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CONCEPTUAL POLLUTION AND STORMWATER CONTROL STRATEGY FOR THE ANCHORAGE CANAL DRAINAGE AREA

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The Anchorage Canal is the northernmost canal in South Bethany and it connects to Little Assawoman Bay. Relative to other canals in South Bethany, it has a large drainage area of 125 acres, 55% of which is impervious cover. Areas of Coastal Highway (Route 1) and its western commercial strip, as well as portions of the Sea Colony high rise complex, the Middlesex Beach community and the Town of South Bethany drain into the canal. Existing studies show that high levels of nitrogen, hydrocarbons, and sediment enter the canal from the watershed, which produces runoff even during light rains. Much of the runoff is collected through a series of stormwater drains along Route 1 and is piped untreated to the Loop Section of the canal. The South Bethany Canals and the Little Assawoman Bay are in poor condition and experience unhealthy levels of dissolved oxygen and bacteria, and dense blooms of algae. Stormwater is a major source of pollutants for these water bodies.

In response to these water quality impairments, the Delaware Department of Natural Resources and Environmental Control (DNREC) listed the Inland Bays Drainage Basin on several of the States 303(d) Lists and mandates a Total Maximum Daily Loads (TMDLs) regulation of 23 percent reduction in bacteria from the 2000-2005 baseline levels in the fresh water portion of the Inland Bays Drainage Basin (DGA, 2006). In addition, DNREC has mandated a TMDL regulation of 40 percent reduction in total nitrogen (TN) and total phosphorus (TP) in the Little Assawoman Bay Watershed (DGA, 2005). To help meet the TMDL regulations, the Pollution Control Strategy for the Inland Bays calls for the stormwater retrofitting of 4,500 acres of urban and residential lands within the watershed (DNREC, 2008).

The severity of water quality problems here, combined with the willingness of participation from multiple communities within a small drainage makes a good choice for a stormwater retrofit demonstration project. Similar conditions exist for the Anchorage Canal drainage area and the drainage areas of adjacent canals in the Inland Bays watershed. Therefore, the types of projects identified within the study are likely to be highly transferrable to these additional drainage areas and the implementation of projects within the Anchorage Canal drainage area can serve for demonstration purposes.

This memorandum presents a conceptual pollution and stormwater control strategy for the Anchorage Canal Drainage area based on field assessments conducted August 19, 2009. Field teams conducted a stormwater retrofit inventory and upland pollution prevention assessment to identify potential restoration opportunities using protocols described in Manuals 3 and 11 of the Small Urban Watershed Restoration Manual Series, *Stormwater Retrofit Practices* (Schueler et al., 2007) and *Unified Subwatershed and Site Reconnaissance User's Guide* (Wright et al., 2005), respectively. Table 1 below provides a summary of the retrofit project opportunities identified during fieldwork, including estimated construction cost and the extent to which they meet the TMDL goal of 40% reduction in TN and TP. A more detailed retrofit summary and explanation of calculations is provided in *Section 3.0: RRI Findings and Recommendations*.

Table 1. Summary of Retrofit Project Opportunities						
Location	**Retrofit ID**	**Proposed Practice**	**Drainage Area (acres)**	**Estimated Construction Cost**	**% of TN TMDL Goal**	**% of TP TMDL Goal**
South Pennsylvania Avenue	R1a	Replace compacted gravel with pervious reinforced turf	1	$71,014	1.6%	4.0%
	R1b	Convert existing ditch to sediment forebay	14	$6,094	-	-
Sea Colony	R2a	Convert existing ditch to wet swale and add filter strips	31	$41,043	5.2%	6.0%
	R2d	Add short control structure upstream of driveway culverts				
	R2b	Create sediment forebays for existing wet pond	5	$24,415	-	
	R2c	Install filter strip at Sea Colony promenade	1	$19,349	0.8%	1.8%
	R2e	Convert existing ditch to wet swale and construct additional curb openings	42.5	$31,216	4.5%	5.2%
	R2f	Add short control structure upstream of sidewalk crossings				
	R2g	Convert existing stone-lined swale to grass swale and add curb openings				
	R2i	Convert existing stone-lined swale to grass swale and add curb openings				
	R2h	Construct wet pond on land-locked parcel	41.5	$335,470	9.1%	38.8%
Coastal Hwy	R3	Construct Coastal Hwy median bioretention	1.01	$23,169	1.4%	3.0%
	R4a	Construct bioretention along right-of-way	0.84	$12,928	0.9%	2.0%
	R4b	Construct Coastal Hwy median bioretention	0.51	$14,203	0.6%	1.5%
	R4c	Cap underdrain in bioretention to promote infiltration	0.39	< $100	0.8%	1.7%
	R5a	Construct bioretention along right-of-way	0.56	$11,322	0.7%	1.5%
	R5b	Construct Coastal Hwy median bioretention	0.65	$16,165	0.8%	1.8%
	R6a	Construct bioretention along right-of-way	1.11	$12,662	0.7%	1.5%
	R6b	Construct Coastal Hwy	0.48	$13,989	0.6%	1.4%

		median bioretention				
	R7a	Construct bioretention along right-of-way	1.55	$10,502	0.5%	1.0%
	R7b	Construct Coastal Hwy median bioretention	0.58	$15,612	0.8%	1.6%
	R8a north	Construct bioretention along right-of-way	0.24	$8,376	0.3%	0.6%
	R8a south	Construct bioretention along right-of-way	0.28	$7,401	0.3%	0.5%
	R8b	Construct Coastal Hwy median bioretention	0.39	$12,379	0.5%	1.1%
Anchorage Canal Loop Section	R9	Construct wetland at canal forebay	85	$235,813	6.0%	30.7%

