08	\$193	
Catchment 4N	1	225	\$18,000	72.73	\$247	
Catchment 2W	3	530	\$42,400	164.55	\$258	
Catchment 4S	1	750	\$60,000	174.73	\$343	Year 3 \$96,800
Catchment 9W	4	460	\$36,800	90.69	\$406	
Catchment 10W	4	355	\$28,400	55.67	\$510	Year 4 \$112,000
Catchment 1W	1	150	\$12,000	21.48	\$559	
Catchment 2E	3	430	\$34,400	60.70	\$567	
Catchment 8W	3	465	\$37,200	64.31	\$578	
Catchment 6NW	2	770	\$61,600	100.13	\$615	Year 5 \$121,200
Catchment 12	1	105	\$20,400	27.14	\$752	
Catchment 7W	4	490	\$39,200	44.69	\$877	
<b>TOTAL</b>	43	6000	\$492,000	1,424.55	\$345	\$492,000

**Table 15**  
**Catchments where BMPs are not Being Recommended**

Catchment	Rationale for Recommending no BMPs
Catchment 3W	Poor cost-benefit (\$33,008/billion colonies reduced).
Catchment 3E	Right-of-way is obstructed with landscaping features such as ornamental plantings.
Catchment 5SW	Right-of-way is too narrow for installation. There is a physical structure (stone wall) on property owner side.

Catchment	Rationale for Recommending no BMPs
Catchment 5NW	There is an existing stormwater system that would need to be significantly restructured and would substantial reduce cost-benefit.
Catchment 5NE	Poor cost-benefit (\$16,157/billion colonies reduced).
Catchment 6SW	There is a large pine tree in the right-of-way. Also the area available is relatively small. Cost-benefit of installation would be poor.
Catchment 13-17	Catchments could potentially impact sensitive cultural areas and further investigation is needed to evaluate the extent of potential impacts and to better estimate overall cost

The Town also intends to install QPAs as opportunities arise at the locations identified in *Appendix A* and *Appendix B*. A written specification for the installation of QPAs is provided in *Appendix F*.

## 9.2 Recommendations and Measureable Goals for Implementation

The following table lists recommendations and measureable goals for implementation of the TMDL strategy for the Pettaquamscutt River.

**Table 16**  
**Recommendations and Measureable Goals for**  
**Implementation of the**  
**Pettaquamscutt River TMDL**

Recommendation	Measureable Goal
Obtain funding of approximately \$100,000 annually for five years (i.e., approximately \$500,000 total).	\$75,000 is being made available annually using a pay-as-you-go capital improvement approach through the general fund.
Draft and introduce a post-construction stormwater ordinance. Continue and codify current redevelopment policy requiring compliance with TMDLs.	Ordinance is introduced in the first year of implementation. Ordinance is adopted by Year 2.
Continue implementation of the Stormwater Phase II GP.	Compliance with the Stormwater Phase II GP.
BMPs are designed, permitted and installed in accordance with a three-year implementation period.	Installation of approximately \$75,000 per year and \$375,000 by Year 5.
Install QPAs at locations indicated in <i>Appendix A</i> and <i>Appendix B</i> and the narrative specifications in <i>Appendix F</i> of this plan as practicable.	Installation of QPAs by Year 3. Actual number will depend on staff availability.

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## 9.3 Funding Options

Stormwater management programs may call for a diversified funding approach including grants, loans, and local sources. This section discusses several funding options that may work well for the Town of South Kingstown.

### 9.3.1 Nonpoint Source Financial Assistance

Nonpoint source (NPS) pollution is a significant cause of water quality impairments in Rhode Island, and is considered a primary source of impairment. NPS grants are primarily intended to provide financial assistance to projects that will restore or improve water quality and enhance the designated uses of our waters—swimming, fishing, shellfishing, drinking water supply and healthy aquatic life. Under the NPS program, RIDEM gives highest priority to those proposals that effectively control or abate NPS impairments on the 303(d) list such as the Pettaquamscutt River. Proposals to implement recommendations associated with other watershed restoration plans are considered, providing the plans document the pollution sources in the watershed that are causing the impairment and comprehensively outline the steps needed to address the pollution sources.

Until recently, DEM also encouraged capital projects that strengthen local stormwater management programs including projects implementing a BMP identified through a DEM-approved stormwater management plan or focusing on the mitigation, control or elimination of illicit connections to storm sewers. EPA Headquarters has recently determined that stormwater management projects in the MS4 General Permit jurisdiction to be ineligible. DEM will consider funding aquatic habitat restoration projects that enhance water quality or support designated uses under federal 319 funding.

Grants offered under the Nonpoint Source Program have an in-kind matching requirement of 20 – 40%. Also, these grants are reimbursable, which means that project must be funded by the grantee initially and may then be reimbursed through a state invoicing process. Therefore, the Town will need to be prepared to front the full cost of nonpoint source grant projects.

In the fall of 2004, Rhode Island voters approved the Narragansett Bay and Watershed Restoration Bond Fund (BWRF) to promote restoration of waters degraded by NPS pollution. State funding for the 2004 BWRF has been expended; however, a new bond allocation of \$4 million was approved by statewide ballot in 2012. Grant applications for that funding are now expected to be released in 2014.

### 9.3.2 State Revolving Fund

The State Revolving Fund (SRF), co-managed by the R.I. Clean Water Finance Agency (RICWFA) and Office of Water Resources, provides below market rate loans for the construction and upgrade of wastewater collection systems and treatment facilities. In its 22-year history, Clean Water SRF has over 300 projects for a total of nearly \$900 million.

The purpose of this program is to provide financial assistance to local governmental units for water pollution abatement projects in the form of loans with below market interest rates or interest rate subsidies which reduce the cost of financing these projects by at least 33%. In order for a project to be eligible for funding, the project must be on DEM's Project Priority List (PPL) and have a Certificate of Approval from DEM. The PPL is updated on an annual basis. Since the inception of the Clean Water State Revolving Fund (CWSRF), loans have been made to various municipalities and the Narragansett Bay Commission (NBC).

SRF funds large infrastructure projects (i.e., projects over \$50,000) and is not typically appropriate for smaller projects. Projects must be backed by a general obligation bond or a dedicated revenue source capable of supporting loan payments.

### 9.3.3 Establishing a Fee System under the Rhode Island Stormwater Management Act

To enable municipalities to meet their stormwater management goals, the Rhode Island General Assembly passed the “Rhode Island Stormwater Management and Utilities District Act of 2002” (SWM Act). The SWM Act allows municipalities to establish a fee system to raise funds for administration and operation of the district. The SWM Act requires that the fee system is reasonable and equitable so that each contributor of runoff to the system shall pay to the extent to which runoff is contributed and the state shall be exempted from the fee system.

A number of Rhode Island communities are considering adoption of stormwater utilities—and have developed or are developing feasibility studies—no stormwater utilities currently operate in Rhode Island. The following table was compiled based on a search of web-available information on stormwater utility districts in other states. There are currently approximately 800 stormwater utility districts operating around the US. The table shows some common uses for stormwater utility districts and the implementation focus of seven communities in seven states.

**Table 17  
Features of Seven Stormwater Utility Districts**

	<b>Operation &amp; Maintenance</b>	<b>Capital Improvement (e.g., Retrofits)</b>	<b>Watershed Management &amp; TMDLs</b>	<b>Design Review</b>	<b>MS4 Storm Water General Permit</b>	<b>Technical Assistance</b>	<b>Demonstration Projects</b>	<b>Public Education</b>	<b>Flood Management</b>
Newton, MA	•	•						•	•
S. Burlington, VT	•	•		•	•	•			•
Alexandria, VA	•	•	•	•	•			•	•
Northeast, OH	•	•	•		•	•	•	•	•
Volusia County, FL	•	•		•					•
Peachtree City, GA	•	•							
Symrna, TN		•	•		•			•	•

The Town of South Kingstown has informally discussed the feasibility of instituting a stormwater utility. A stormwater utility does not currently have enough support for implementation and the Town is not planning to pursue it as a funding alternative at this time.

### 9.3.4 General Funds and Bonding

Two very commonly used approaches for funding stormwater management include use of proceeds from the general fund and local bonding. Although municipal general funds can be quite competitive, the Town of South Kingstown has committed to setting aside \$75,000 per year for stormwater infrastructure improvements to address TMDLs.

Many towns in Rhode Island are relatively financially healthy and can go to referendum for general obligation bond. Since South Kingstown has already committed funding through its general fund, bonding is not being pursued at this time. The Town may wish to consider using the local funds it has set aside to leverage state grants and loans (e.g., nonpoint source financial assistance and the state revolving fund).

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## **9.4 Program Evaluation and Revisions to the Storm Water Management Program**

Town will evaluate TMDL implementation in the Pettaquamscutt River Watershed on an annual basis. This will occur as part of annual reporting for the Stormwater Phase II GP. If needed, revisions to the Town's storm water management plan will be made as part of the annual evaluation.

## 10 References

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## Figures

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PROJ. No.: 20131360.A10  
 DATE: JULY 2013  
**CS-100**

TOWN OF SOUTH KINGSTOWN  
 CONCEPT INDEX PLAN  
 PETTAQUAMSCUTT (NARROW) RIVER  
 DRAINAGE CATCHMENT STUDY  
 SOUTH KINGSTOWN RHODE ISLAND



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 HORZ.: 1" = 250'  
 VERT.:  
 DATUM:  
 HORZ.:  
 VERT.:  
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PROJ. No.: 20131360.A10  
 DATE: JULY 2013  
**CS-100B**

TOWN OF SOUTH KINGSTOWN  
 CONCEPT INDEX PLAN 2  
 PETTAQUAMSCUTT (NARROW) RIVER  
 DRAINAGE CATCHMENT STUDY  
 SOUTH KINGSTOWN RHODE ISLAND



SCALE:  
 HORZ.: 1" = 250'  
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 GRAPHIC SCALE

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
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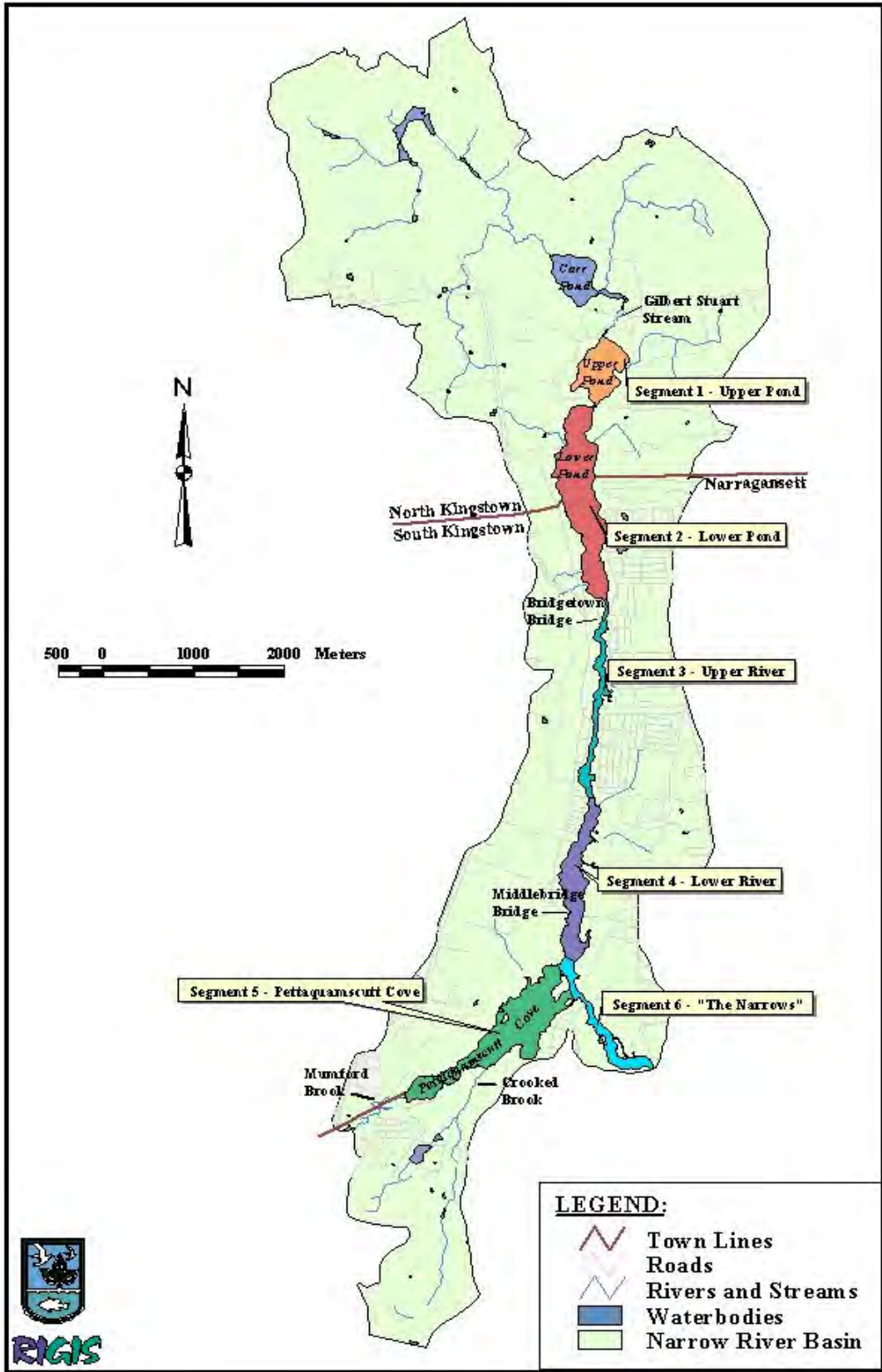


Figure 2 Narrow River Segments

## Appendix A

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### Conceptual BMP Layout Plans – With Aerials



File Path: J:\DWG\2013\20131360A10\Civil\Plan\20131360A10\_STP02.dwg Layout: CS-100 Plotted: Thu, July 07, 2016 - 4:13 PM User: rweiler  
 LMS VIEW: PLOTTER: DWG TO PDF.PC3 CTB File: FO.STB

PROJ. No.: 20131360.A10  
 DATE: JULY 2013  
**CS-100**

TOWN OF SOUTH KINGSTOWN  
 CONCEPT INDEX PLAN  
 PETTAQUAMSCUTT (NARROW) RIVER  
 DRAINAGE CATCHMENT STUDY  
 SOUTH KINGSTOWN RHODE ISLAND



SCALE:	HORZ.: 1" = 250'
	VERT.:
DATUM:	
	HORZ.:
	VERT.:
GRAPHIC SCALE	

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

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 PLOTTER: DWG TO PDF.PC3 CTB File: FO.STB  
 LAYER: STATE



PROJ. No.: 20131360.A10  
 DATE: JULY 2013  
**CS-100B**

TOWN OF SOUTH KINGSTOWN  
 CONCEPT INDEX PLAN 2  
 PETTAQUAMSCUTT (NARROW) RIVER  
 DRAINAGE CATCHMENT STUDY  
 SOUTH KINGSTOWN RHODE ISLAND



SCALE:	HORIZ.: 1" = 250'				
	VERT.:				
DATUM:	HORIZ.:				
	VERT.:				
250 125 0 250		GRAPHIC SCALE			
No.	1.	DATE	DESCRIPTION	DESIGNER	REVIEWER



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 Plotter: DWG TO PDF.pc3 CTB File: FD.STB  
 LAYER STATE:

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
		SEAL		
		SEAL		

1.				
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SCALE:	
HORZ.	
VERT.	
DATUM:	
HORZ.	
VERT.	
GRAPHIC SCALE	

**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'

NAD83  
NAVD88





CATCHMENT 2W

CATCHMENT 2E

File Path: J:\DWG\2012\1960\100\Plan\Plan.dwg  
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No.	DATE	DESCRIPTION
1.		

SEAL	SEAL

DESIGNER	REVIEWER	DESCRIPTION

SCALE	SCALE
HORIZ.: VERT.:	HORIZ.: VERT.:
DATUM:	DATUM:
HORIZ.: VERT.:	HORIZ.: VERT.:
GRAPHIC SCALE	GRAPHIC SCALE

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SCALE	SCALE
HORIZ.: VERT.:	HORIZ.: VERT.:
DATUM:	DATUM:
HORIZ.: VERT.:	HORIZ.: VERT.:
GRAPHIC SCALE	GRAPHIC SCALE

**LEGEND**

- Subcatchment
- Stormwater
- Cutfall
- Catchment
- Basin
- Culvert
- Potential
- Proximity



CATCHM

CATCHMENT 3W

CATCHMENT 3E

File Path: L:\DWG\312012\1360A\100\3120121360A.dwg  
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HORZ.: \_\_\_\_\_

VERT.: \_\_\_\_\_

DATUM: \_\_\_\_\_

HORZ.: \_\_\_\_\_

VERT.: \_\_\_\_\_

GRAPHIC SCALE

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**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'	30	30
NAD83		
NAV88		



File Path: L:\DWG\2012\1960\4100\DWG\3\F20121960.dwg  
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 Plot Date: 7/10/2016 4:18 PM  
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SCALE:	HORZ.:	VERT.:
DATUM:	HORZ.:	VERT.:
GRAPHIC SCALE		

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**LEGEND**

	SUBCATCHMENT DELINEATION	30
	STORMWATER PIPE	
	OUTFALL	
	CATCH BASIN	
	DRAIN MANHOLE	
	CULVERT	
	POTENTIAL BMP LOCATIONS	
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES	

1" = 30'	
NAD83	
NAVDB8	30



File Path: I:\V\DWG\2012\1960\4100\3\wallPlan.dwg  
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No.	DATE	DESCRIPTION	DESIGNER	REVIEWER	SEAL	SEAL								

SCALE:	HORZ.:	VERT.:
DATUM:	HORZ.:	VERT.:
GRAPHIC SCALE		

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**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- | OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- ▲ CULVERT
- ▨ POTENTIAL BMP LOCATIONS
- ▧ POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'
NAD83
NAV88



File Path: L:\DWG\2017\1967\410 - 3rd\Plan\2017\1967\10 - STP\02.dwg Layer: CS-106-Plots.ctb July 07, 2016 - 4:20 PM User: nveiler  
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DESIGNER	REVIEWER	SEAL	SEAL

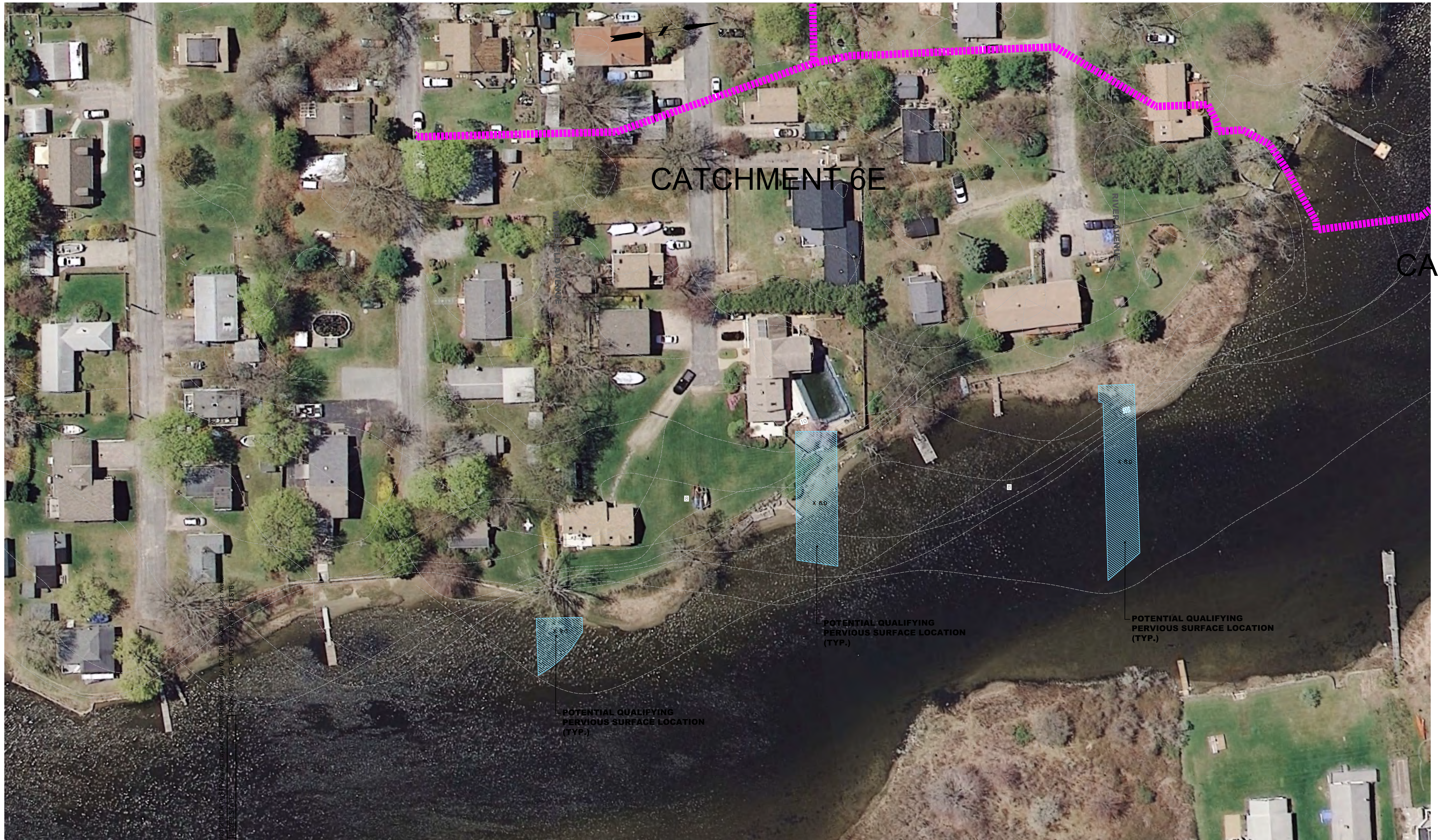
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HORIZ.: _____	
VERT.: _____	
DATUM: _____	
HORIZ.: _____	
VERT.: _____	
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GRAPHIC SCALE	