The purpose of this memo is to document field activities, provide a summary of fieldwork findings, map locations of potential restoration opportunities, and provide overall management recommendations. This technical memo is organized into the following parts:

Section 1.0: Methodology
Section 2.0: USSR Findings and Recommendations
Section 3.0: RRI Findings and Recommendations
Section 4.0: References

Appendix A: Field Forms
Appendix B: Photos (on CD)
Appendix C: Stormwater Retrofits Concepts
Appendix D: Routine Maintenance Requirements

1.0 Methodology

Field assessments were conducted on August 19, 2009 by 3 field teams; one conducted the Unified Subwatershed and Site Reconnaissance (USSR) and two conducted the Retrofit Reconnaissance Investigation (RRI). The Anchorage Canal drainage area, as well as the field sites, is shown in Figure 1. A schedule of fieldwork, staffing breakdown, and assessment sites of each field team is presented in Table 2. The remainder of this section details the USSR and RRI assessments and their applicability to the Anchorage Canal drainage area.

Figure 1. Anchorage Canal drainage area and field assessment sites. N indicates a neighborhood assessment site and R indicates a retrofit site.

Table 2. Anchorage Canal Drainage Area Field Assessment Teams		
Team ID	**Team Members**	**Assessment Sites**
USSR Team #1	Lisa Fraley-McNeal (Team Lead - CWP) Chris Bason (CIB) George Junkin (South Bethany) Buzz Henfin (Fenwick Island)	Entire Drainage Area (N1, N2, N3, N4)
Retrofit Team #1	Greg Hoffmann (Team Lead - CWP) Susan Barton (Univ. of DE) Marianne Walch (DelDOT) Dave Wieking (Middlesex Beach)	Middlesex Beach (R3, R4, R5, R6, R7, R8)
Retrofit Team #2	Larry Trout (Team Lead - JMT) Patrick Davis (SeaColony) Aaditya Pise (JMT)	SeaColony (R1, R2)

1.1 Unified Subwatershed and Site Reconnaissance (USSR)

The Unified Subwatershed and Site Reconnaissance (USSR) is a rapid field survey designed to evaluate potential pollution sources and restoration opportunities in upland areas of a subwatershed where neighborhoods and businesses are located. The concept behind the USSR is to provide a quick but thorough characterization of all upland areas to identify major pollutant source areas and control them through source controls, pervious area management, and improved municipal maintenance. Two major assessment components of the USSR utilized as part of this investigation were the Neighborhood Source Assessment (NSA) and Hotspot Site Investigation (HSI). For detailed information about the USSR, refer to Wright et al., 2005. NSA and HSI field forms are included in Appendix A and photos are in included in Appendix B.

1.1.1 Neighborhood Source Assessment (NSA)

The NSA profiles pollution source areas, stewardship behaviors, and residential restoration opportunities within individual neighborhoods. Each residential neighborhood usually has a distinctive character in terms of age, lot size, tree cover, drainage, lawn size, general upkeep, and resident awareness. In addition, neighborhoods are often rather homogenous when it comes to resident behaviors, stewardship, and involvement in restoration efforts. These unique characteristics directly influence the ability to widely implement restoration practices, such as on-site retrofits, neighborhood source controls, and better stewardship.

The first step when conducting the NSA is a desktop analysis to delineate neighborhoods within the subwatershed. Geographic Information System (GIS) data layers (parcel boundaries, roads, etc.) and aerial photos were used to analyze neighborhoods within the Anchorage Canal drainage area. Distinct neighborhoods were delineated according to basic lot size, road widths, setbacks, and house types. A total of four neighborhoods were identified within the drainage area, and include:

- N1 – Bethany Beach
- N2 – Middlesex Beach
- N3 – South Bethany
- N4 – South Bethany

While some neighborhood characteristics can be discerned from maps and aerial photographs, field assessments are needed to get quantitative data on pollutant source areas and their restoration potential. Every street within the four neighborhoods was driven as part of the assessment and the NSA field forms were used to document the stormwater-related practices of the residents, such as the prevalence of trash, fertilizer use, storm drain stenciling, etc. Field forms are available in Appendix A.

1.1.2 Hotspot Site Investigation (HSI)

The HSI evaluates the pollution-producing behaviors at commercial, industrial, institutional, municipal, or transport-related operations that produce higher levels of stormwater pollutants, and/or present a higher potential risk for spills, leaks or illicit discharges. Each hotspot has its own unique operations, drainage system, and potential pollution risk. As a result, each hotspot must be individually inspected and the HSI field form used to document current practices, spill risks, and stormwater problems. Potential structural or operational practices are then identified to help minimize or eliminate stormwater contamination.

The entire Anchorage Canal drainage area was driven in search of potential hotspots, with particular attention to the commercial strip along the west side of Coastal Highway. However, no potential hotspots were identified as part of this investigation.