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**LEGEND**

-  SUBCATCHMENT DELINEATION
-  STORMWATER PIPE
-  OUTFALL
-  CATCH BASIN
-  DRAIN MANHOLE
-  CULVERT
-  POTENTIAL BMP LOCATIONS
-  POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'
NAD83
NAVD88
30



File Path: L:\DWG\2012\1980\100\1980.dwg  
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 Plot Scale: 1" = 30'  
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 Plot Device: HP DesignJet 560c  
 Plot Path: L:\DWG\2012\1980\100\1980.dwg

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No.	DATE	DESCRIPTION

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DESIGNER	REVIEWER
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SCALE:

HORZ.:	
VERT.:	

DATUM:

HORZ.:	
VERT.:	

GRAPHIC SCALE

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**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'

NAD83	30
NAV88	30



CATCHMENT 8W

CATCHMENT 8E









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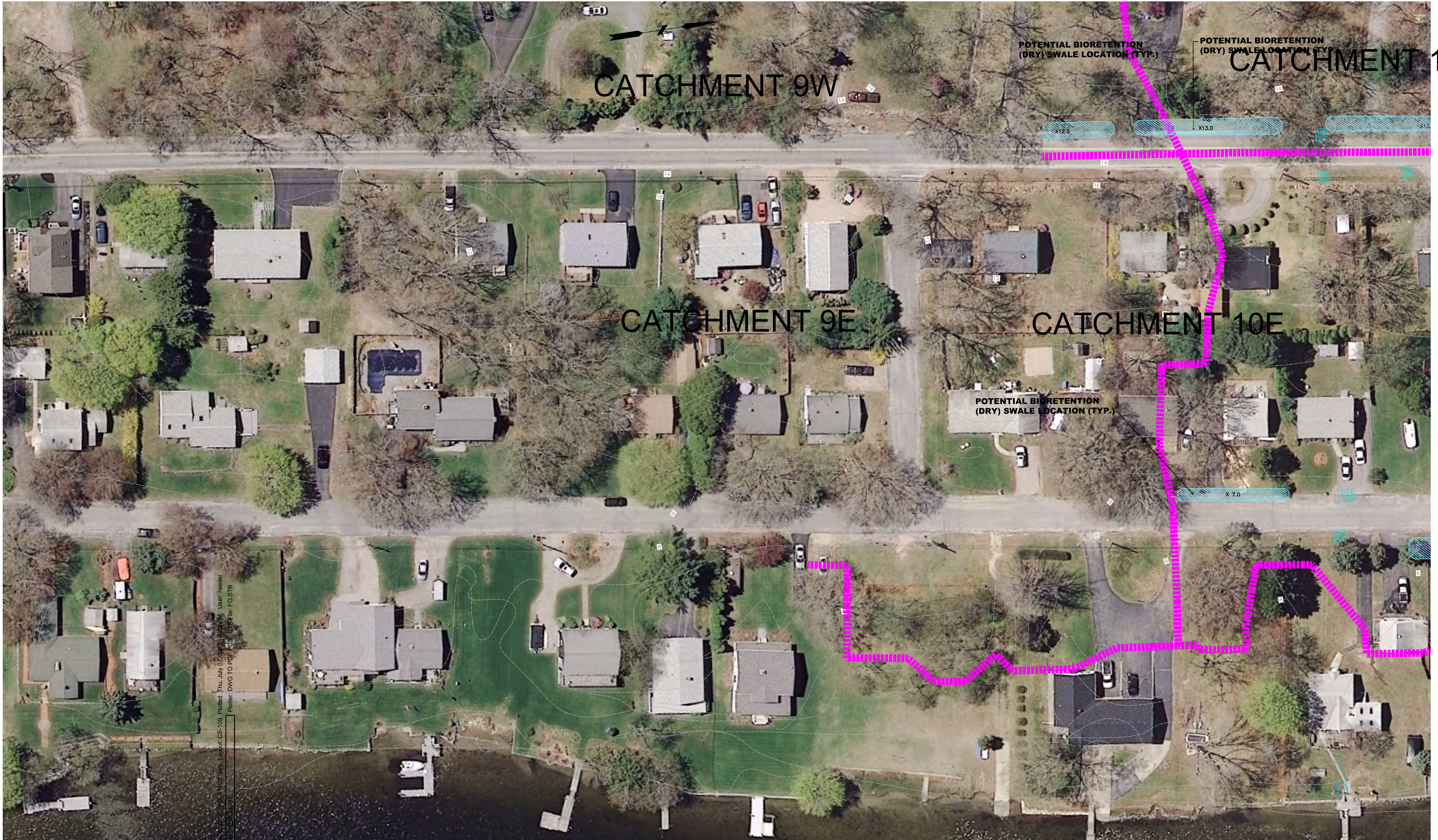
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		SEAL		
		SEAL		

SCALE:
HORIZ.:
VERT.:
DATUM:
HORIZ.:
VERT.:
0
GRAPHIC SCALE


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LEGEND	
	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'
NAD83
NAVD88



File Path: L:\DWG\2012\1980\4100\3\wallPlan.dwg  
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 Title: 4100-3-WALL PLAN

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SEAL		SEAL					

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HORIZ.:	
VERT.:	

DATUM:

HORIZ.:	
VERT.:	

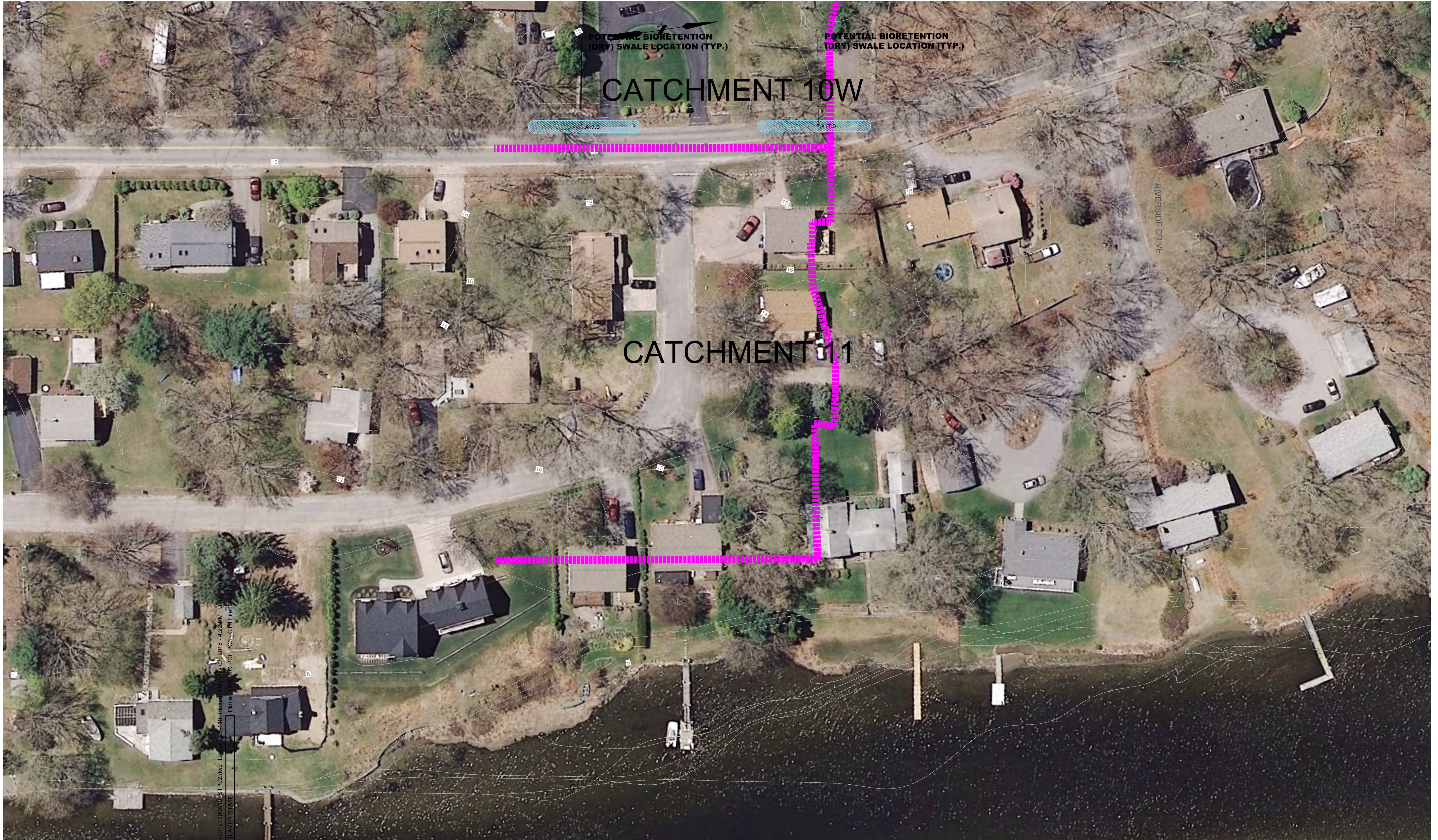
GRAPHIC SCALE

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**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'	
NAD83	
NAVD88	



File Path: L:\DWG\2012\1860\410 - 3x11Plan.dwg, Plot Date: 07/20/16, 4:22PM, User: jwheeler  
 Plot Path: TO PDF, PCS, CTB, Filter:   
 LAYER STATE:

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No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
		SEAL		
		SEAL		

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HORIZ.: \_\_\_\_\_

VERT.: \_\_\_\_\_

DATUM:

HORIZ.: \_\_\_\_\_

VERT.: \_\_\_\_\_

GRAPHIC SCALE

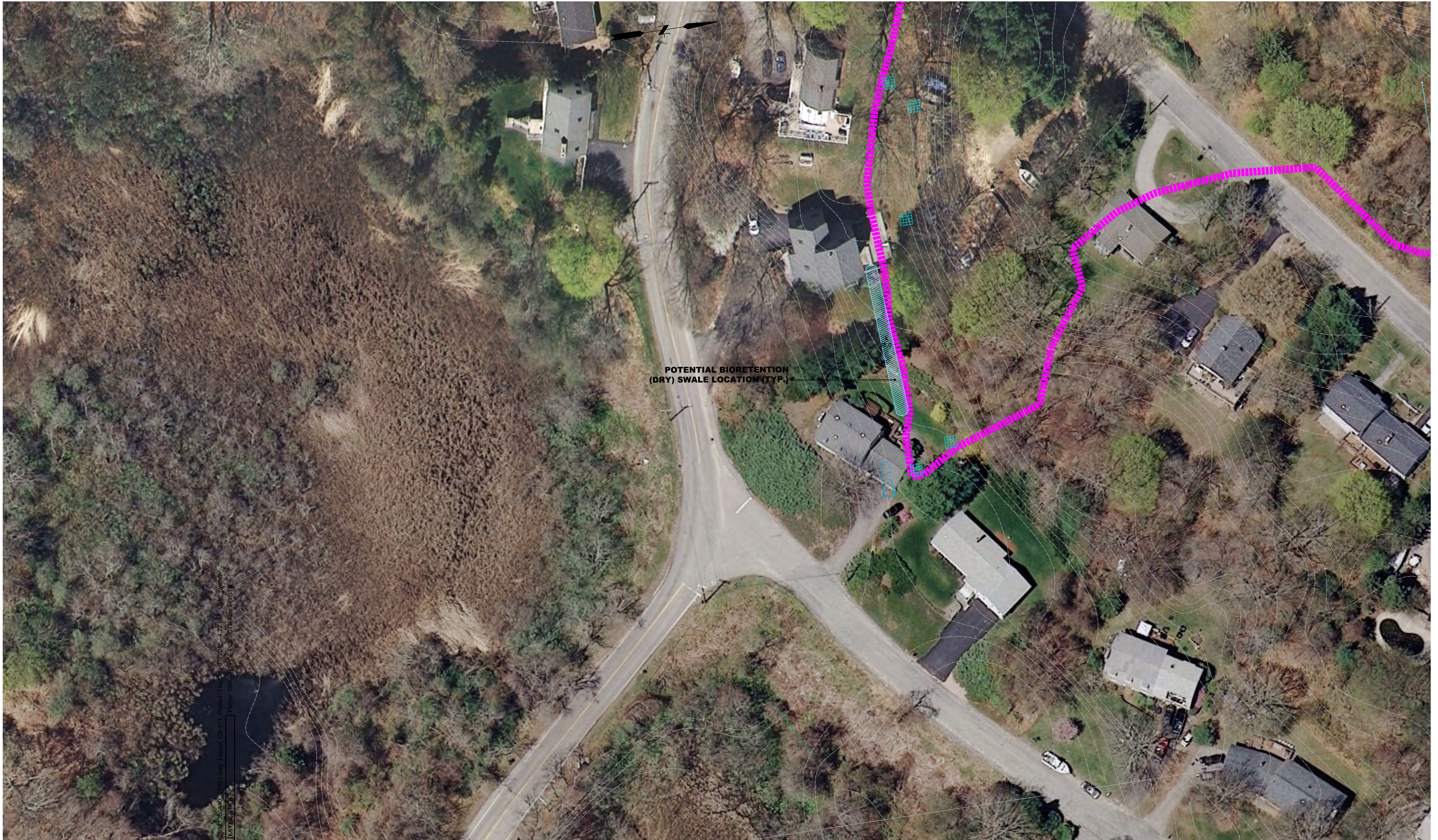
**FUSS & O'NEILL**

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LEGEND

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'
NAD83
NAVD88



File Path: L:\DWG\2017\1960\4100\1960.dwg  
 Plotted: Thu, 07/20/2016 4:22 PM  
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 Printer: DWG TO PDF PLOT CTB  
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No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

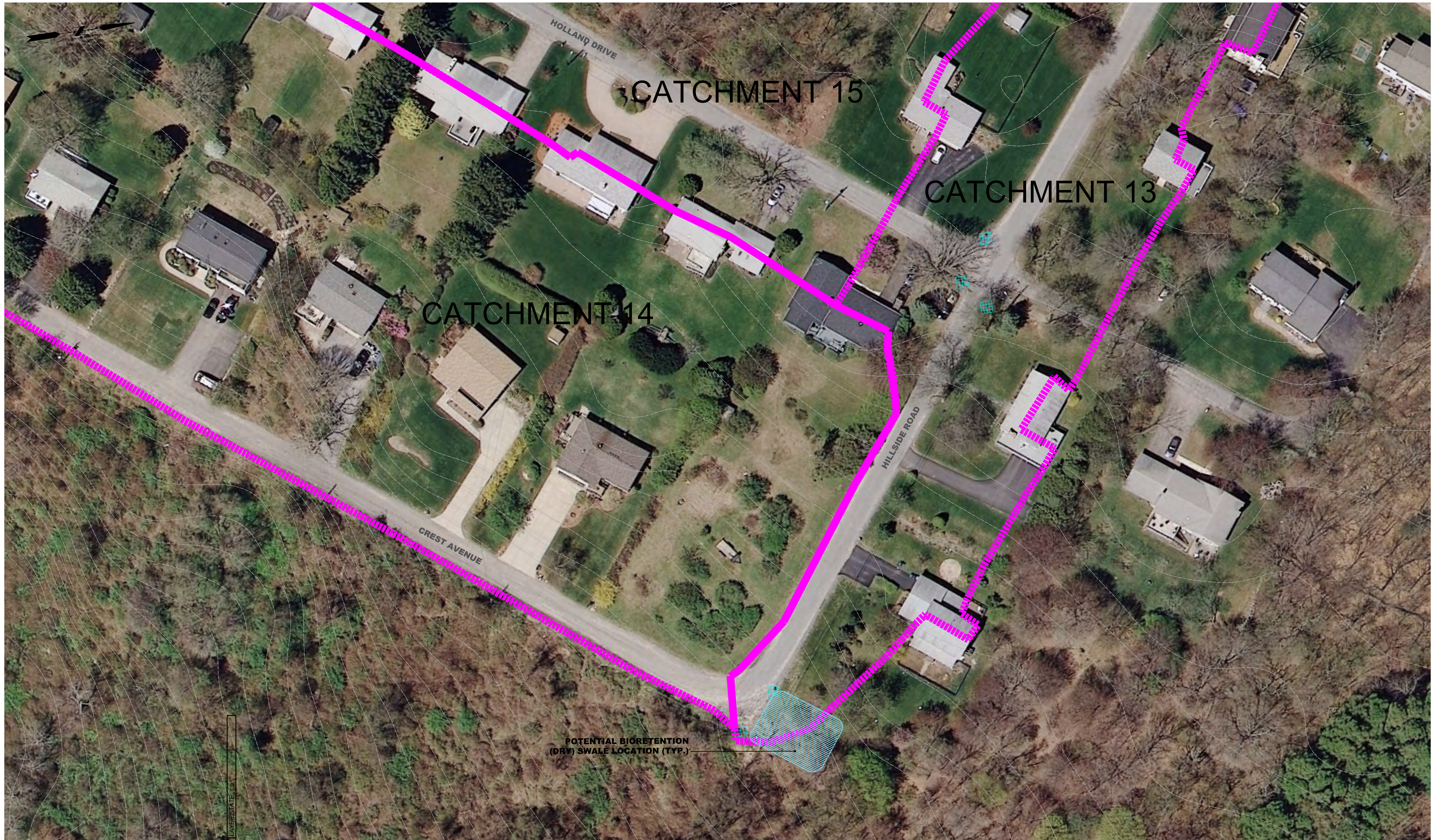
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 HORZ.:  
 VERT.:  
 DATUM:  
 HORZ.:  
 VERT.:  
 GRAPHIC SCALE


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LEGEND

	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1"	=	30'
NAD83		
NAVD88		



File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_STP02.dwg Layout: CS-112 Plotted: Thu, July 07, 2016 - 4:24 PM User: rweiler  
 Plotter: DWG TO PDF.PC3 CTB File: FO.STB

LAYER/STATE

No.	DATE	DESCRIPTION
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SEAL	SEAL
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DESIGNER	REVIEWER

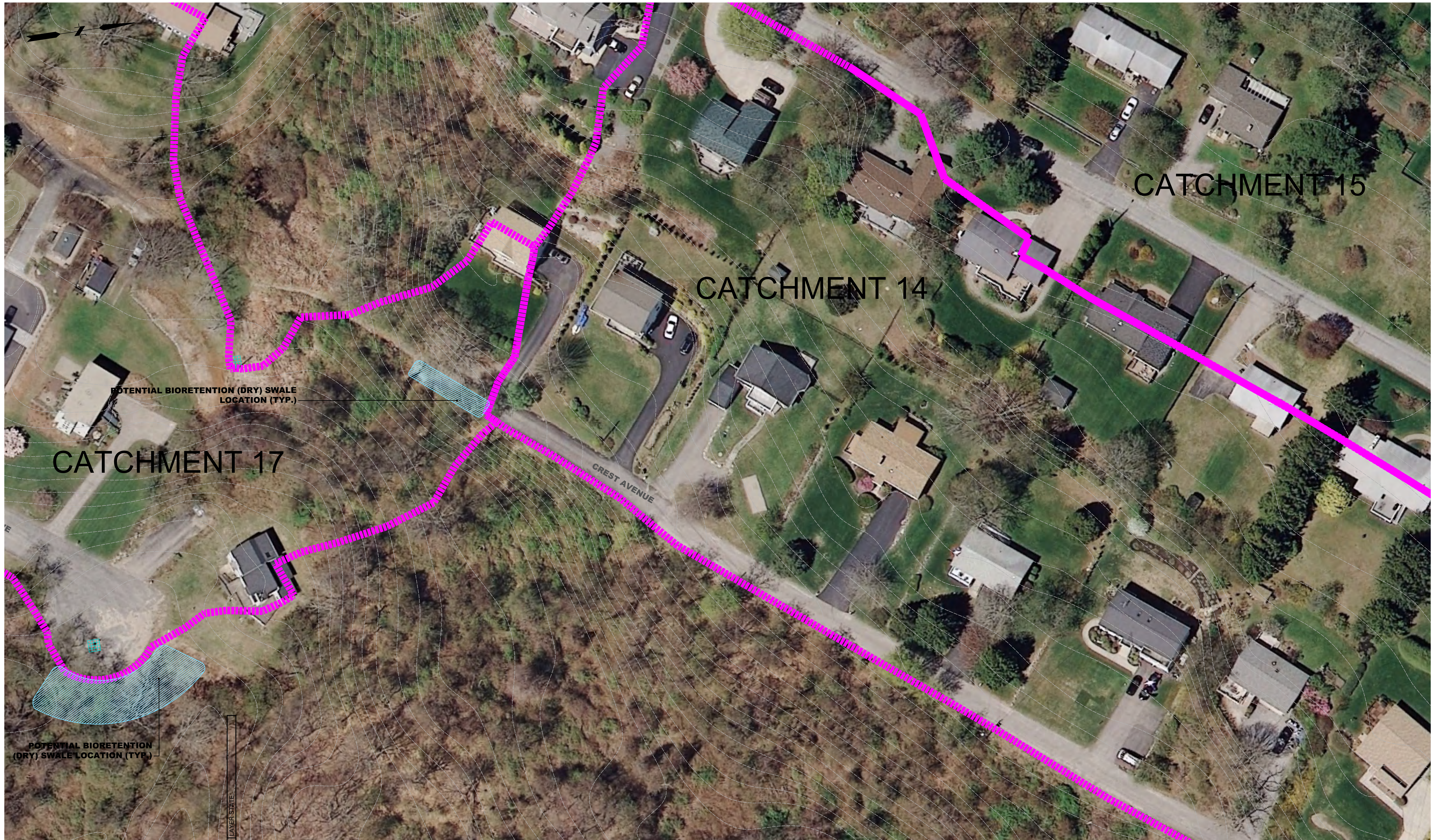
LEGEND	
	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

SCALE:	HORIZ.: 1" = 30'
	VERT.:
DATUM:	HORIZ.: NAD83
	VERT.: NAVD88
GRAPHIC SCALE	

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TOWN OF SOUTH KINGSTOWN  
 CONCEPTUAL BMP LAYOUT PLAN No. 12  
 PETTAQUAMSCUTT (NARROW) RIVER DRAINAGE  
 CATCHMENT STUDY  
 SOUTH KINGSTOWN RHODE ISLAND

**CS-112**



File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_STP02.dwg Layout: CS-113 Plotted: Thu, July 07, 2016 - 4:25 PM User: rweiler  
 Plotter: DWG TO PDF.PC3 CTB File: FO.STB

No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER

SEAL	SEAL

SCALE:	
HORZ.:	
VERT.:	
DATUM:	
HORZ.:	
VERT.:	
GRAPHIC SCALE	

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1" = 30'
NAD83
NAVD88

TOWNSHIP OF SOUTH KINGSTOWN  
 CONCEPTUAL PLAN  
**CS-113**  
 SOUTH KINGSTOWN



File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_STP02.dwg Layout: CS-114 Plotted: Thu, July 07, 2016 - 4:25 PM User: rweiler  
 Plotter: DWG TO PDF.PC3 CTB File: FO.STB

No.	DATE	DESCRIPTION

DESIGNER	REVIEWER

LEGEND	
	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

SCALE:	
HORZ.:	
VERT.:	
DATUM:	
HORZ.:	
VERT.:	
GRAPHIC SCALE	

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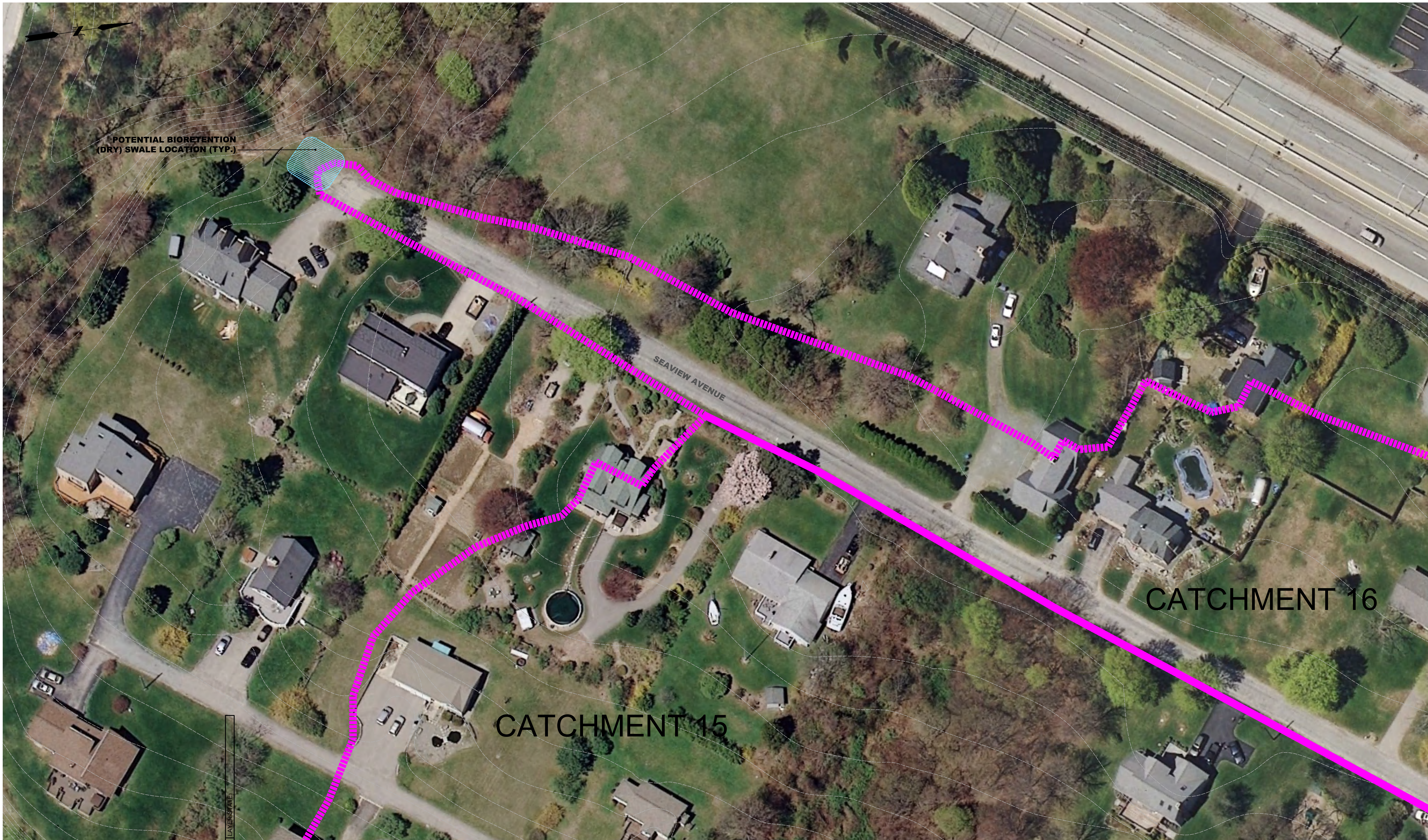
1" = 30'
NAD83
NAVD88

TOWNSHIP

CONCEPTUAL PLAN

**CS-114**

SOUTH KINGSTOWN



File Path: J:\DWG\20121360A\10\Civil\Plan\20121360A10\_STP02.dwg Layout: CS-115 Plotted: Thu, July 07, 2016 - 4:28 PM User: rweiler  
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No.	DATE	DESCRIPTION

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DESIGNER	REVIEWER

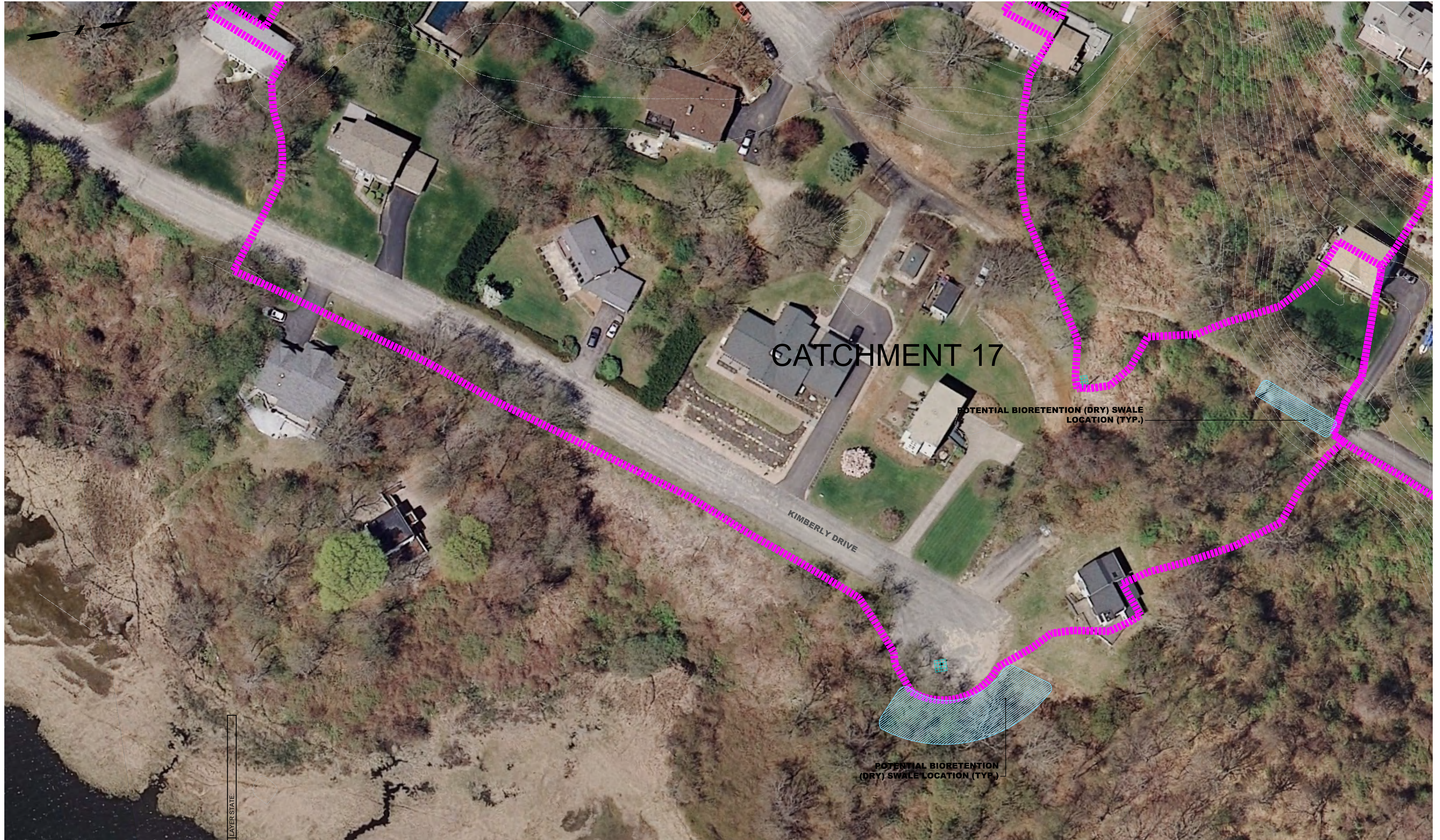
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	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

SCALE:	HORZ.:	
	VERT.:	
DATUM:	HORZ.:	
	VERT.:	
 GRAPHIC SCALE		

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1" = 30'
NAD83
NAVD88

TOWNSHIP
CONCEPTUAL
<b>CS-115</b>
SOUTH KINGSTOWN



CATCHMENT 17

KIMBERLY DRIVE

POTENTIAL BIORETENTION (DRY) SWALE LOCATION (TYP.)

POTENTIAL BIORETENTION (DRY) SWALE LOCATION (TYP.)

File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_STP02.dwg Layout: CS-116 Plotted: Thu, July 07, 2016 - 4:28 PM User: rweiler  
 Plotter: DWG TO PDF.PC3 CTB File: FO.STB

LAYER STATE:  
 MS VIEW:

No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER
SEAL	SEAL

**LEGEND**

- - - SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- △ CULVERT
- ▨ POTENTIAL BMP LOCATIONS
- ▩ POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

**SCALE:**

HORIZ.:  
 VERT.:

**DATUM:**

HORIZ.:  
 VERT.:

30 15 0 30  
 GRAPHIC SCALE

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1" = 30'

NAD83  
 NAVD88

TOW  
 CONCEPTU.  
**CS-116**  
 SOUTH KINGSTOWN

## Appendix B

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### Conceptual BMP Layout Plans – With As-Built Sewer Plans





File Path: J:\DWG\2012\1960\100\3\utilPlan\20121960A10\_STP02.dwg  
 Plotted: Fri, July 26, 2013, 2:23 PM  
 User: Signs  
 Plotter: DVG TO PDF.PCS  
 Layer State:

No.	DATE	DESCRIPTION

DESIGNER	REVIEWER


SCALE:

HORIZ.	
VERT.	

DATUM:

HORIZ.	
VERT.	

GRAPHIC SCALE



LEGEND

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'

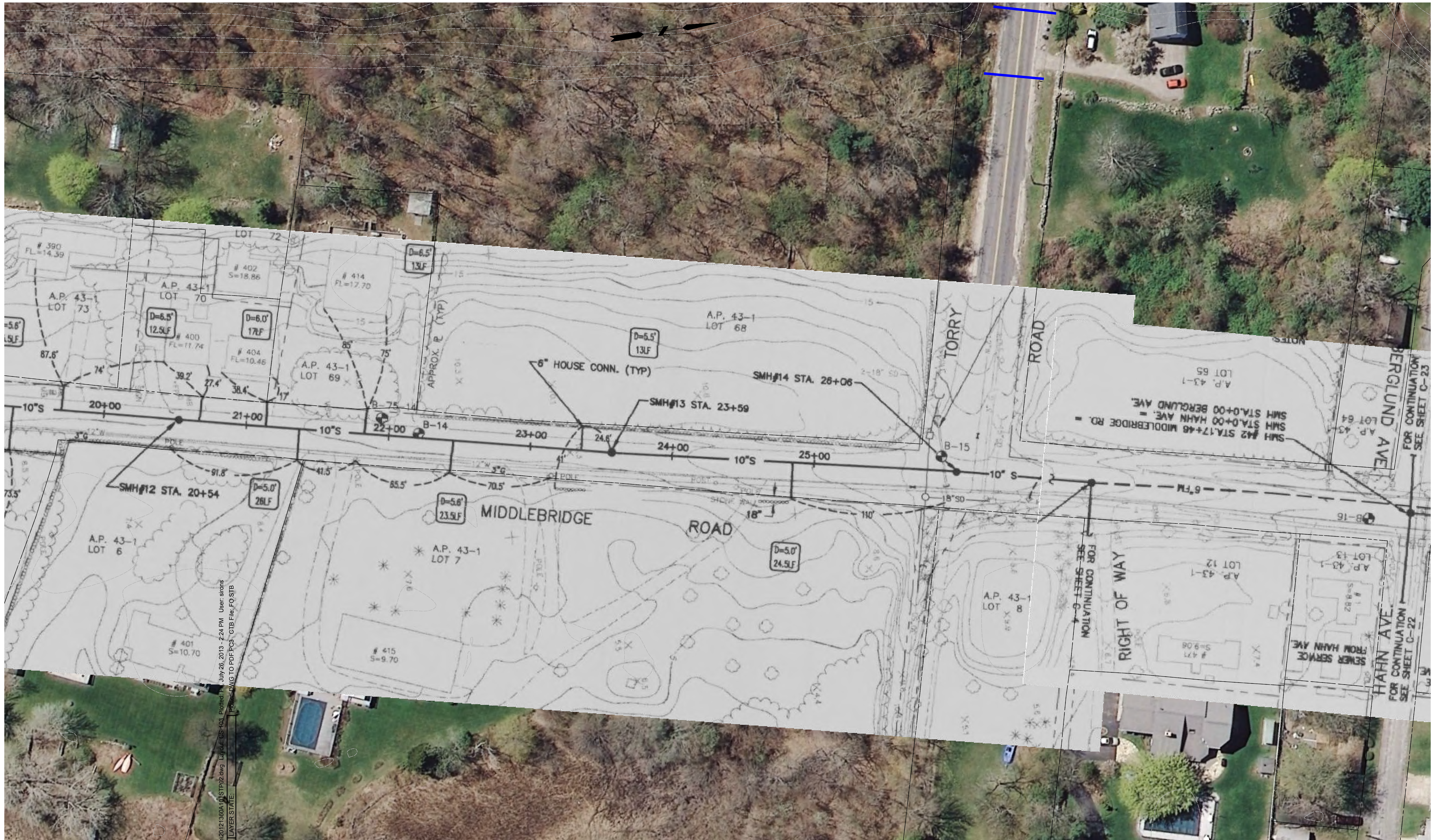
NAD83  
NAVD88

30

30







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 LAYER STATE:

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

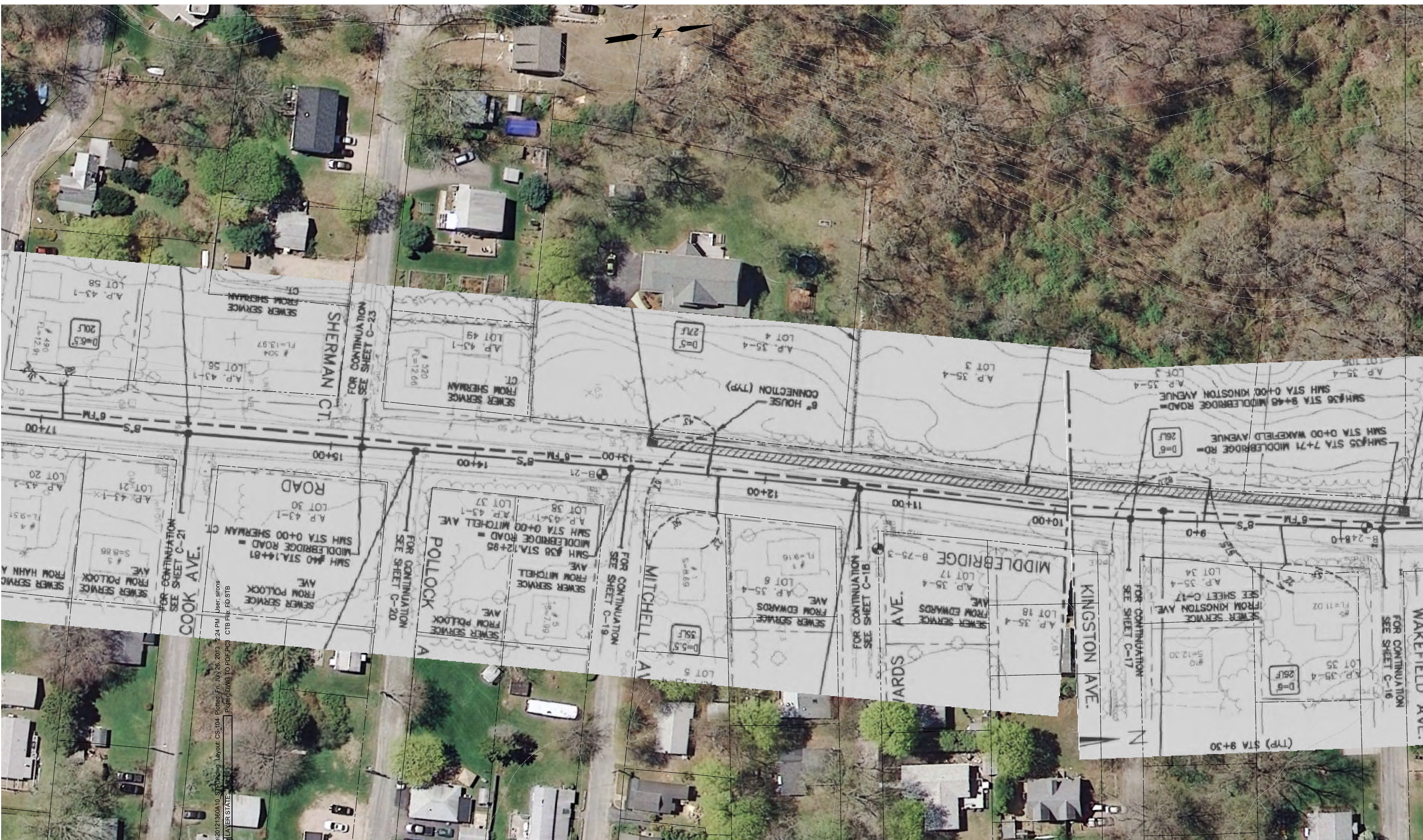
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SCALE:	HORIZ.:	
	VERT.:	
DATUM:	HORIZ.:	
	VERT.:	
GRAPHIC SCALE		

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LEGEND	
	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'	
NAD83	
NAV888	
30	30



File Path: L:\DWG\2012\1960\100\2\1960.dwg  
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 Layer State: CTB File: F0.STB  
 Plot Style: CTB File: F0.STB

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
1.				