1.2 Retrofit Reconnaissance Investigation (RRI)

The RRI identifies potential treatment practices designed to address stormwater quantity or quality where no practice previously existed. These treatment practices, also known as retrofits, are designed to store, infiltrate, and/or treat stormwater runoff from as much development as possible. Stormwater retrofits differ from "regular" treatment practices mainly in terms of when they are installed – they are installed well after development is complete, rather than during or even before construction. For this reason, stormwater retrofitting can sometimes be difficult. Finding the space available to install stormwater treatment practices without negatively impacting existing uses of the land is not always possible. For additional information about the RRI, refer the Schueler et al., 2007. RRI field forms are included in Appendix A and photos are in Appendix B.

The overall objective for the RRI is to reduce stormwater runoff volumes and pollutants to the maximum extent practicable across the Anchorage Canal drainage area given the built-out nature of and extensive development within the watershed. The retrofit goals in Table 3 are presented to outline the key performance targets for individual retrofits.

Table 3. Retrofit Objectives	
Description	**Primary Objectives**
Target Pollutant Removal Volume	1. Retrofits shall reduce pollutants of concern from the sites they capture. The goal is a 40% reduction in N and P, and a 23% reduction in bacteria.
Description	**Secondary (Community Benefits) Objectives**
Coastal Concerns	2. Retrofits shall account for the potential effects of future sea level rise and storm impacts.
Aesthetics, Safety, Nuisance Concerns	3. Retrofits shall be well-integrated into the native coastal vegetation landscape and not cause any risk to public safety or nuisance issues.
Education and Outreach	4. Provide outdoor learning and community outreach opportunities on public and private lands.
Maintenance	5. Retrofits shall require the minimum amount of maintenance possible.
Drainage Problems	6. Retrofit designs shall work towards alleviating existing drainage problems when feasible.
Habitat	7. Create desirable wildlife habitat areas.
Naturalization and Recreation	8. Support existing greenway, trail, and stream corridor naturalization efforts, while not interfering with existing active recreational uses.
Land Acquisition	9. Identify potential land acquisition opportunities that would enable the construction of retrofits or of new stormwater BMPs.

A desktop assessment utilized aerial photographs and GIS data, including topographic data, property boundaries, and storm sewer information to identify potential retrofit locations. Ideal retrofit locations are those which already collect stormwater runoff (relative low points in the landscape) and have the space available to treat the runoff without significantly disrupting existing uses of the site. Government properties, parks, schools, churches, and wide road right-of-ways are the types of sites that can be identified as potential retrofit locations on the desktop analysis. The desktop analysis for the Anchorage Canal drainage area identified nine potential retrofit sites at commercial and residential sites along Coastal Highway. These sites include:

- R1 – Pennsylvania Ave at north end of watershed
- R2 – SeaColony
- R3 – Coastal Highway Median at north end of watershed
- R4 – Adjacent to Jack Hickman Real Estate and Resort Quest
- R5 – Adjacent to Shore Foods
- R6 – Adjacent to Dollar General and Seaside Village
- R7 – Adjacent to Long and Foster Realtors
- R8 – Adjacent to McDonald's and Bennett Realty
- R9 – Sediment Forebay in Anchorage Canal Loop Section

Each of the sites was assessed in the field by one of the two retrofit teams. Field work involved visiting the site, analyzing the drainage patterns to determine the contributing drainage area to the site, taking photographs, and making measurements to determine potential stormwater retrofit feasibility. Upon completion of fieldwork, the initial intent was to rank each stormwater retrofit project based on factors derived from the goals in Table 3. However, due to the limited number of retrofit types identified, each project should be considered individually, rather than scored against one another for implementation. For example, the retrofit concept developed for businesses along the west side of Coastal Highway (R4, R5, R6, R7, R8) was transferrable among each of the businesses. Although individual retrofits were not ranked, water quality volume estimates and/or pollutant removal estimates, as well as cost estimates for most of the retrofit concepts are provided to help determine the feasibility of each project.

2.0 USSR Findings and Recommendations

2.1 Residential Stormwater Practices, Education and Pollution Prevention

The four neighborhoods within the Anchorage Canal drainage area exhibit similar characteristics, independent of their age and location within the drainage area. These similar characteristics include:

- Single family detached housing with ¼ acre average lot size or less
- The average lot consists of approximately 40-50% impervious cover, 30% gravel/rock cover, 10-15% landscaping, and 10-15% grass cover
- Open section roads, without a curb and gutter system
- No downspouts directly connected to storm drains or sanitary sewer (except for homes along Anchorage Canal). Approximately 75% or more of the downspouts are directed to pervious areas. The remaining 25% are directed either to impervious cover or French drains.

Based on observations made during the NSA, a variety of stormwater treatment, education, and pollution prevention practices are recommended throughout the neighborhoods within the drainage area and are listed in Table 4. The Inland Bays Pollution Control Strategy (PCS) identifies education as a general principle needed "across the board," with emphasis on the younger generation (DNREC, 2008). All of these recommendations serve as education opportunities for homeowners to teach them about pollution prevention and stormwater treatment within their neighborhoods.