SEAL SEAL

SCALE:  
 HORZ.:  
 VERT.:  
 DATUM:  
 HORZ.:  
 VERT.:  
 GRAPHIC SCALE

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**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'  
 NAD83  
 NAVD88  
 30 30



File Path: L:\DWG\1211860\1100\1100.dwg  
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No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

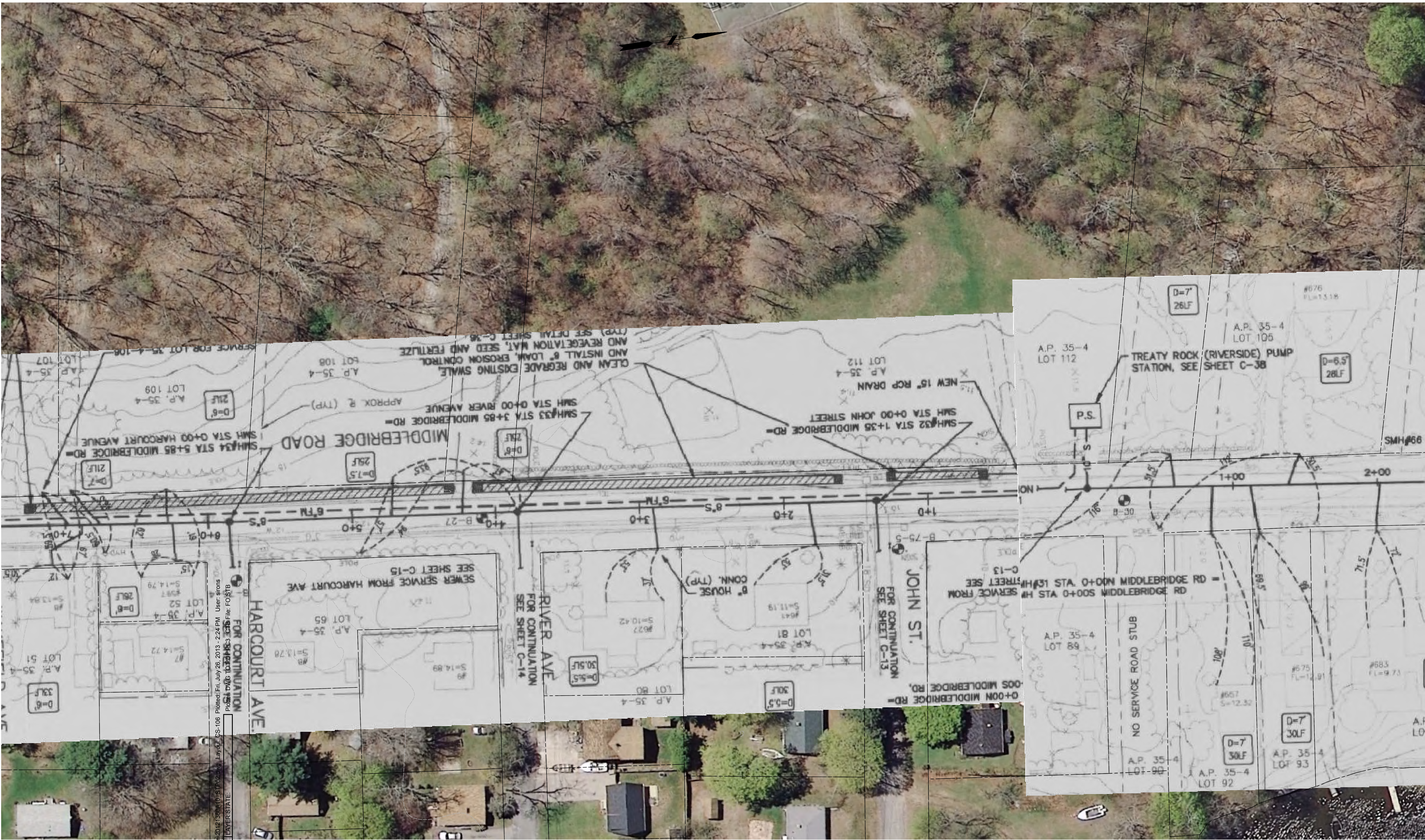
SEAL	SEAL
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SCALE:	
HORZ.:	
VERT.:	
DATUM:	
HORZ.:	
VERT.:	
GRAPHIC SCALE	

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LEGEND	
	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'
NAD83 NAVD88



File Path: X:\DWG\2012\1987\100 - Sewer\Plan\2012\1987.dwg  
 User: jst  
 Date: 7/26/2013 2:24 PM  
 PLOT: 0  
 USER STATE:

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	SEAL
	SEAL
	DESIGNER
	REVIEWER

SCALE:  
 HORZ.:  
 VERT.:  
 DATUM:  
 HORZ.:  
 VERT.:  
 0  
 GRAPHIC SCALE

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**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

30



File Path: L:\DWG\2012\1960\410 - SewerPlan.dwg  
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 User: fando\jason.fando  
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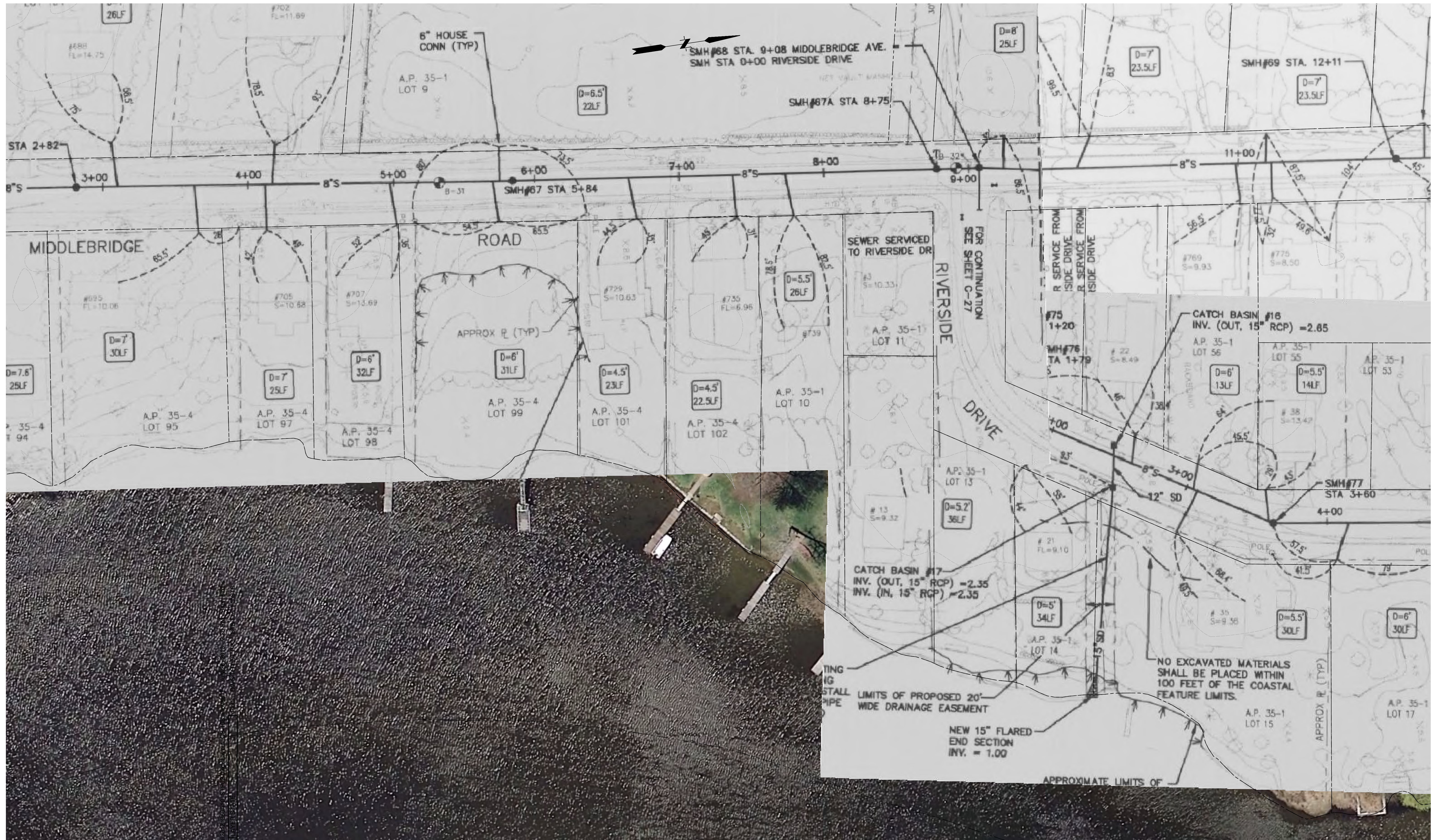
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		SEAL		
		SEAL		

SCALE:
HORIZ.:
VERT.:
DATUM:
HORIZ.:
VERT.:
0
GRAPHIC SCALE


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LEGEND	
	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'
NAD83
NAVD88
30
30



1.									
No.	DATE	DESCRIPTION	DESIGNER	REVIEWER					

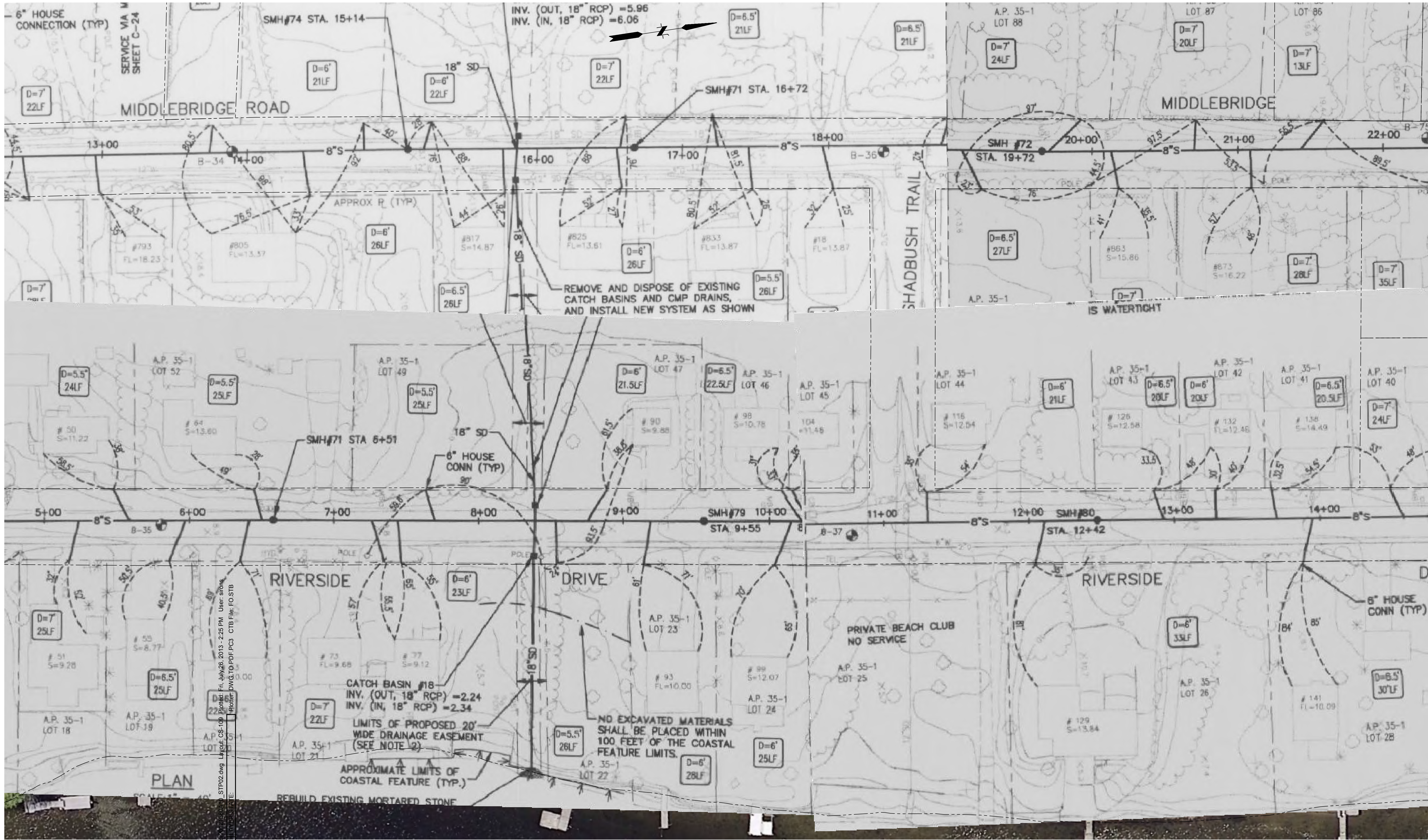
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DATUM:	HORZ.:	VERT.:
GRAPHIC SCALE		

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LEGEND	
	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'
NAD83
NAVD88
30



File Path: L:\DWG\1211967\100\Drawings\1211967.dwg  
 User: stb  
 Date: 7/26/2013 2:25 PM  
 Plot Date: 7/26/2013 2:25 PM  
 Plotter: DWG TO PDF.PC3  
 CTB File: FOSTB

**PLAN**

SCALE: 1" = 40'

REBUILD EXISTING MORTARED STONE

CATCH BASIN #18  
 INV. (OUT, 18" RCP) = -2.24  
 INV. (IN, 18" RCP) = -2.34  
 LIMITS OF PROPOSED 20' WIDE DRAINAGE EASEMENT (SEE NOTE 2)

NO EXCAVATED MATERIALS SHALL BE PLACED WITHIN 100 FEET OF THE COASTAL FEATURE LIMITS.

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

SCALE:

HORIZ.:	
VERT.:	

DATUM:

HORIZ.:	
VERT.:	

GRAPHIC SCALE

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**LEGEND**

	SUBCATCHMENT DELINEATION
	STORMWATER PIPE
	OUTFALL
	CATCH BASIN
	DRAIN MANHOLE
	CULVERT
	POTENTIAL BMP LOCATIONS
	POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'

NAD83  
NAVD88



File Path: L:\DWG\312\1960\410\3121960.dwg; User: stions; Plotted: Fri, Jul 26, 2013, 2:26 PM; User: stions; Plotter: DWG TO PDF; CTS File: FOSTB; LAYER STATE:

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

SEAL					

SCALE:

HORIZ.: \_\_\_\_\_

VERT.: \_\_\_\_\_

DATUM: \_\_\_\_\_

HORIZ.: \_\_\_\_\_

VERT.: \_\_\_\_\_

0

GRAPHIC SCALE

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**LEGEND**

- SUBCATCHMENT DELINEATION
- STORMWATER PIPE
- OUTFALL
- CATCH BASIN
- DRAIN MANHOLE
- CULVERT
- POTENTIAL BMP LOCATIONS
- POTENTIAL BMP LOCATIONS IN PROXIMITY TO UNDERGROUND UTILITIES

1" = 30'

NAD83  
 NAVD88

30

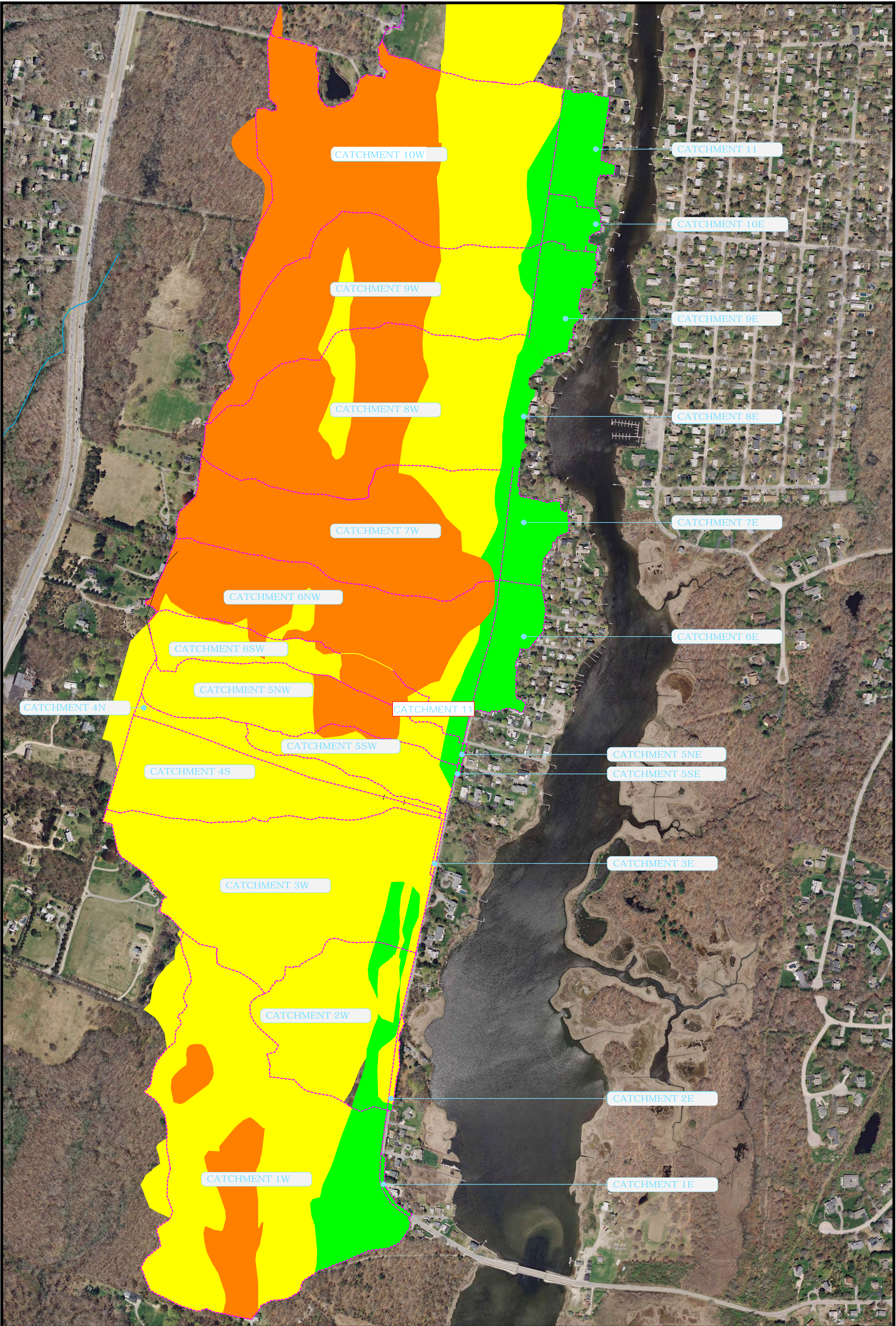
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## Appendix C

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### Conceptual BMP Layout Plans – With Soils Layer

File Path: J:\DWG\20121360A10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-117 Plotted: Fri, July 08, 2016 - 9:38 AM User: rwriter  
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 LAYER STATE:



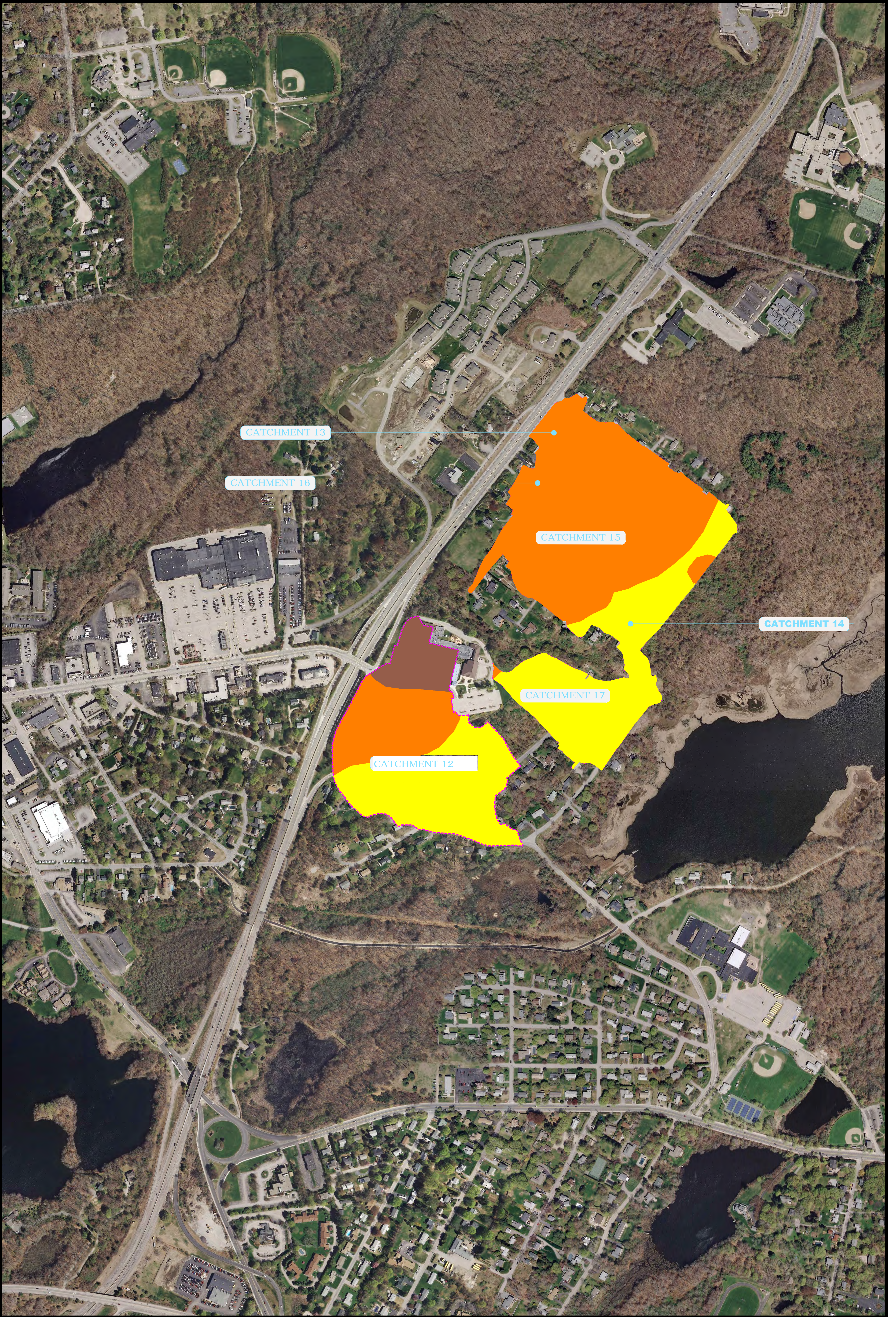
PROJ. No.: 20131360.A10  
 DATE: JULY 2014  
**CS-111**

TOWN OF SOUTH KINGSTOWN  
 SOILS INDEX PLAN  
 PETTAQUAMSCUTT (NARROW) RIVER  
 DRAINAGE CATCHMENT STUDY  
 SOUTH KINGSTOWN RHODE ISLAND



SCALE:  
 HORZ.: 1" = 250'  
 VERT.:  
 DATUM:  
 HORZ.:  
 VERT.:  
 250 125 0 250  
 GRAPHIC SCALE

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
1.				



CATCHMENT 13

CATCHMENT 16

CATCHMENT 15

CATCHMENT 14

CATCHMENT 17

CATCHMENT 12

File Path: J:\DWG\2012\1360A10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-117 (B) Plotter: Fri, July 08, 2016 - 11:06 AM User: rweiler  
 LMS VIEW: Layers State:

PROJ. No.: 20131360.A10  
 DATE: JULY 2014  
**CS-117B**

TOWN OF SOUTH KINGSTOWN  
 SOILS INDEX PLAN 2  
 PETTAQUAMSCUTT (NARROW) RIVER  
 DRAINAGE CATCHMENT STUDY  
 SOUTH KINGSTOWN RHODE ISLAND



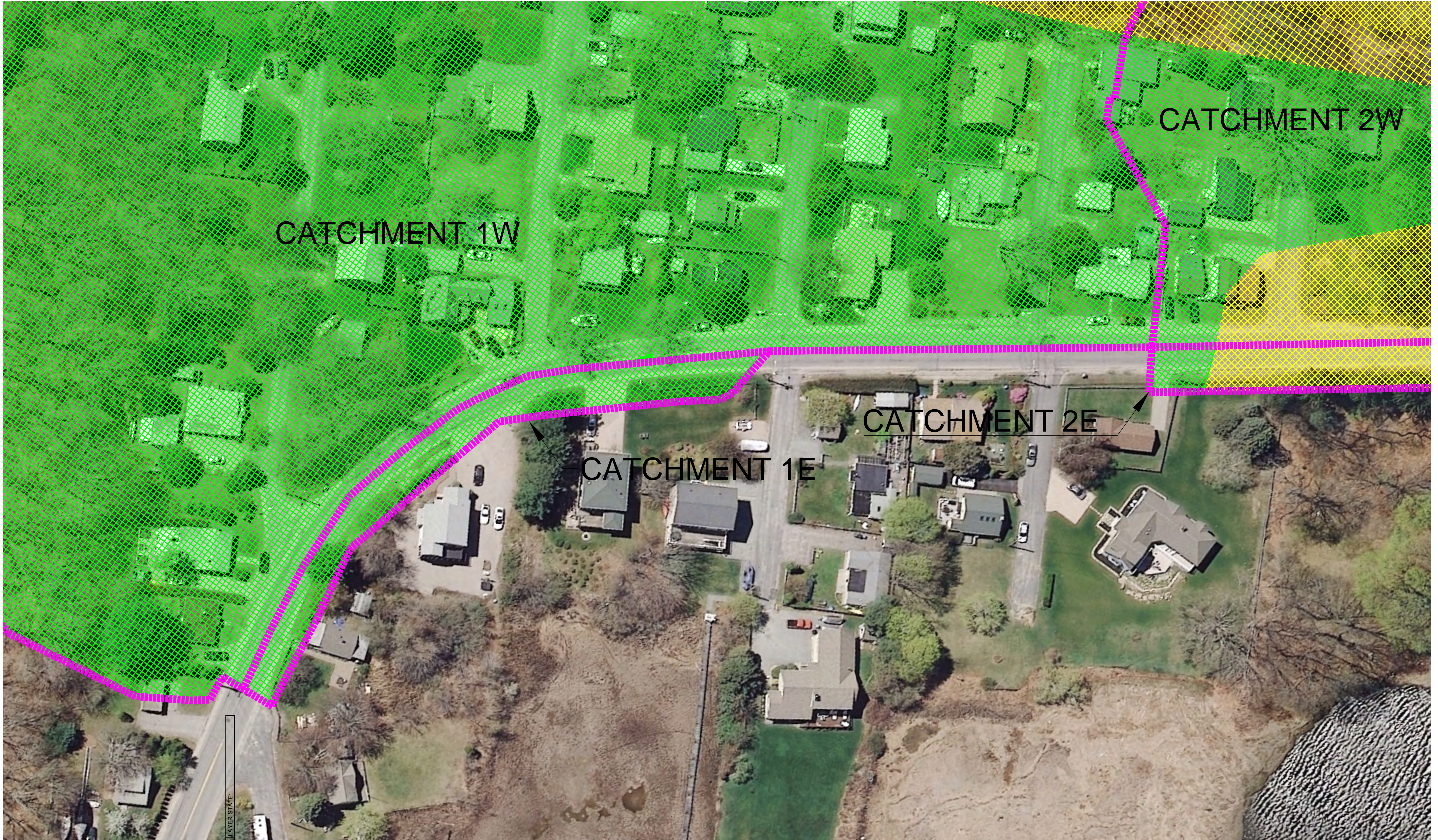
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HORIZ.:	1" = 250'
VERT.:	
DATUM:	
HORIZ.:	
VERT.:	

250 125 0 250

GRAPHIC SCALE

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
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 Plotter: DWG TO PDF.PC3 CTB File: FOSTB

LAYER STATE:  
 MS VIEW:

No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER	HYDROLOGIC SOIL GROUP

SEAL	SEAL

- A A/VAR
- B B/B/D
- C C/C/D
- VARIABLE

SCALE:

HORIZ.:	
VERT.:	

DATUM:

HORIZ.:	
VERT.:	

GRAPHIC SCALE

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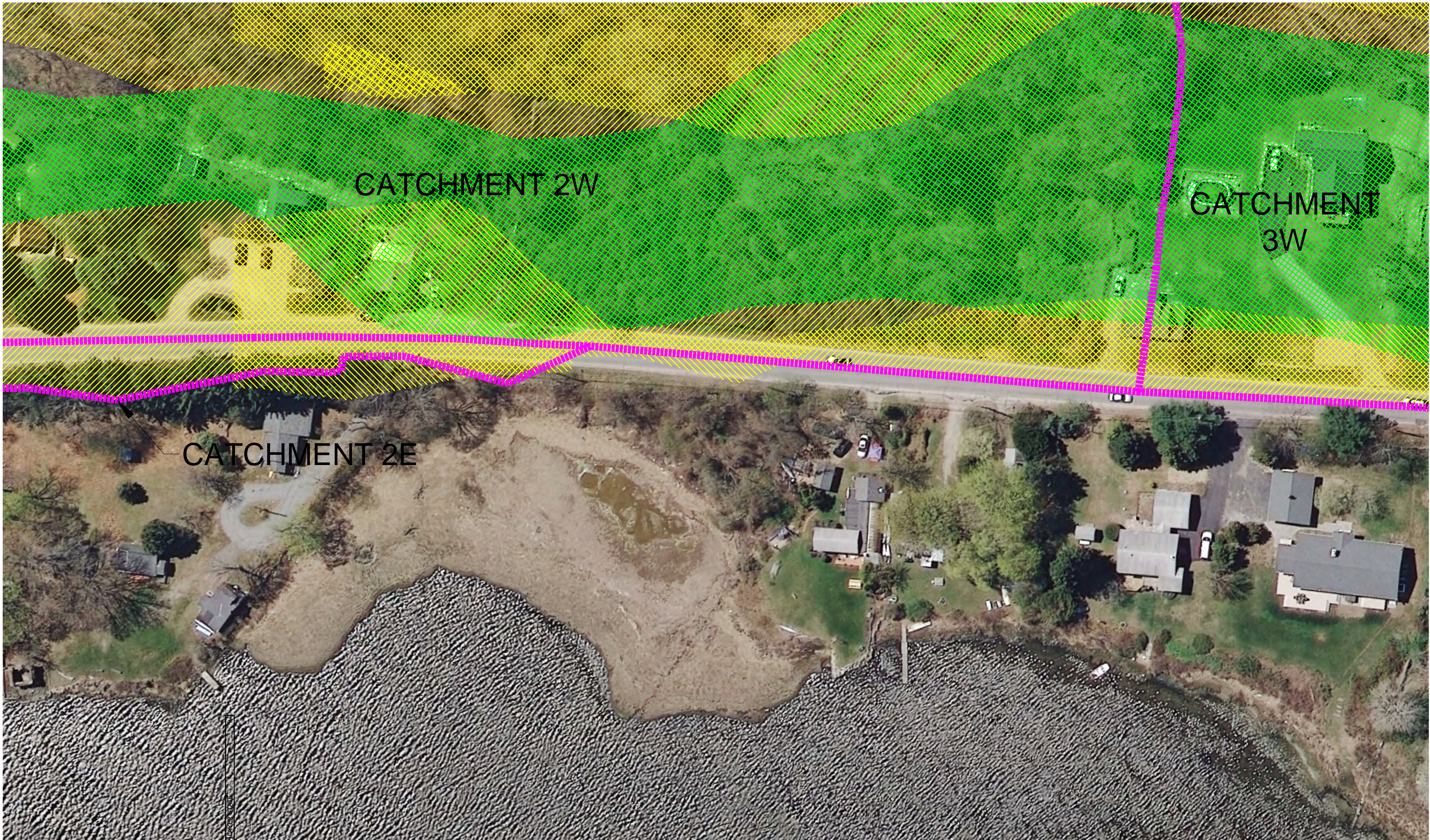
1" = 30'

NAD83  
 NAVD88

CS-118

TOW  
 SOUTH KINGSTOWN

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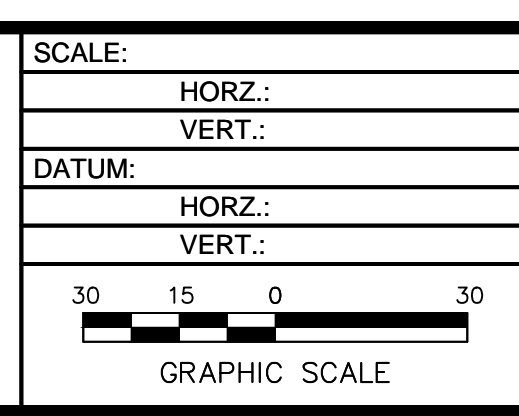


No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER

HYDROLOGIC SOIL GROUP
A A/VAR
B B/B/D
C C/C/D
VARIABLE

SCALE:
HORZ.: _____
VERT.: _____
DATUM:
HORZ.: _____
VERT.: _____

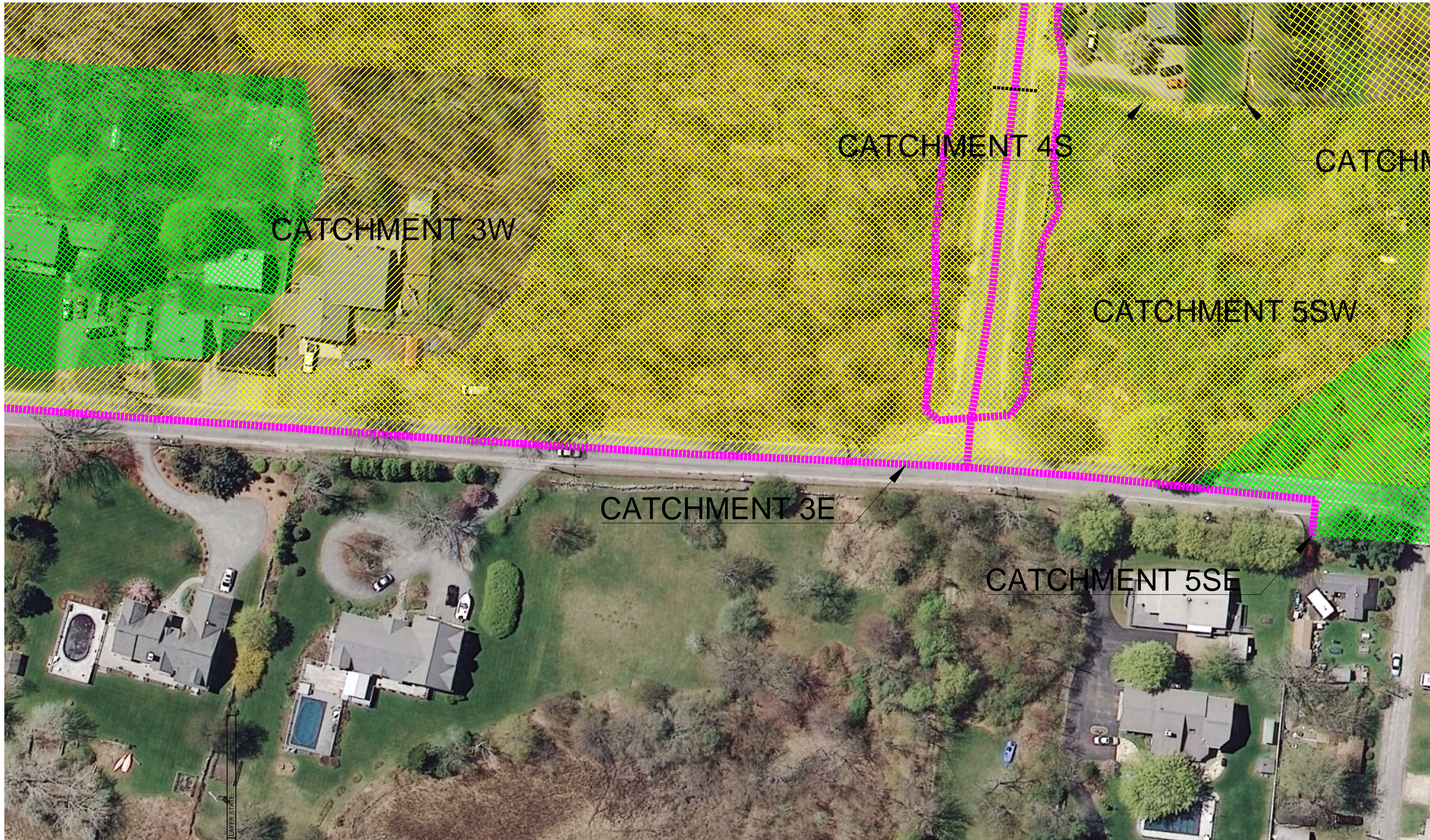


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1" = 30'
NAD83
NAVD88

CS-119  
 SOUTH KINGSTOWN

File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-120 Plotted: Fri, July 08, 2016 - 9:46 AM User: weiler  
 Plotter: DWG TO PDF.PC3 CTB File: FOSTB



LAYER STATE:  
 MS VIEW:

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

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B /B/D	Yellow	B
C /C/D	Orange	C
VARIABLE	Brown	

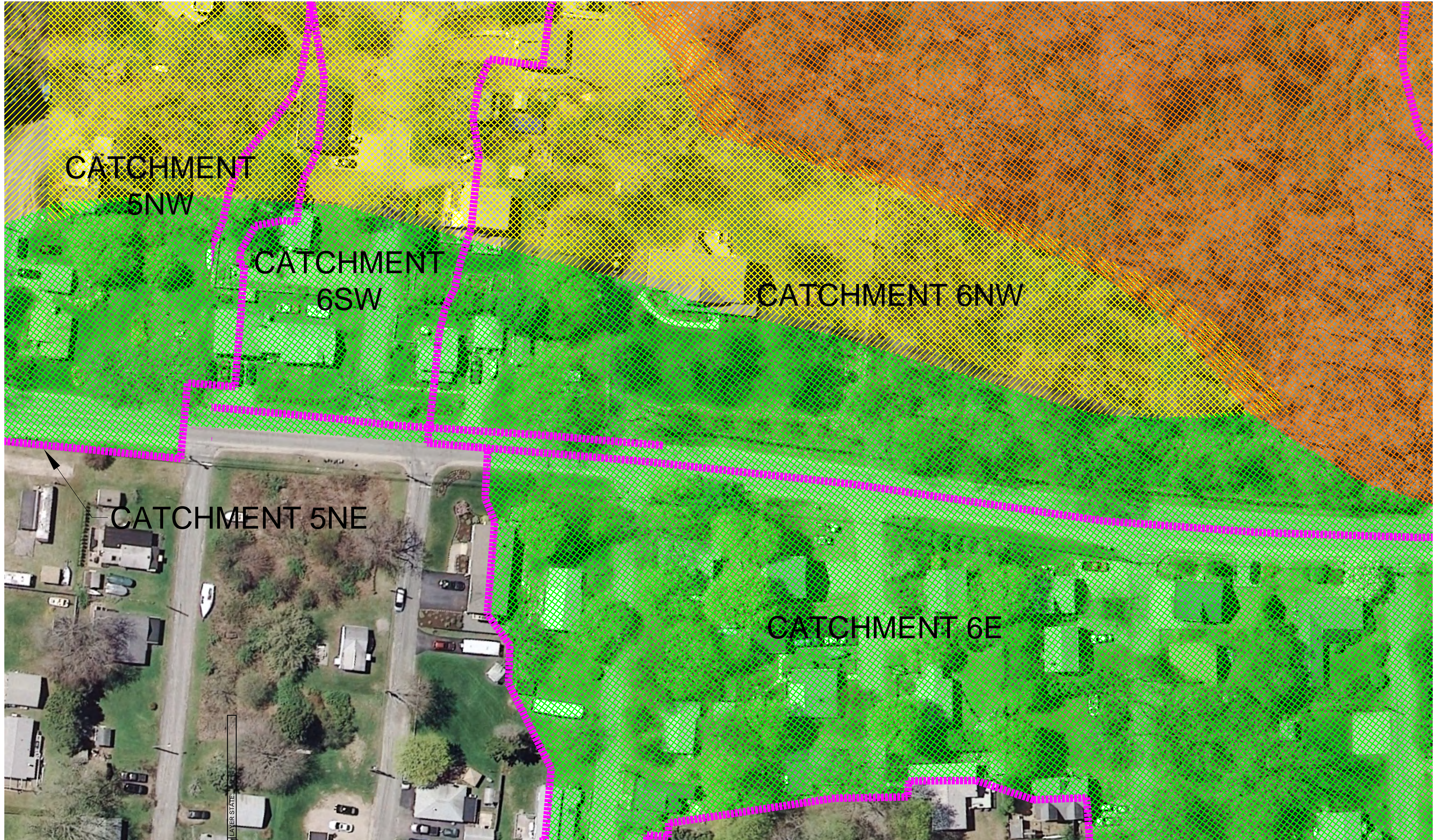
SEAL	SEAL

SCALE:  
 HORZ.:  
 VERT.:  
 DATUM:  
 HORZ.:  
 VERT.:  
 30 15 0 30  
 GRAPHIC SCALE

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1" = 30'  
 NAD83  
 NAVD88

CS-120  
 SOUTH KINGSTOWN TOWNSHIP



File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-121 Plotted: Fri, July 08, 2016 - 9:46 AM User: weiler  
 Plotter: DWG TO PDF.PC3 CTB File: FO.STB