Table 4. Neighborhood Recommendations

Recommendation	N1 Bethany Beach Area: 17.3 ac # Lots: 89	N2 Middlesex Beach Area: 18.3 ac # Lots: 79	N3 South Bethany Area: 5.2 ac # Lots: 27	N4 South Bethany Area: 23.4 ac # Lots: 153
Lawn care Education	X	X	X	X
Downspout and Outdoor Shower Disconnection				X
Storm Drain Stenciling/Marking			X	X
Impervious Cover Reduction	X	X	X	X
Inlet Retrofits				X

2.1.1 Lawncare Education

Although the average grass cover on individual lots was only 10-15%, a majority was medium to highly managed. Highly managed turf is defined as lawns where fertilizers, pesticides, and irrigation appear to be used to maintain a dense grass cover, which can result in polluted stormwater runoff. Lawns that are lush, dense, and consistently green may suggest the use of fertilizers and/or herbicides, particularly if they are managed by a lawn care company. Pollutants from the lawn can be washed into storm drains from either rainfall or routine lawn watering. Figure 3 illustrates some of the typical lawn conditions found throughout the drainage area.

Figure 3. Typical lawn care conditions within the drainage area. From left to right: lawn facing the Anchorage Canal in N4 (South Bethany), N2 (Middlesex Beach), N1 (Bethany Beach).

The ideal behavior in terms of water quality is to avoid lawn fertilization entirely. The next best thing for homeowners who feel they must fertilize is to practice natural lawn care: using low inputs of organic or slow release fertilizers that are based on actual needs as determined by a soil test. Two approaches have shown promise in changing fertilization behaviors within a neighborhood, and both involve direct contact with individual homeowners. The first relies on using neighbors to spread the message to other residents, through master gardening programs. Individuals tend to be very receptive to advice from their peers, particularly if it relates to common interest in healthy lawns. The second approach is similar in that it involves direct assistance to individuals at their homes (e.g., soil tests and lawn advice) or at the point of sale. The most common techniques for changing fertilization behaviors include:

- seasonal media awareness campaigns
- distribution of lawn care outreach materials (brochures, newsletters, posters, etc.)
- direct homeowner assistance and training
- master gardener program
- exhibits and demonstration at point-of-sale retail outlets
- free or reduced cost for soil testing
- training and/or certification of lawn care professionals
- lawn and garden shows on radio
- local restrictions on phosphorus content in fertilizer

The Delaware Nutrient Management Commission (DNMC) has produced a brochure on proper lawn maintenance and distributes them through most retail outlets that sell fertilizer in the Inland Bays Watershed. The Inland Bays Tributary Action Team has also run an advertisement about proper lawn care on a local television station (DNREC, 2008). These education programs should be evaluated to ensure they are reaching the residents within the Anchorage Canal drainage area. In addition, a more stringent educational program focusing on the drainage area should also be developed.

Lawn care education and outreach costs will vary depending on the approach taken. In general, lawn care advice ranges from $1.75 to $3.20 per household (Schueler et al., 2005). Rain gardens on individual homeowner properties are also a feasible option within the drainage area to reduce turf cover, treat runoff, and create aesthetic appeal. The average cost of homeowner installation of rain gardens is $3 to $5 per square foot (CIB brochure; Schueler et al, 2007).

Recommendations and comments from the November 2009 Strategy Meeting include:

- A master gardener program does exist. Sally Boswell is the contact.
- CIB educators need to work more closely with property owners' associations.
- Person-to-person education is important. In addition, targeting specific homeowners with highly managed lawns is a good strategy.
- A demonstration yard that includes xeriscaping/rain gardens would be beneficial. Green grass is difficult to achieve in the region without heavy fertilizer use.
- An incentive program, such as Gardens by the Sea could be effective.

2.1.2 Rooftop Downspout and Outdoor Shower Disconnection for Homes along Anchorage Canal

Many of the homes in N4 (South Bethany) that are directly adjacent to the Anchorage Canal have rooftop downspouts and outdoor showers that are piped directly into the canal. A simple recommendation for these homes is to disconnect the downspouts and showers to pervious areas on the individual properties. This would allow the water to infiltrate and help prevent the discharge of pollutants into the canal. Figure 4 shows some of the outfalls draining to the canal from rooftop downspouts and outdoor showers. In the case of outdoor showers, disconnection may require addition of loose gravel around the shower to aid infiltration and avoid creation of muddy areas.

Figure 4. Examples of rooftop downspout and outdoor shower discharge directly into the Anchorage Canal from N4 (South Bethany).

The average cost for simple disconnection of a downspout is $25 to cover the cost of necessary materials. In addition to simple disconnection, rain barrels may be installed at a cost ranging from $50 to $300 per 55 gallon rain barrel (Schueler et al., 2007). For disconnection of outdoor showers, french drains may be needed to promote infiltration and prevent water ponding. The average cost of french drains ranges from $15 - $17 per linear foot (Schueler et al., 2007).

Recommendations and comments from the November 2009 Strategy Meeting include:

- Talking with homeowners to have them voluntarily disconnect their downspouts and outdoor showers is the best approach.
- Providing technical and financial assistance to homeowners is important.
- Rain barrels and stormwater planters are an option. Ace Hardware has square, tan rain barrels designed to look better than the traditional barrels constructed of recycled food containers. In addition, the Rain Gardens for the Inland Bays program could be promoted in the Anchorage Canal drainage area.

2.1.3 Storm Drain Stenciling/Marking

None of the storm drain inlets in the neighborhoods had stenciling or markers. These inlets are sometimes used as a means of disposal for trash, yard waste and household products. Storm drain stenciling/marking teaches residents that what enters a storm drain eventually goes downstream, or in this case, to the Anchorage Canal. A message, such as, "Don't dump, drains to Anchorage Canal" sends a clear message to keep trash and debris, leaf litter and organic matter out of the storm drain system. Stenciling/marking may also reduce residential spills and illicit discharges. Examples of residential inlets are provided in Figure 5.

Figure 5. Examples of storm drain inlets that are not stenciled or marked. Left – N3 (South Bethany) and Right – N4 (South Bethany).

The cost of stenciling materials generally ranges from $300 to $400 per neighborhood (Schueler et al., 2005). However, the cost may be lower in the Anchorage Canal drainage area due to the limited number of inlets.

Recommendations and comments from the November 2009 Strategy Meeting include:
- Beth Krumrine is the contact at DNREC that can help with storm drain stenciling.

Recommendations and comments from the May 2010 Public Meeting include:
- The collection of organics and household hazardous waste would help prevent people from dumping material down the storm drain.
- There is currently only one drop-off day per year and there are many waste items that are not collected. The suggested collection frequency is four times per year.

2.1.4 Impervious Cover Reduction

For all neighborhoods within the Anchorage Canal drainage area, individual lots contain an average of 40-50% impervious cover (rooftops, decks, sidewalks, and driveways) and 50-60% pervious cover (landscaping, grass cover, and gravel cover). Most houses have pervious driveways in the form of gravel cover, which is preferable to paved driveways in terms of residential stormwater management. However, as redevelopment and remodeling take place within the neighborhoods, the trend is for residents to increase impervious cover in the form of decks, patios, walkways, home additions, and paved driveways. This is contributing to stormwater ponding throughout the neighborhoods, which has been noted as one of the main homeowner concerns. Figure 6 shows examples of impervious cover trends throughout the neighborhoods.

Figure 6. Examples of impervious cover trends throughout the neighborhoods. Top Left – Pervious gravel driveway half converted to impervious cover driveway in N4 (South Bethany); Top Right – Large portion of lot converted to impervious cover to serve as a parking area in N2 (Middlesex Beach); Bottom Left – Large portion of lot converted to impervious cover to serve as a parking area in N3 (South Bethany); and Bottom Right – The conversion of gravel driveways to impervious cover has led to water ponding along the right of way in N1 (Bethany Beach).

One solution to deter homeowners from increasing impervious cover on their lots is an impervious cover ordinance, which restricts the amount of impervious cover that is allowable on individual lots. Homeowners must instead use pervious materials, such as gravel, mulch, grass, shells, natural vegetation, sand, or permeable pavers. An example of an effective impervious cover ordinance from Fenwick Island is provided below.

- Fenwick Island, DE – "No part of any required building setback area in the front, rear or side of any lot in the Residential Zone may be covered or paved with impervious or semi-impervious materials such as concrete, asphalt, brick, flagstone, etc., for driveways, parking spaces or any other purpose except for a single walkway, no more than three feet in width, in any front, rear or side yard. Such coverings or pavings existing at the time of enactment of this subsection may continue to be used and repaired as a nonconforming use but may not be expanded in any horizontal dimension nor rebuilt or replaced with such materials." (Fenwick Island Town Code, §160-6A(11))

An educational program encouraging the use of permeable pavers is another solution to prevent homeowners from installing additional impervious cover. Permeable Interlocking Concrete Pavement (PICP) consists of concrete pavement separated by joints filled with small stones (www.icpi.org). It treats and reduces stormwater runoff from impervious surfaces and can also allow for surface storage or infiltration of runoff, which can reduce stormwater flows, compared to conventional surfaces, like concrete or asphalt pavement. The transformation of gravel lots to impervious cover appears to occur as part of redevelopment when homeowners are making improvements to their properties. Many of the homeowners have chosen designs of impervious pavement in their driveways that are similar to the design of permeable pavers. Figure 7 provides an example of the impervious driveway designs identified throughout the neighborhoods. An education program for permeable pavers would be beneficial in encouraging homeowners to utilize permeable pavement. This program could guide homeowners through the process of installing permeable pavement, such as choosing materials and design, and identifying a certified contractor. In addition, a demonstration project at a highly visible residential lot within the drainage area could provide homeowners with a first-hand look at the benefits of permeable pavement, including:

- increased property value and aesthetic appeal
- reduced stormwater runoff and water ponding in neighborhoods
- simplified repairs over conventional pavement
- cooler temperature than conventional pavement

Figure 7. Many impervious surfaces utilized for driveways within the neighborhoods are similar to the design of permeable pavers. Both photos are from N3 (South Bethany). The photo on the right appears to have permeable pavement between the driveway and the right of way, but the base of the pavers is actually impermeable.

In addition to driveway applications, permeable pavers can be used to help address seasonal parking and reduce impervious cover. Figure 8 provides examples of overflow parking throughout neighborhoods that are utilized more heavily during the summer when there are a higher number of visitors to the area.

Figure 8. Examples of parking utilized more heavily during the tourist season, where permeable pavers could be installed to help reduce impervious surface within the drainage area. Left – impervious paved parking spaces in N3 (Middlesex Beach) and Right – gravel metered parking spaces along Pennsylvania Ave at N1 (Bethany Beach).

The pollutant and runoff reduction potential of permeable pavers are included below. This data was obtained from recent research compiled in Hirschman et al. (2008). In terms of runoff reduction, the use of an underdrain for permeable pavers is dependent upon the soil conditions and infiltration capacity. The drainage area for the Anchorage Canal most likely has high infiltration capacity and would not require an underdrain. However, tests to determine infiltration potential within the neighborhoods should be conducted prior to installation of permeable pavers.