LAYER STATE

No.	DATE	DESCRIPTION

DESIGNER	REVIEWER

HYDROLOGIC SOIL GROUP

SCALE:
HORIZ.:
VERT.:
DATUM:
HORIZ.:
VERT.:
30 15 0 30
GRAPHIC SCALE


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1" = 30'
NAD83
NAVD88

**CS-121**  
 SOUTH KINGSTOWN  
 TOW





File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-122 Plotted: Fri, July 08, 2016 - 9:46 AM User: weiler  
 Plotter: DWG TO PDF.PC3 CTB File: FO.STB




CATCHMENT 6E

No.	DATE	DESCRIPTION
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	C	C /C /D
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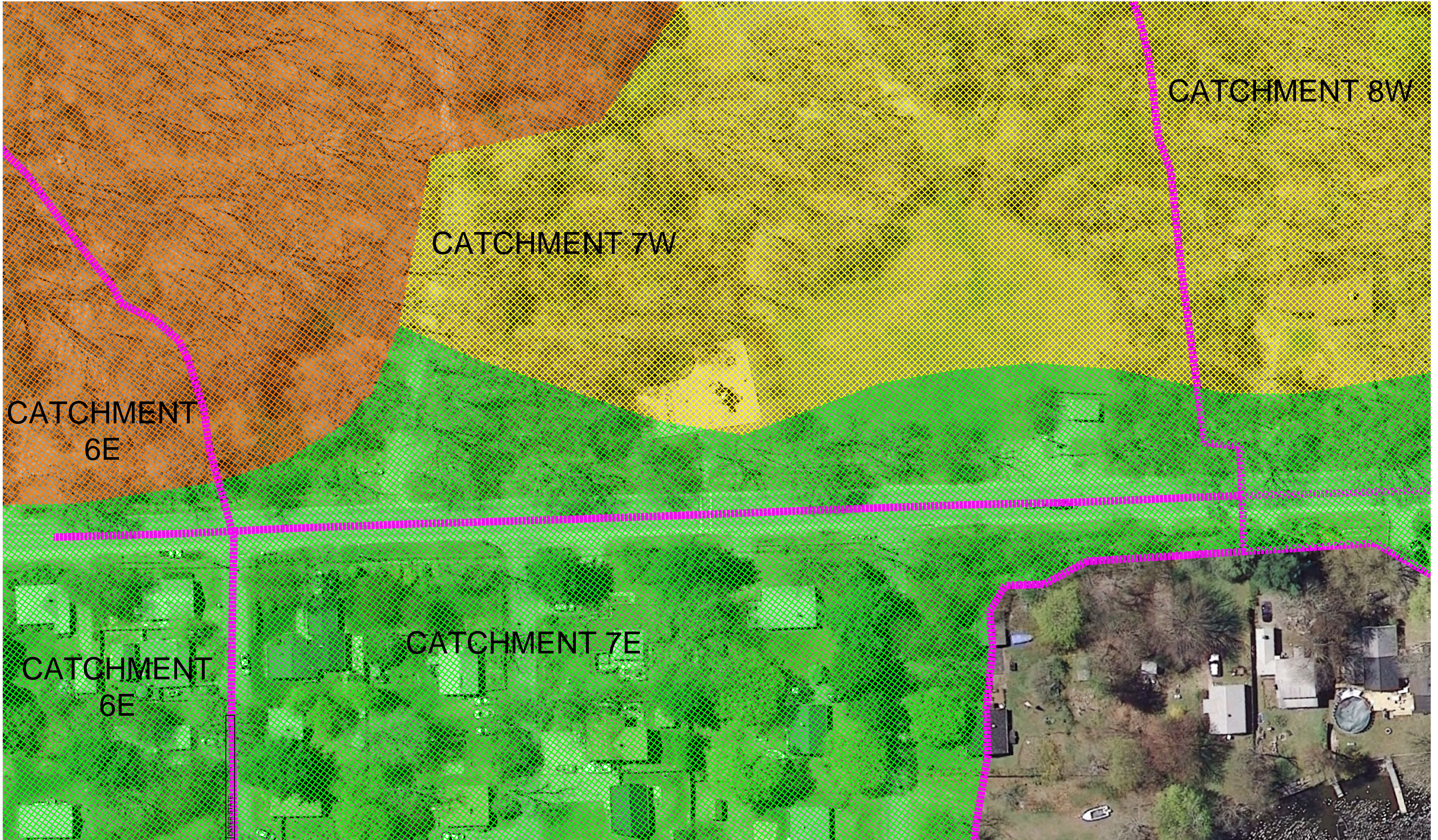
HYDROLOGIC SOIL GROUP	

SCALE:	HORZ.:	
	VERT.:	
DATUM:	HORZ.:	
	VERT.:	
		
GRAPHIC SCALE		

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1" = 30'
NAD83 NAVD88

CS-122	TOW SOUTH KINGSTOWN
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File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-123 Plotted: Fri, July 08, 2016 - 9:47 AM User: weiler  
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No.	DATE	DESCRIPTION

DESIGNER	REVIEWER	SEAL	SEAL

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	B /B/D							
	C /C/D							
	VARIABLE							

SCALE:	HORZ.: _____
	VERT.: _____
DATUM:	HORZ.: _____
	VERT.: _____
GRAPHIC SCALE	

**FUSS & O'NEILL**

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1" = 30'
NAD83 NAVD88

<p><b>CS-123</b></p> <p>SOUTH KINGSTOWN</p>	<p>TOW</p> <p>15 TAQUAMS</p>
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File Path: J:\DWG\20121360A\10\CivilPlan\20121360A10\_SOILS.dwg Layout: CS-124 Plotted: Fri, July 08, 2016 - 9:48 AM User: weiler  
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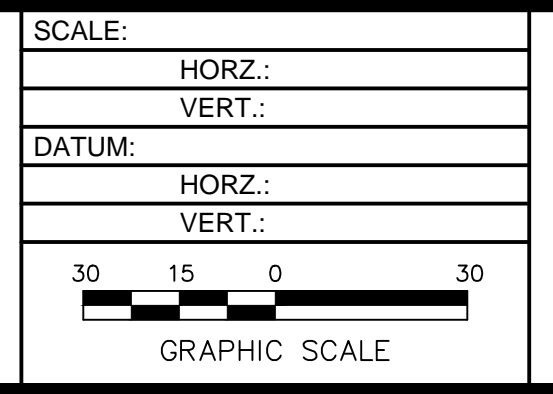


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SEAL	SEAL

DESIGNER	REVIEWER

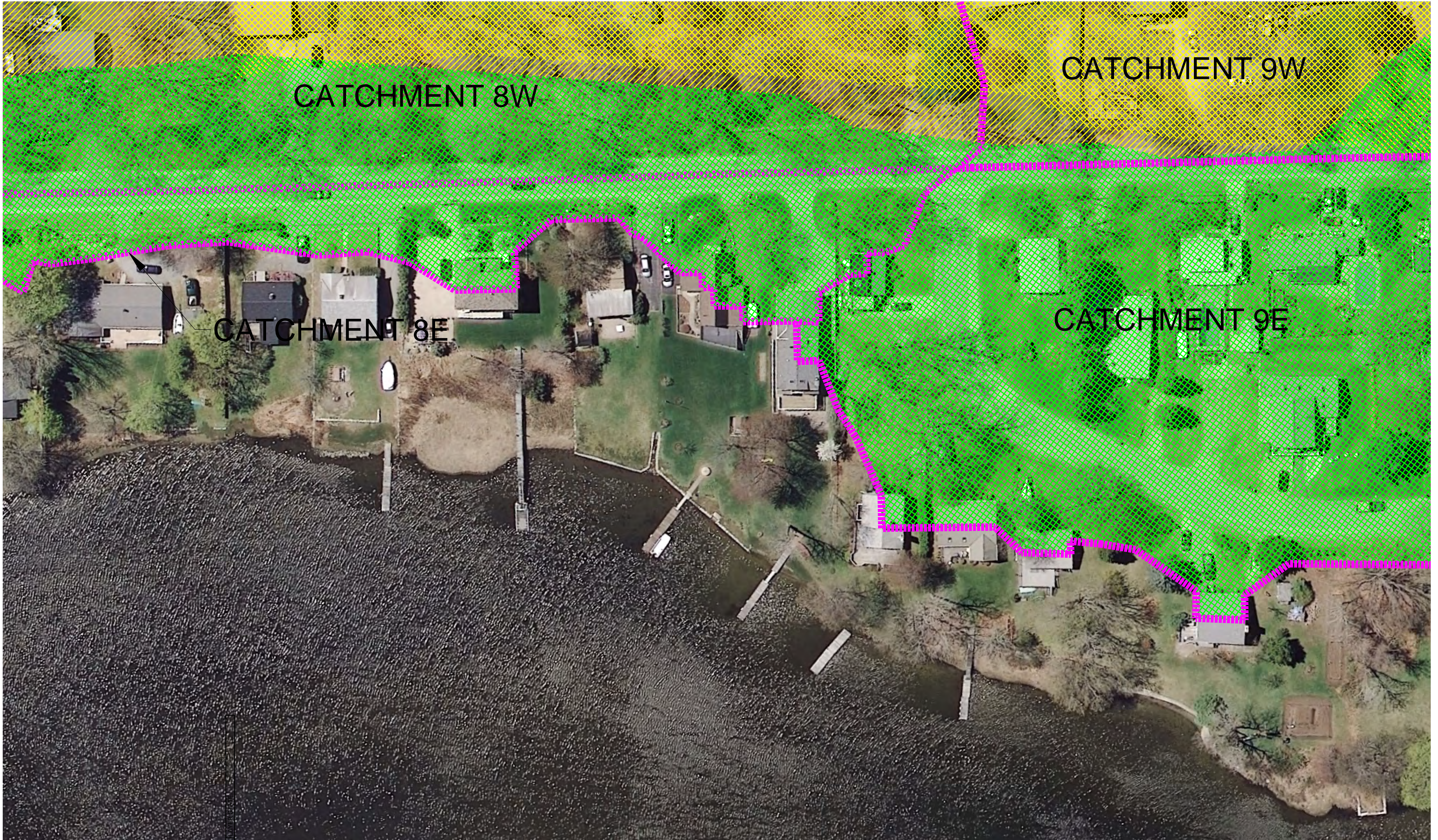
HYDROLOGIC SOIL GROUP



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1" = 30'
NAD83
NAVD88

**CS-124**  
SOUTH KINGSTOWN TOWNSHIP



File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-125 Plotted: Fri, July 08, 2016 - 9:48 AM User: reuter  
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No.	DATE	DESCRIPTION

DESIGNER	REVIEWER

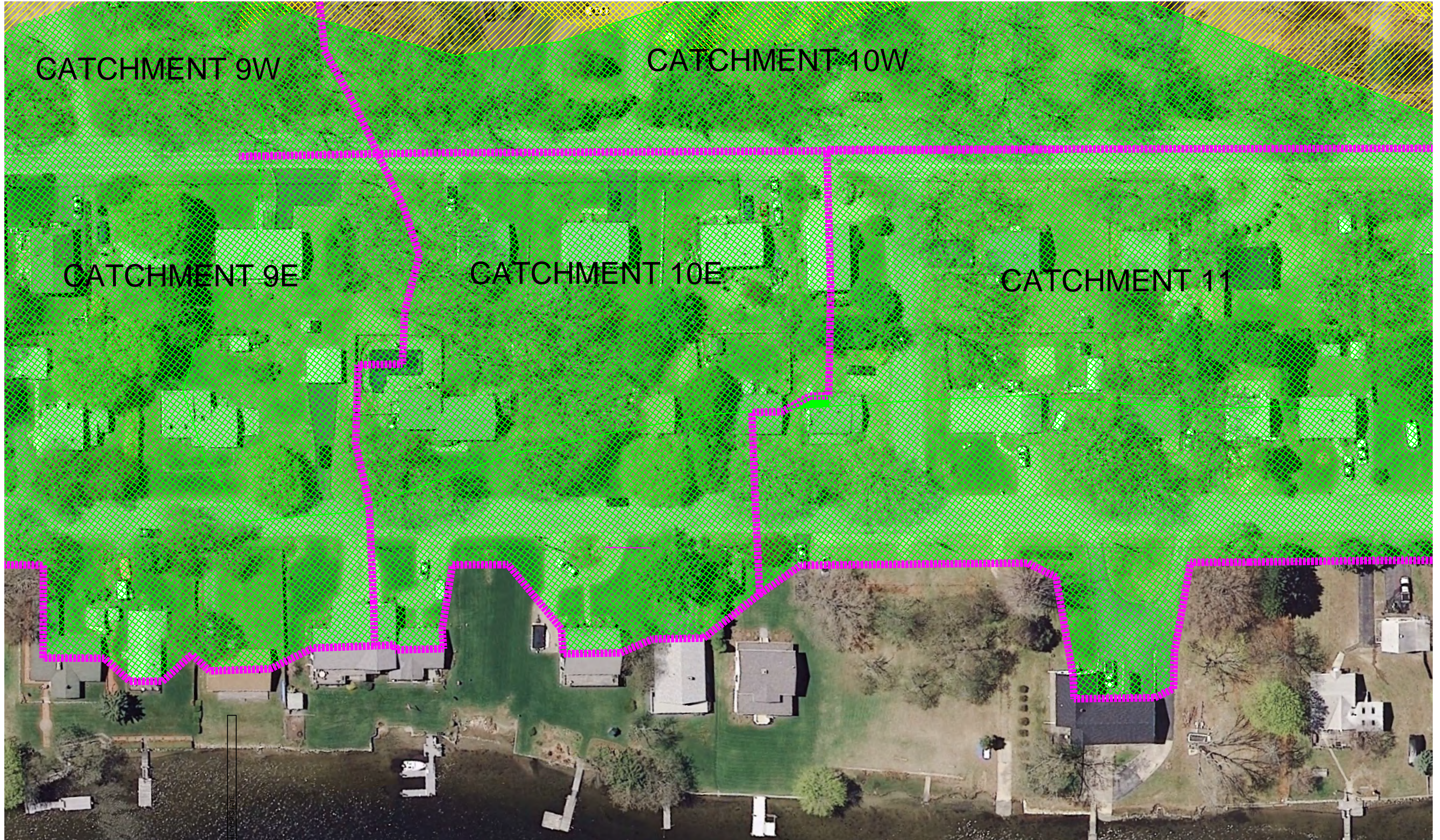
HYDROLOGIC SOIL GROUP

SCALE:	HORIZ.:
	VERT.:
DATUM:	HORIZ.:
	VERT.:
GRAPHIC SCALE	

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1" = 30'
NAD83
NAVD88

TOW  
 CS-125  
 SOUTH KINGSTOWN



File Path: J:\DWG\20121360A\10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-126 Plotted: Fri, July 08, 2016 - 9:49 AM User: weiler  
 Plotter: DWG TO PDF.PC3 CTB File: FOSTB

1.					

No.	DATE	DESCRIPTION	DESIGNER	REVIEWER

SEAL	SEAL
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SCALE:

HORIZ.:	
VERT.:	

DATUM:

HORIZ.:	
VERT.:	

30 15 0 30  
GRAPHIC SCALE

**f** **FUSS & O'NEILL**  
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 PROVIDENCE, RI 02908  
 401.861.3070  
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1" = 30'

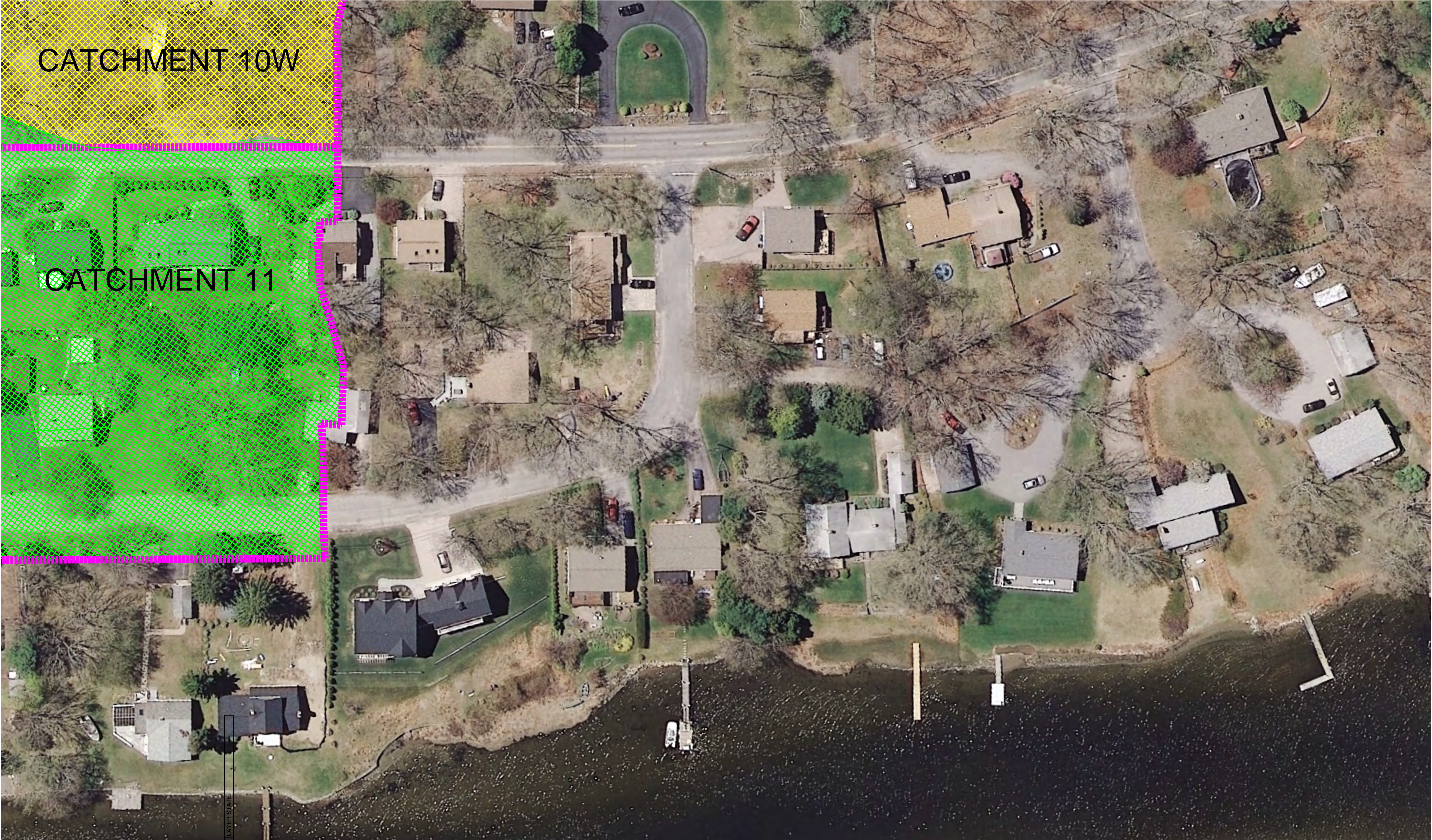
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NAVD88

CS-126  
SOUTH KINGSTOWN

TOW

CS-126

SOUTH KINGSTOWN



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 Plotter: DWG TO PDF.PC3 CTB File: FO.STB

MS VIEW	No.	DATE	DESCRIPTION

DESIGNER	REVIEWER	HYDROLOGIC SOIL GROUP

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- B B/B/D
- C C/C/D
- VARIABLE

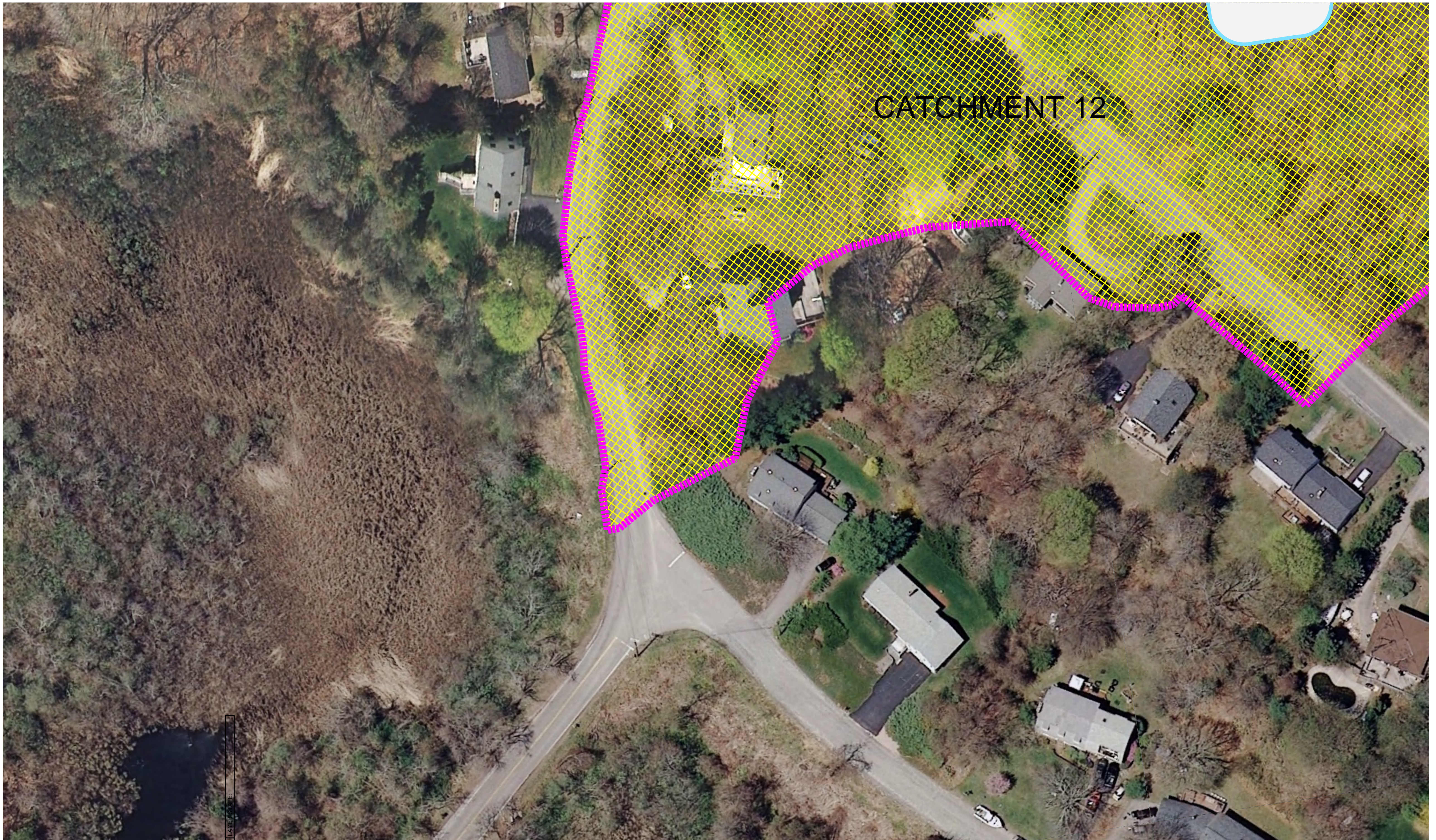
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	VERT.:	
DATUM:	HORZ.:	
	VERT.:	
GRAPHIC SCALE		

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1" = 30'
NAD83
NAVD88

CS-127	TOW
SOUTH KINGSTOWN	15 TAQUAMS

File Path: J:\DWG\2012\1360A\10\Civil\Plan\20121360A10\_SOILS.dwg Layout: CS-128 Plotted: Fri, July 08, 2016 - 9:50 AM User: reuter  
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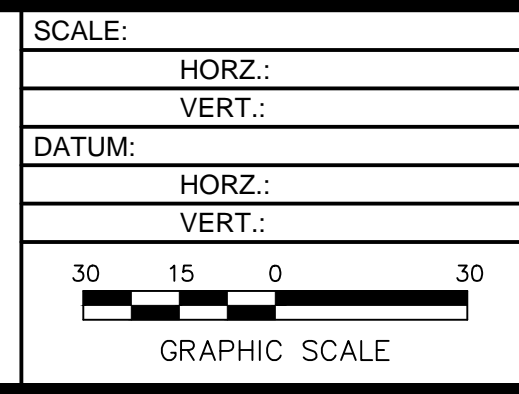
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No.	DATE	DESCRIPTION	DESIGNER	REVIEWER
1.				

SEAL	SEAL

HYDROLOGIC SOIL GROUP
A A/VAR
B B/B/D
C C/C/D
VARIABLE

SCALE:
HORZ.:
VERT.:
DATUM:
HORZ.:
VERT.:



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1" = 30'
NAD83
NAVD88

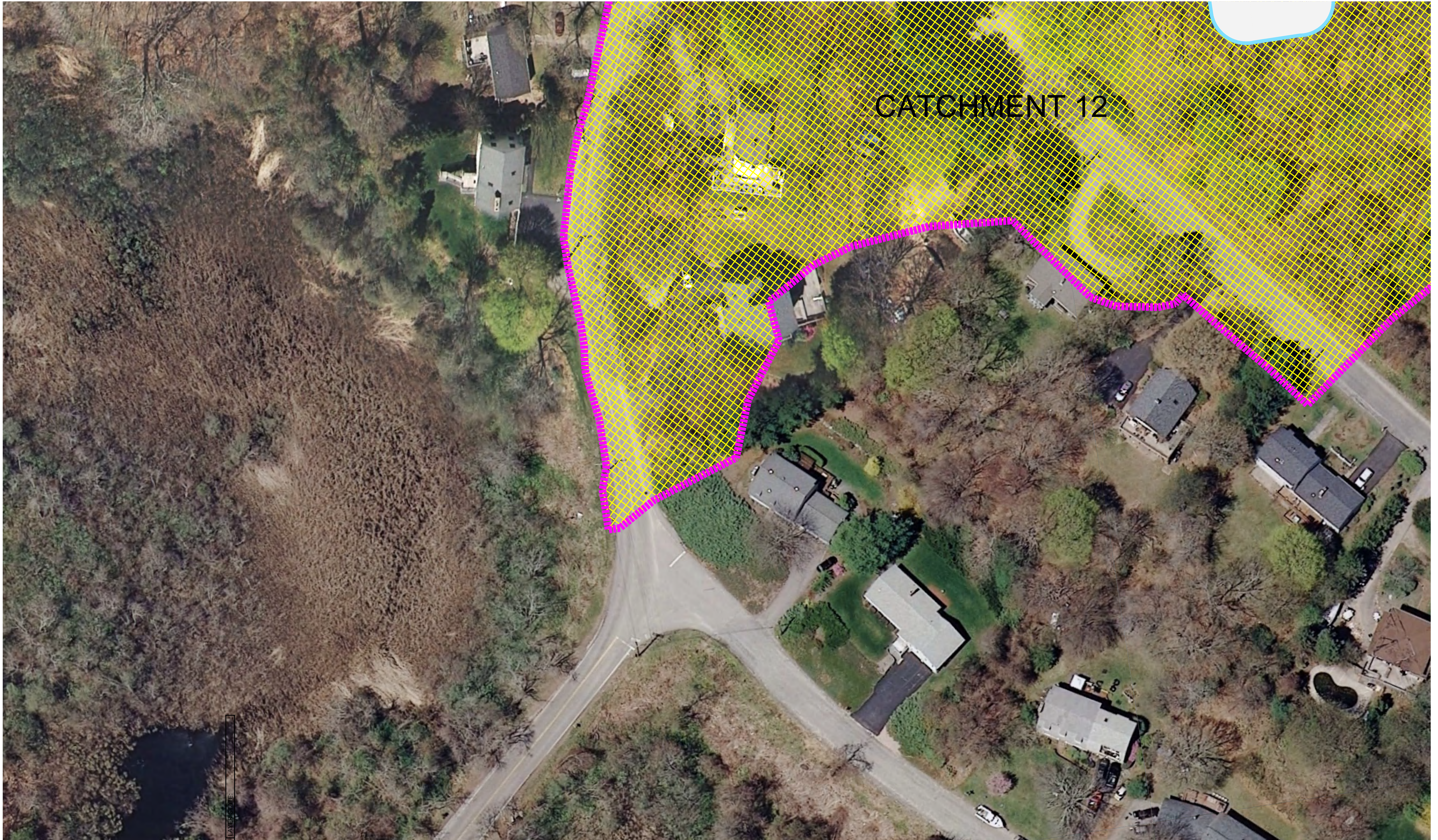
**CS-128**  
SOUTH KINGSTOWN

TOW

117 AQJAMS

SOUTH KINGSTOWN

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LAYER STATE

No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER

HYDROLOGIC SOIL GROUP
A A/VAR
B B/B/D
C C/C/D
VARIABLE

SEAL	SEAL

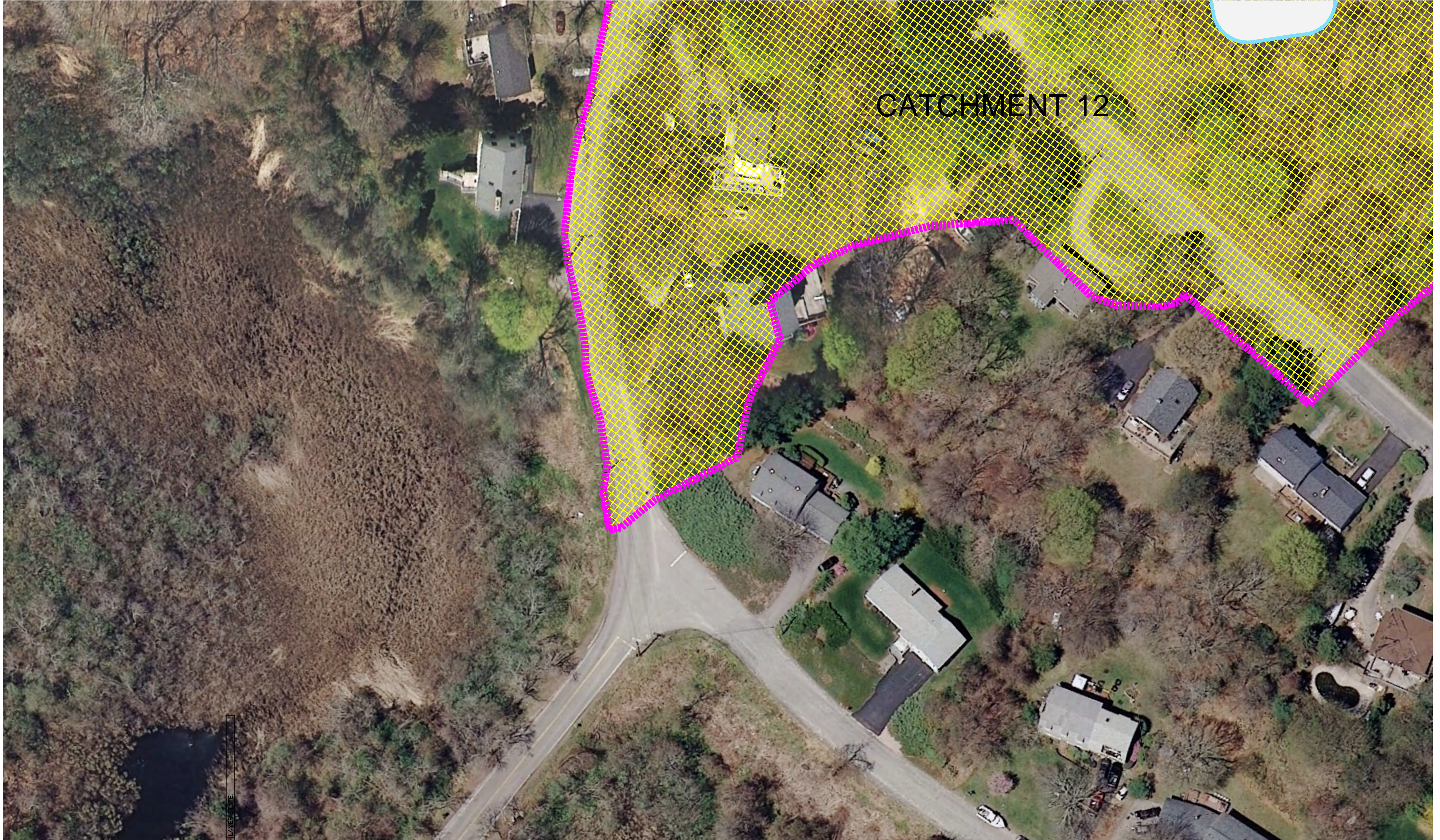
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	VERT.:	
DATUM:	HORZ.:	
	VERT.:	
GRAPHIC SCALE		

**f** **FUSS & O'NEILL**  
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1" = 30'
NAD83 NAVD88

**CS-129**  
 SOUTH KINGSTOWN

TOW  
 QUAMS



No.	DATE	DESCRIPTION
1.		

SEAL	SEAL
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<span style="color: yellow;">■</span> B	B /B/D
<span style="color: orange;">■</span> C	C /C/D
<span style="color: brown;">■</span>	VARIABLE

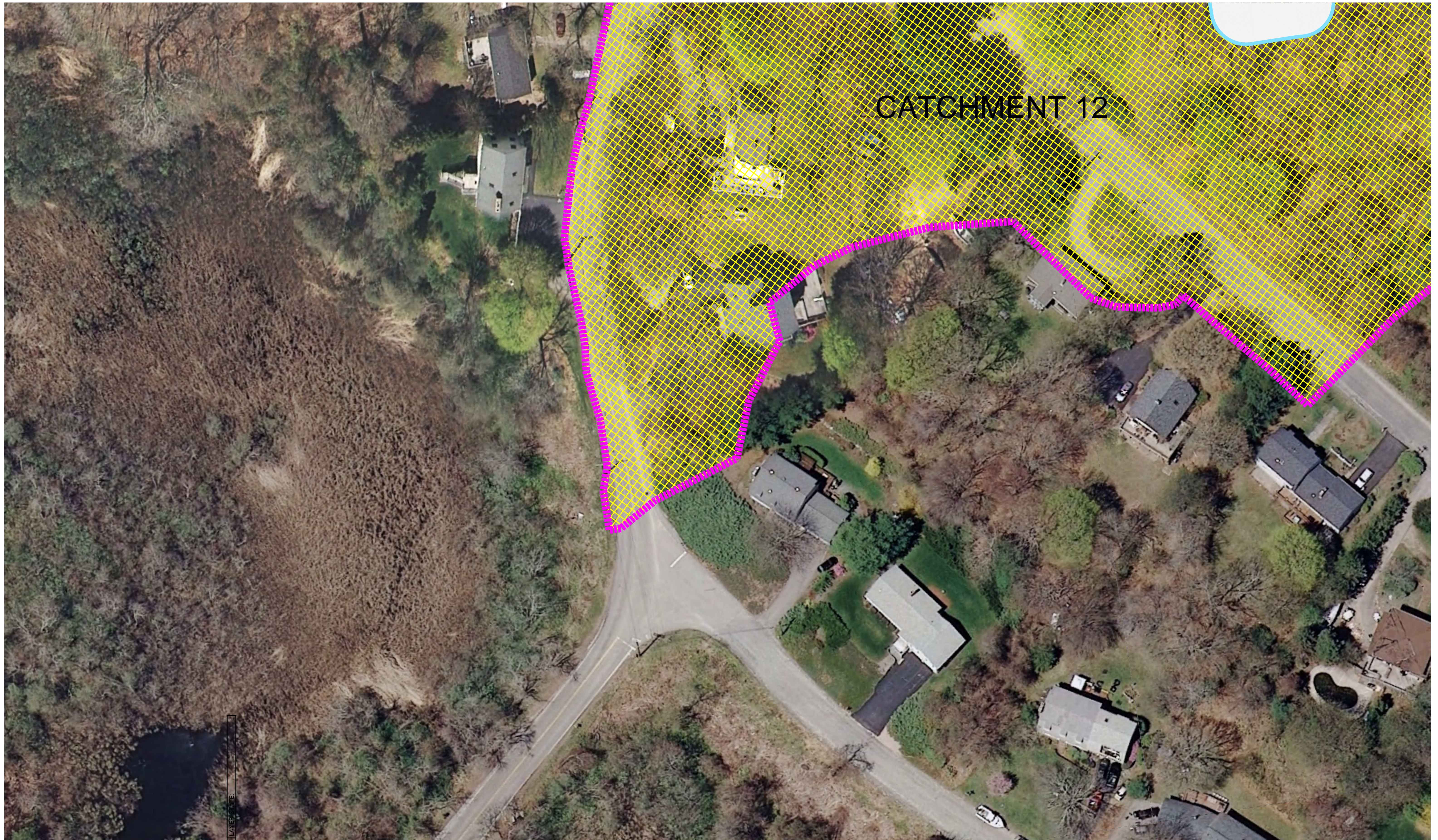
DESIGNER	REVIEWER

SCALE:	
HORZ.:	
VERT.:	
DATUM:	
HORZ.:	
VERT.:	
GRAPHIC SCALE	

**f** **FUSS & O'NEILL**  
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1" = 30'
NAD83
NAVD88

**CS-130**  
 SOUTH KINGSTOWN  
 TOW  
 JAMES



LAYER STATE

No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER

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	A /VAR							
	B /B/D							
	C /C/D							
	VARIABLE							

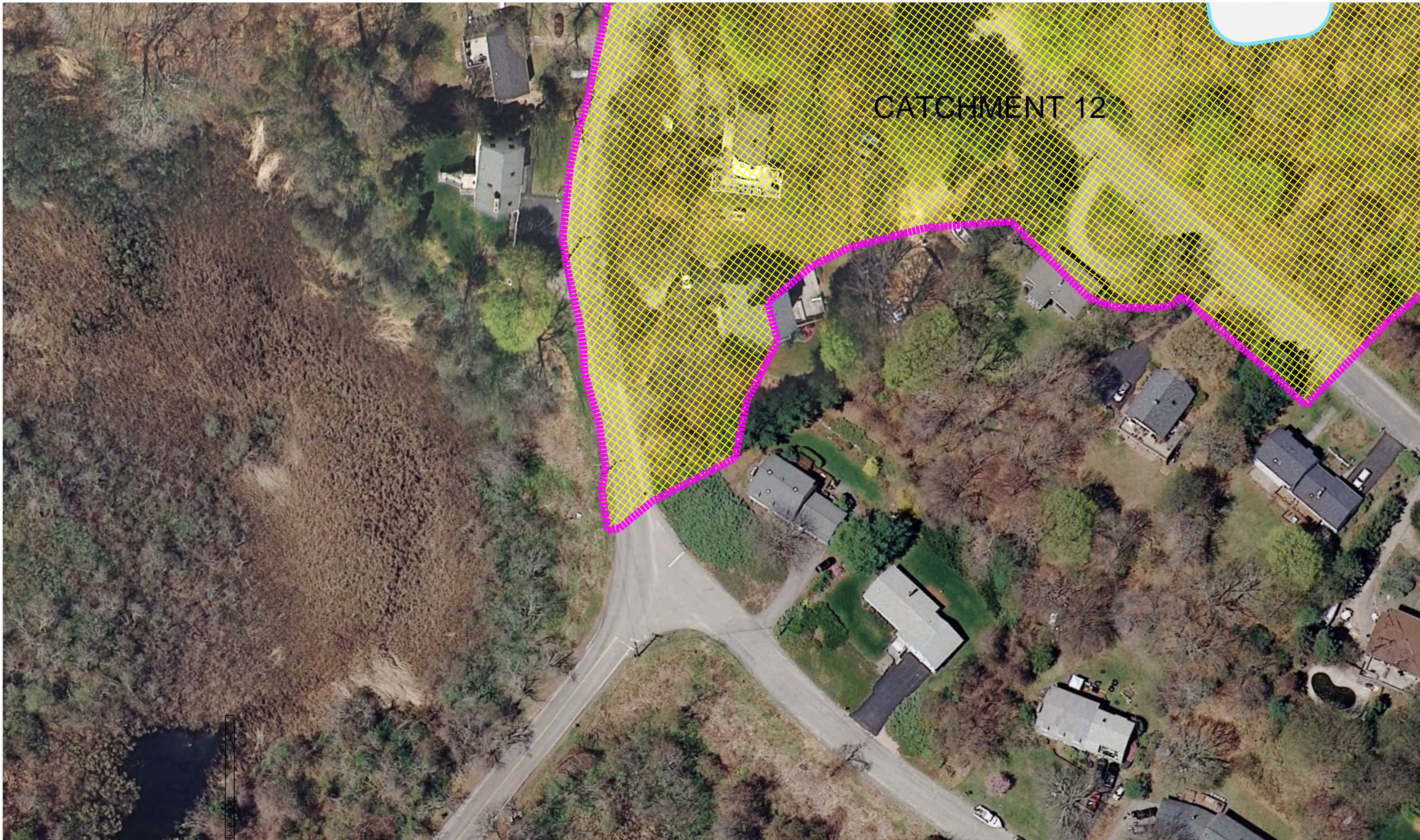
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DATUM:	HORZ.:	VERT.:
GRAPHIC SCALE		