- TP and TN removal underdrain: 59%
- TP and TN removal without underdrain: 81%

The cost of permeable pavers is slightly higher than conventional concrete and asphalt pavement and is provided below. Data was obtained from www.paversearch.com.

- Asphalt: $0.50 to $1.00 per square foot
- Grass/Gravel Pavers: $1.50 to $5.75 per square foot
- Porous Concrete: $2.00 to $6.50 per square foot
- Interlocking Concrete Paver Blocks: $5.00 to $10.00 per square foot

Recommendations and comments from the November 2009 Strategy Meeting include:

- The South Bethany ordinance requiring 55% of the setback area be pervious on individual lots is not as rigorous as other communities, such as Fenwick, which requires 100% of the setback area to be pervious.
- An impervious cover ordinance is possible in Middlesex and Bethany Beach. After the South Bethany ordinance is established, it can be used as an example for these communities.
- The main concern with the use of permeable pavement is finding materials that are handicap compliant. Some permeable pavements may not meet the requirements due to void spaces, etc.

2.1.5 Inlet Retrofits

Within N4 (South Bethany) there were many inlets located in small depression areas. Examples are provided in Figure 9. One potential retrofit to improve stormwater quality before entering the inlet is to remove the pavement and rip-rap surrounding these inlets. Grass and native vegetation can then be planted around the inlets to serve as pretreatment.

Figure 9. Inlets surrounded by rip-rap and concrete in N4 (South Bethany) that can be modified to remove the impervious cover and include grass/native vegetation pretreatment.

The main cost for these inlet retrofits will be for impervious cover removal and site restoration, which includes soil removal (assume 2 ft deep), topsoil, seeding and mulch, and temporary inlet protection. The total cost estimate is $1,800 per inlet based on RS Means (2006). This estimate is on the high end and will be lower for inlets surrounded by rip-rap instead of concrete.

Recommendations and comments from the November 2009 Strategy Meeting include:

- Additional options to consider include catch basin inserts or filter socks.
  - Catch basin inserts are devices that can be inserted into an existing catch basin to remove pollutants in stormwater runoff. Inserts are constructed of metal, plastic, and fabric, and usually have some sort of filter material. Their most frequent application is the removal of sediment, oil, and grease from stormwater runoff. However, they must be frequently cleaned and maintained. Otherwise they tend to clog with sediment and become ineffective. The cost of catch basin inserts can range from $100 - $1,500 depending on size, type of filter media, the filtering system, and the material used to construct the insert (http://www.fhwa.dot.gov/environment/ultraurb/3fs13.htm).
  - Filter socks consist of a mesh tube filled with filter media – typically compost. They are most frequently used to inlet protection to trap and filter sediments during construction. They could be used as post-construction devices, but their long-term durability and the required frequency of sediment clean-up may make them more difficult to use.
- Mosquitoes may be a concern for some homeowners with this type of practice, but generally these can be designed to drain within 24-48 hours, so mosquitoes will not be a problem.
- Perforated pipes with outlets to a catch basin or the Canal are often used in the watershed to mitigate small drainage problems. In the future, these could be re-designed to better provide drainage improvements and stormwater filtering at the same time.

Recommendations and comments from the May 2010 Public Meeting include:

- The recommended cleaning frequency for catch basin inserts is every 6 months.

2.2 Pollution Prevention at Hotspot Operations

No hotspot operations were identified within the Anchorage Canal drainage area. Due to the limited size, only one commercial strip (R4-R8) was located within the drainage area. No significant pollution generating practices were found at this commercial area to indentify any of the sites as a potential hotspot.

3.0 RRI Findings and Recommendations

Numerous stormwater retrofit opportunities were identified throughout the drainage area and are displayed in Figure 10. A summary of these retrofits is provided in Table 5, along with information about cost and pollutant removal potential for each site. The main types of opportunities identified include: converting ditches to wet swales along S. Pennsylvania Ave in the areas adjacent to Sea Colony; bioretention in the Coastal Highway medians; and bioretention along the Coastal Highway right-of-way adjacent to the commercial strip. Stormwater retrofit concept descriptions and concept sketches are provided in Appendix C. A list of routine maintenance activities associated with the recommended retrofits is provided in Appendix D.

The primary RRI objective is to reduce total nitrogen (TN) and total phosphorus (TP) each by 40%, and is based on a mandate by DNREC for Total Maximum Daily Load (TMDL) regulation of 40% reduction in these pollutants in the Little Assawoman Bay Watershed (DGA, 2005). According to a study by Martin et al. (2001), an average of 592 lb of TN and 33 lb of TP from stormwater runoff is discharged annually into the loop section of the Anchorage Canal. To meet the RRI objective of 40% reduction in these pollutants, approximately 237 lb of TN and 13 lb of TP would need to be removed annually through practices that treat stormwater runoff. For each retrofit identified in Table 5, the percentage to which that practice meets the targeted 40% reduction is calculated (i.e., the ratio of TN and TP removed by the practice compared to the total pollutant load reduction required to meet the TMDL).

All of the retrofit opportunities included in this report appear feasible, with strong pollutant removal potential. However, it appears that the Coastal Highway medians should be given highest priority. These are high priority projects because they contain more than enough land area to provide sufficiently sized practices, the sites are on public land, with only one land owner (DelDOT), the practices will be relatively low cost, and they will be very visible to residents and visitors, providing a great public education resource. The west side of Coastal Highway would be similar, although more work will be necessary to verify property lines and develop cooperative agreements with the adjacent property owners. Projects on the east side of Coastal Highway, as well as projects near Sea Colony and at the canal itself may require greater planning and engineering. This does not mean that they should be considered lower priority, just that it make take longer for construction to commence with these projects.

Recommendations and comments from the November 2009 Strategy Meeting include:

- Median Retrofits (R3, R4b, R5b, R6b, R7b, R8b)
  - The existing condition may be considered a "grass filter strip," which affects the treatment value calculations for the proposed practices.
  - Seashore Park can be used as an example of what the median retrofits would look like.
- An example of a wet swale can be seen in Berlin, south of the CIB office.
- R2E – Sea Colony – rip-rap is currently in place to protect the banks. Options for regrading, while preventing bank erosion, include matting and check-dams to reduce flow velocity.
- R2H – Keeping the bike path next to the fence would be ideal, but this would need to be discussed with DelDOT.
- R9 – Floating wetlands may be an option for a retrofit at the sediment forebay.
- It is important to note that all pollutant removal numbers presented in this strategy are stand alone and do not take into account the cumulative pollutant removal from practices upstream. For example, if all the retrofits upstream are completed, the proposed retrofit at R9 may have a reduced benefit. However, as none of these proposed practices provide 100% removal of pollutants, retrofits in series will increase the pollutant removal in the watershed.
- The wet pond retrofit near Sea Colony (R2H) and the most downstream wet swale retrofit near Sea Colony (R2E) can both be constructed with benefit gained from each. Although the retrofits would be parallel to each other, it is anticipated that a diversion would be constructed towards the upstream end of the wet swale so that a portion of the water

quality discharge would be directed to the wet pond while a portion would continue into the wet swale. Flows that exit the wet pond would then be directed into the downstream end of the wet swale. Neither of the retrofit sites alone would have sufficient water quality volume to treat all of the discharge independently, so construction of both would be beneficial.

Figure 10. Retrofit sites located within the Anchorage Canal drainage area.

Table 5. Summary of Retrofit Opportunities										
Location	**Retrofit ID**	**Proposed Practice**	**Drainage Area (acres)**	**Estimated Constructi on Cost***	**TN Removal (lbs/yr)**	**Cost / lb/yr TN Removed**	**% of TN TMDL Goal**	**TP Removal (lbs/yr)**	**Cost / lb/yr TP Removed**	**% of TP TMDL Goal**
South Pennsylvania Avenue	R1a	Replace compacted gravel with pervious reinforced turf	1	$71,014	3.72	$19,090	1.6%	0.52	$136,565	4.0%
	R1b	Convert existing ditch to sediment forebay	14	$6,094	-	-		-	-	
Sea Colony	R2a	Convert existing ditch to wet swale and add filter strips	31	$41,043	12.24	$3,353	5.2%	0.78	$52,619	6.0%
	R2d	Add short control structure upstream of driveway culverts								
	R2b	Create sediment forebays for existing wet pond	5	$24,415	-	-	-	-	-	
	R2c	Install filter strip at Sea Colony promenade	1	$19,349	1.78	$10,870	0.8%	0.24	$80,621	1.8%
	R2e	Convert existing ditch to wet swale and construct additional curb openings	42.5	$31,216	10.76	$2,901	4.5%	0.68	$45,906	5.2%
	R2f	Add short control structure upstream of sidewalk crossings								
	R2g	Convert existing stone-lined swale to grass swale and add curb openings								
	R2i	Convert existing stone-lined swale to grass swale and add curb openings								
	R2h	Construct wet pond on land-locked parcel	41.5	$335,470	21.60	$15,531	9.1%	5.05	$66,430	38.8%

Coastal Hwy	R3	Construct Coastal Hwy median bioretention	1.01	$23,169	3.25	$7,129	1.4%	0.39	$59,408	3.0%
	R4a	Construct bioretention along right-of-way	0.84	$12,928	2.17	$5,958	0.9%	0.26	$49,723	2.0%
	R4b	Construct Coastal Hwy median bioretention	0.51	$14,203	1.57	$9,046	0.6%	0.19	$74,753	1.5%
	R4c	Cap underdrain in bioretention to promote infiltration	0.39	< $100	1.85	$54	0.8%	0.22	$456	1.7%
	R5a	Construct bioretention along right-of-way	0.56	$11,322	1.56	$7,257	0.7%	0.19	$59,589	1.5%
	R5b	Construct Coastal Hwy median bioretention	0.65	$16,165	2.00	$8,083	0.8%	0.24	$67,354	1.8%
	R6a	Construct bioretention along right-of-way	1.11	$12,662	1.66	$7,627	0.7%	0.20	$63,310	1.5%
	R6b	Construct Coastal Hwy median bioretention	0.48	$13,989	1.47	$9,516	0.6%	0.18	$77,717	1.4%
	R7a	Construct bioretention along right-of-way	1.55	$10,502	1.08	$9,724	0.5%	0.13	$80,785	1.0%
	R7b	Construct Coastal Hwy median bioretention	0.58	$15,612	1.78	$8,771	0.8%	0.21	$74,343	1.6%
	R8a north	Construct bioretention along right-of-way	0.24	$8,376	0.70	$11,966	0.3%	0.08	$104,700	0.6%
	R8a south	Construct bioretention along right-of-way	0.28	$7,401	0.62	$11,937	0.3%	0.07	$105,728	0.5%
	R8b	Construct Coastal Hwy median bioretention	0.39	$12,379	1.20	$10,316	0.5%	0.14	$88,421	1.1%
Anchorage Canal Loop Section	R9	Construct wetland at canal forebay	85	$235,813	14.28	$16,514	6.0%	3.99	$59,101	30.7%