**FUSS & O'NEILL**  
317 IRON HORSE WAY, SUITE 204  
 PROVIDENCE, RI 02908  
 401.861.3070  
 www.fando.com

1" = 30'
NAD83 NAVD88

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 Plotter: DWG TO PDF.PC3 CTB File: FO.STB



No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER	DESCRIPTION

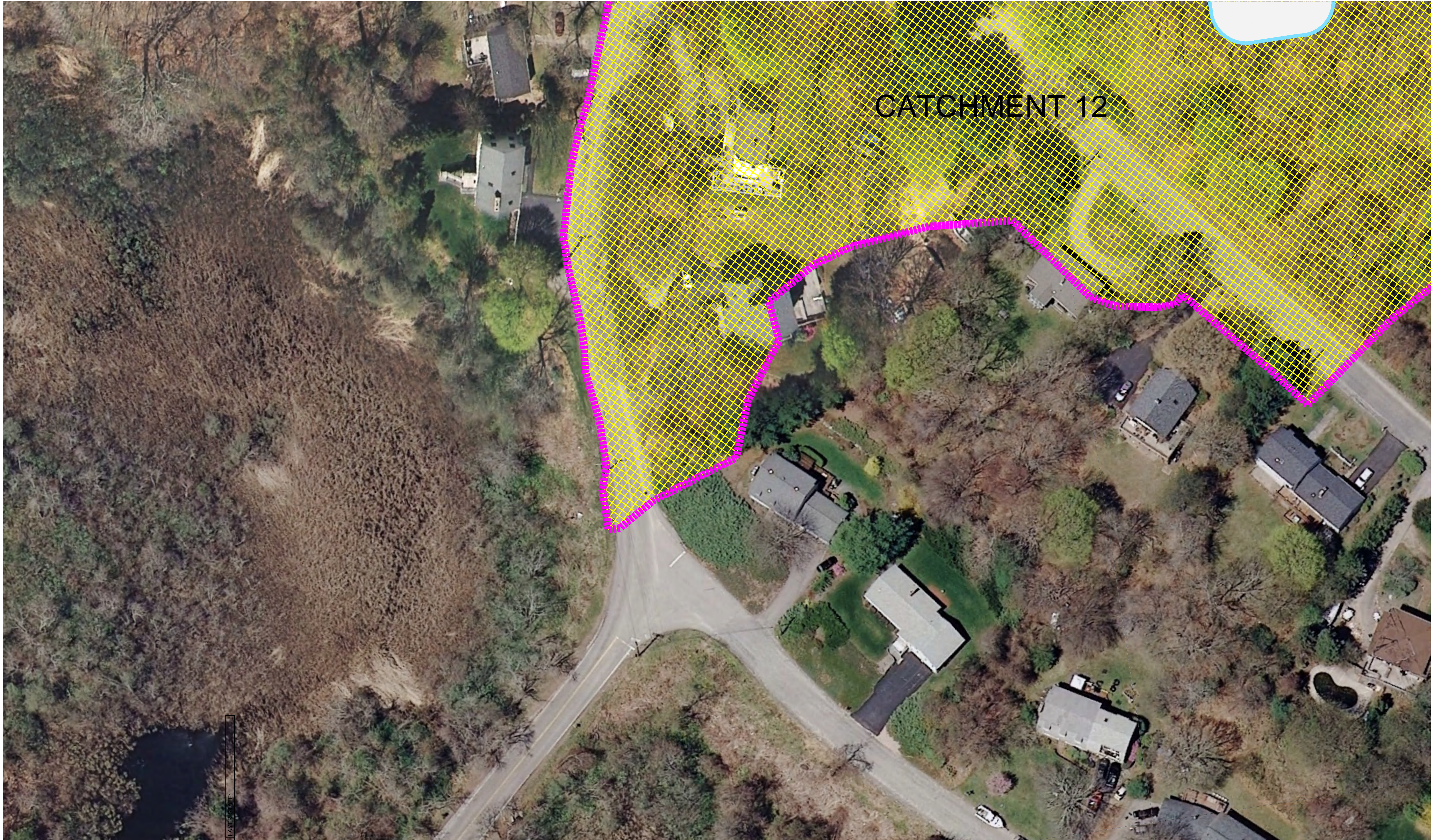
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**f** **FUSS & O'NEILL**  
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1" = 30'
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CS-132	TOW
SOUTH KINGSTOWN	1131 AQUAMS



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 Plotter: DWG TO PDF.PC3 CTB File: FO.STB

LAYER STATE

No.	DATE	DESCRIPTION
1.		

DESIGNER	REVIEWER

HYDROLOGIC SOIL GROUP
A A/VAR
B B/B/D
C C/C/D
VARIABLE

SEAL	SEAL

SCALE:	HORZ.:	VERT.:
DATUM:	HORZ.:	VERT.:
GRAPHIC SCALE		



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1" = 30'
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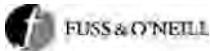
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 SOUTH KINGSTOWN

TOW  
 JAMES

## Appendix D

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### Order of Magnitude Opinion of Costs per Linear Bioretention Basins



**FUSS & O'NEILL, INC.**

317 Iron Horse Way, Suite 204  
Providence, RI 02908

OPINION OF COST		DATE PREPARED :	07/17/13	SHEET	1	OF	1
PROJECT : 20121360.A10		BASIS :					
LOCATION : Middlebridge Road, South Kingstown, Rhode Island		2012 MassDOT and RIDOT Weighted Average Unit Prices, 2009 RS Means Site and Landscaping					
DESCRIPTION Order of Magnitude Opinion of Cost for Bioretention		Construction Cost, and Previous Construction Projects.					
DRAWING NO. 20121360A10_STP02		ESTIMATOR : AMB		CHECKED BY : SDA			
<p>Since Fuss &amp; O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s) methods of determining prices, or over competitive bidding or market conditions, Fuss &amp; O'Neill's opinion of probable Total Project Costs and Construction Cost are made on the basis of Fuss &amp; O'Neill's experience and qualifications and represent Fuss &amp; O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss &amp; O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss &amp; O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.</p>							
ITEM NO.	ITEM DESCRIPTION	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST		
1	Earth/Unclassified Excavation	CY	180	\$ 30.00	\$	5,400.00	
2	Imported Soil Media (Loamy Sand or Sandy Loam)	CY	35	\$ 40.00	\$	1,400.00	
3	Topsoil (4" Depth)	CY	15	\$ 40.00	\$	600.00	
4	Seeding	SY	135	\$ 2.00	\$	300.00	
5	Clearing and Grubbing/Trimming and Fine Grading	SY	135	\$ 3.00	\$	400.00	
6	Mobilization and Demobilization (10% Project)	LS	1	\$ 900.00	\$	900.00	
7	Erosion and Sedimentation Controls	LF	320	\$ 5.00	\$	1,600.00	
8	Geotextile Fabric for Stabilization	SY	135	\$ 5.00	\$	700.00	
					\$	-	
<b>SUBTOTAL</b>					\$	<b>11,300.00</b>	
<b>CONTINGENCY (25%)</b>					\$	<b>2,900.00</b>	
<b>TOTAL COST</b>					\$	<b>14,200.00</b>	
<b>UPPER COST RANGE LIMIT (+50%)</b>					\$	<b>17,000.00</b>	
<b>LOWER COST RANGE LIMIT (-30%)</b>					\$	<b>8,000.00</b>	
<b>TOTAL COST PER LINEAR FOOT (ROUNDED)</b>					\$	<b>80.00</b>	
<b>UPPER COST RANGE LIMIT (+50%)</b>					\$	<b>110.00</b>	
<b>LOWER COST RANGE LIMIT (-30%)</b>					\$	<b>50.00</b>	
<b>TOTAL COST PER CUBIC FOOT OF STORAGE</b>					\$	<b>14.00</b>	
<b>UPPER COST RANGE LIMIT (+50%)</b>					\$	<b>17.00</b>	
<b>LOWER COST RANGE LIMIT (-30%)</b>					\$	<b>8.00</b>	

Notes: The above number of units for each item description have been modeled for Bioretention Basin 1 in Subcatchment 1A. The total cost for a bioretention basin of this size, as well as the upper and lower range limits, have been divided by the length of this particular bioretention basin to provide general costs per linear foot for bioretention basins of similar width and depth. Total cost, as well as the upper and lower range limits, have also been divided by the available water storage provided both above ground and within the filter bed to provide a rough cost estimate of bioretention basins of similar width and depth per cubic foot of storage. The length of Bioretention Basin 1 in Subcatchment 1, as well as the available water storage volume, was obtained from mkf\_BioSizing\_20130528.xlsx.

## Appendix E

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### Possible Pollutant Loading Reductions

Potential Reductions per Catchment

Catchment	Bacteria Loading (billion colonies)	Bioretention in this Catchment	Bacterial Removal Efficiency of Bioretention if Sized to treat 75% WQv	Maximum Percent WQv Actually Achievable <sup>1</sup>	Actual Percent Reduction	Bacteria Reduction (billion colonies)	NET Load After Installation (billion colonies)
Catchment 1W	341.32	Y	70%	9%	6.3%	21.50	319.82
Catchment 1E	58.21	Y	70%	97%	67.9%	39.53	18.69
Catchment 2W	250.45	Y	70%	94%	65.8%	164.80	85.65
Catchment 2E	86.71	Y	70%	100%	70.0%	60.70	26.01
Catchment 3W	240.80	N	0%	0%	0.0%	0.00	240.80
Catchment 3E	2.01	Y	70%	100%	70.0%	1.41	0.60
Catchment 4W	300.94	Y	70%	83%	58.1%	174.85	126.09
Catchment 4E	305.65	Y	70%	34%	23.8%	72.74	232.90
Catchment 5SW	269.87	N	0%	0%	0.0%	0.00	269.87
Catchment 5NW	186.92	N	0%	0%	0.0%	0.00	186.92
Catchment 5SE	12.51	N	0%	0%	0.0%	0.00	12.51
Catchment 5NE	20.63	Y	70%	100%	70.0%	14.44	6.19
Catchment 6SW	131.86	N	0%	0%	0.0%	0.00	131.86
Catchment 6NW	142.79	Y	70%	100%	70.0%	99.95	42.84
Catchment 6E	710.58	Y	70%	12%	8.4%	59.69	650.89
Catchment 7W	63.87	Y	70%	100%	70.0%	44.71	19.16
Catchment 7E	538.84	Y	70%	37%	25.9%	139.56	399.28
Catchment 8W	109.33	Y	70%	84%	58.8%	64.28	45.04
Catchment 8E	196.82	Y	70%	24%	16.8%	33.07	163.76
Catchment 9W	287.63	Y	70%	45%	31.5%	90.60	197.03
Catchment 9E	653.43	Y	70%	22%	15.4%	100.63	552.80
Catchment 10W	342.08	Y	70%	22%	15.4%	52.68	289.40
Catchment 10E	304.89	Y	70%	16%	11.2%	34.15	270.74
Catchment 11	611.03	Y	70%	33%	23.1%	141.15	469.88
Catchment 12	650.09	Y	70%	6%	4.2%	27.30	622.78
Catchment 13	843.77	Y	70%	70%	49.0%	413.45	430.32
Catchment 14	650.35	Y	70%	31%	21.7%	141.13	509.23
Catchment 15	1191.20	Y	70%	35%	24.5%	291.84	899.35
Catchment 16	285.47	Y	70%	76%	53.2%	151.87	133.60
Catchment 17	418.72	Y	70%	139%	97.3%	407.41	11.31

<sup>1</sup>From mkf\_BioSizing\_20130528.xls

## Appendix F

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### QPA Construction Specification

## QPA CONSTRUCTION SPECIFICATION

### PART 1 - GENERAL

#### 1.1 SUMMARY

- A. Section Includes:
  - 1. Pavement Removal and Replacement with Topsoil and Seed.
  - 2. Stone Diaphragm Construction.

#### 1.2 DEFINITIONS

- A. Crushed Stone Reservoir: Crushed stone to be placed within stone diaphragm trench locations at upstream lengths of QPA.
- B. Filter Fabric: Geotextile filter fabric to be placed on bottom and sides of stone diaphragm trench between the native earth and crushed stone.
- C. Topsoil: Native or imported topsoil, or surface soil modified to become topsoil; mixed with soil amendments.

#### 1.3 RECORD KEEPING

- A. Maintain records of the dimensions of pavement removed and of each stone diaphragm.

#### 1.4 CONDITIONS

- A. Prior to removal of pavement, installation of stone diaphragms or completing any earthwork, contact DIG SAFE at 811 and wait to preform work until the DigSafe ticket has been issued.

#### 1.5 COORDINATION

- 1. Coordinate the removal of sections of the existing pavement with the appropriate authorities within the Public Services Department.
- 2. Coordinate with utility companies present in the area to avoid interruption of services.

### PART 2 - PRODUCTS

#### 2.1 TOPSOIL

- A. Topsoil Media: The imported soil media shall be a uniform mix, free of stones, stumps, roots or other similar objects larger than two inches. No other materials or substances should be mixed or dumped within the soil that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The soil should be free of noxious weeds. The top soil shall have a pH range of 5.5 to 7 and a minimum of 6 percent and a maximum of 20 percent organic material.

2.2 SEED MIX

- A. The seed mix can either be spread in the dry or by means of hydroseeding. Dependent on the area of application a lawn seed mix, a wetland seed mix or a tall grass mix can be used to initially stabilize the site. Suggested seed mixes for the above referenced mixes are below:
  - 1. Lawn seed mix: Fine fescue, perennial ryegrass, and bluegrass mixes.
  - 2. Wetland seed mix: Use New England Wetland Plants Roadside Matrix Upland Seed Mix (species include Virginia Wild Rye, Little Blue Stem, Creeping Red Fescue, Big Bluestem, Indian Grass, Switch Grass and assorted wild flowers.
  - 3. Tall grass mix: Ryegrass and fescue.
- B. Apply seed at application rate indicated by manufacturer.

2.3 CRUSHED STONE

- A. Crushed stone shall consist of material composed of uniformly graded 1-inch to 2-inch crushed stone forming to the gradation requirements of M.01.09 Table 1 from the RIDOT Standard Specifications for Road and Bridge Construction Amended December 2010 (see below):

**M.01.09 GRADATION OF AGGREGATES.** Aggregates for use in base and subbase courses and other applications shall conform to the gradation requirements indicated in the following Table I.

Table I

Sieve Size	Gradation - Percent Passing						
	I Gravel Borrow		II Crushed Stone	III	IV	V	VI
	la Bank Run Proc Sand/ Gravel	lb Reclaimed Processed Material	Crushed Stone or Crushed Gravel	Keystone	Pervious Fill	Filter Stone	Cover Stone
3"	60-100	100			100		
2 1/4"			100				
2"			90-100				
1 1/2"		70-100	30-55				
1 1/4"			0-25				
1"			0-5	100		100	
3/4"		50-85		90-100		70-85	100
1/2"	50-85			20-55		10-40	90-100
3/8"	45-80			0-20		0-20	30-60
#4	40-75	30-55		0-5	30-100	0-5	0-15
#8							0-5
#40	0-45						
#50		8-25					
#200	0-10	2-10			0-8		

## 2.4 GEOTEXTILE FILTER FABRIC

- A. Filter fabric shall be Mirafi 180N or comply with the following standards: nonwoven needle-punched geotextile, manufactured for subsurface drainage applications and placed in accordance with the manufacturer's instructions. It shall be made from polyolefins or polyesters with a weight of at least 8 oz. per square yard; with elongation greater than 50 percent; complying with ASSHTO M288 and the following minimum properties, measured per test methods referenced:
1. Survivability: Class 2; ASSHTO M288.
  2. Grab Tensile Strength: 205 lbf; ASTM D 4632.
  3. Sewn Seam Strength: 142 lbf; ASTM D 4632.
  4. Tear Strength: 75 lbf; ASTM D 4533.
  5. Puncture Strength: 130 lbf; ASTM D 4833.
  6. Apparent Opening Size: No. 80 sieve, maximum; ASTM D 4751.
  7. Permittivity: 1.35 per second, minimum; ASTM D 4491.
  8. UV Stability: 70 percent after 500 hours exposure; ASTM D 4355

## PART 3 - EXECUTION

### 3.1 PAVEMENT REMOVAL

- A. Preparation: Protect and maintain surrounding structures, utilities, sidewalks, adjacent pavement and other facilities from damage during removal and disposal of pavement. Protect and maintain benchmarks and survey control points from disturbance during construction.
- B. Remove and dispose roadway pavement (bituminous and concrete), aggregate base, and curbs (including returns, if any) within limits of pavement to be removed.
1. Take care to protect adjacent and adjoining structures during removal.
  2. Neatly sawcut length of pavement to remain before removing existing pavement. Sawcut faces vertically.
    - a. If sawcut edges of roadway are damaged during construction they shall be sawcut again to produce clean edges.
  3. All pavement removed shall be properly disposed of off-site.

### 3.2 STONE DIAPHRAGM

- A. Preparation: Protect surrounding structures, utilities, sidewalks, pavements and other facilities from damage caused by settlement, lateral movement, undermining, washout and other hazards created by earth moving operations.
- B. Excavate to indicated elevations and dimensions immediately adjacent to the newly cut or existing edge of pavement. Do not disturb bottom of excavation. Trim bottoms to required lines and grades to leave solid base to receive other work.

- C. Place the filter fabric over the entire bottom of the excavation extending the edges up the side of the excavated area. Overlap geotextile joints 12 inches or per manufacturer's instructions.
- D. Install crushed stone within trench to match surrounding grade. Ensure stone is compacted (by hand) so that movement or settlement will not significantly reduce the volume of stone in the trench. To do this, place stone in 6-inch lifts and hand compact after each lift.
- E. Cut excess filter fabric from edges at the surface between the native ground and new stone.

### 3.3 TOPSOIL AND SEEDING

- A. Immediately following installation of stone diaphragm, the disturbed areas (specifically the areas where pavement has been removed) shall be covered in 4 inches of topsoil and seed.
  - 1. Remove stones larger than one inch in any dimension, sticks, roots, rubbish and other extraneous material from the site to be seeded and legally dispose of them.
  - 2. Spread topsoil to a depth of 4 inches, but not less than required to meet finished grades after settlement. Do not spread topsoil if topsoil or subgrade is frozen, muddy or excessively wet.
  - 3. No seed shall be spread during high winds or when the ground is not in proper condition for seeding. Equipment shall be operated in a manner to ensure complete coverage of the entire area to be seeded.
- B. Provide erosion control measures to prevent erosion or displacement of soils and discharge of soil-bearing water runoff or airborne dust to adjacent properties.
- C. Maintain seeded areas until a healthy, well-rooted, vegetative cover has established with a 90% density free of weeds, open joints, bare areas and irregularities. This will include watering as needed to ensure proper growth. If satisfactory cover is not established, reseed and maintain area until established.

### 3.4 CLEANING

- A. Perform cleaning of stone during the installation and upon completion of the Work.
- B. Remove from site all excess materials, debris and equipment. Remove tracked materials and any other materials from pavement to remain.
- C. Repair any damage to adjacent materials and surfaces resulting from the Work.

END OF SECTION