*Notes on the costs provided in Table 5:

- Costs provided are planning level estimates only. While attempts were made to include estimates for all expected components of each project, higher costs, due to necessary changes in the design, or differing unit costs are possible.
- Costs are an estimate of the base construction cost only. Design and engineering (D & E) expense can be estimated as a minimum of 35% of the base construction cost provided in Table 5. D & E expenses include: project management, design, permitting, landscaping, and erosion and sediment control. Any stormwater retrofits that require significant environmental permits should estimate D & E expense as a minimum of 40% of the base construction cost.
- Costs include the assumption that each project will be constructed separately. Savings may be realized if several retrofits are constructed concurrently.
- R1b and R2b do not include pollutant removal calculations, as it is difficult to quantify removal for sediment forebays that are part of a larger system.

4.0 References

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R1a: REINFORCED TURF TO REPLACE GRAVEL /GRASS PARKING ADJACENT TO SOUTH PENNSYLVANIA AVENUE.

Description

The retrofit site is located along South Pennsylvania Avenue, between Maplewood Street and just south of Cedarwood Lane. At this location there exists a compacted gravel/grass overflow parking area to either side of South Pennsylvania Avenue. The parking area acts as very shallow swale that carries runoff from South Pennsylvania Avenue. The runoff ultimately is conveyed to a downstream swale along South Pennsylvania Avenue, south of Cedarwood Lane.

Existing Conditions

The overflow parking to the either side of South Pennsylvania Avenue, between Maple Street and just south of Cedarwood Lane conveys runoff from South Pennsylvania Avenue (via sheet flow surface runoff). The drainage areas to east and west-side overflow parking area are 0.22 and 0.29 Ac, respectively. The drainage area these parking areas has impervious cover.

The overflow parking area to the east and west-side of the south Pennsylvania Avenue is 0.21 and 0.28 Ac., respectively.

Figures 1&2: Existing Gravel/grass overflow parking to be replaced by reinforced turf overflow parking

Proposed Conditions

Under the existing condition, the gravel/grass overflow parking area serves a shallow swale to convey runoff from South Pennsylvania Avenue to downstream swales. In order to improve the quality of runoff it is proposed to replace the compacted gravel/grass area by reinforced turf. Reinforced turf offers exceptional aesthetics, permeability, turf protection and load support for pedestrian or vehicle traffic areas. Additionally it provides strong stabilized surfaces facilitating stormwater retention and infiltration, thereby significantly reducing runoff quantity and improving water quality.

To create the reinforcement Turf, the following activities are necessary:

- Remove the compacted gravel and grass from the bottom of the existing overflow parking area.
- Place cellular confinement (Geoblock®, Geoweb®, Turf Cell®, or equivalent). Fill the 6" confinement cells with 4" gravel and 4" topsoil.
- Seed and mulch the topsoil

The primary pollutant removal mechanism for cellular confinement system is infiltration/runoff reduction and filtering.

Site Constraints

- None

Preliminary Plans

Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction.

Preliminary Hydrologic Conditions

Preliminary sizing Reinforced Turf is provided in the table below:

Parameter	Value
Drainage Area, A	1 acres
Imperviousness, I	100%
Runoff Coefficient, R_v	0.95
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	3,448 cu.ft.
Minimum storage volume provided (cu ft)*	2,014 cu.ft
% of Water Quality Volume Treated, %WQv	59%
Total Nitrogen Removal, TNr	3.72 lbs/yr
Total Phosphorous Removal, TPr	0.52 lbs/yr

*Based on 20% porosity in the confinement cells. Approximate width of proposed reinforced turf to the west and east of South Pennsylvania Avenue is approximately 15', road width draining to each side is 17' and length of the turf is 760' and 590', respectively.

Sizing Calculations and Assumptions

In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

Rv = 0.05 + 0.009 x I

WQ_v = P/12 x Rv x A

%WQv = TV / WQ_v x 100

TPr = Removal% x P_{annual} x P_j x [WQv/43,560/P] x C x 2.72 x %WQv (if less than 100)

TNr = Removal% x P_{annual} x P_j x [WQv/43,560/P] x C x 2.72 x %WQv (if less than 100)

Where:

Removal % = Total nutrient removal percentage for reinforced turf (removal considered similar to filter strip) = 20% for phosphorous, 20% for nitrogen

P_{annual} = average annual rainfall depth (inches) = 46 inches

P_j = fraction of rainfall events that produce runoff = 0.9

C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen

2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Next Steps

- Discuss the project proposal with appropriate City of South Bethany and DelDOT representatives.
- Collect additional information needed to further develop the reinforced turf, including product/vendor availability in the area, and infiltration rates in the proposed retrofit area.
- Hold a pre-application meeting with permitting representatives from City of South Bethany to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the retrofit according to the guidance provided in the Delaware & Maryland Stormwater Design Manual.
- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities typically associated with reinforced turf are summarized in Appendix D.

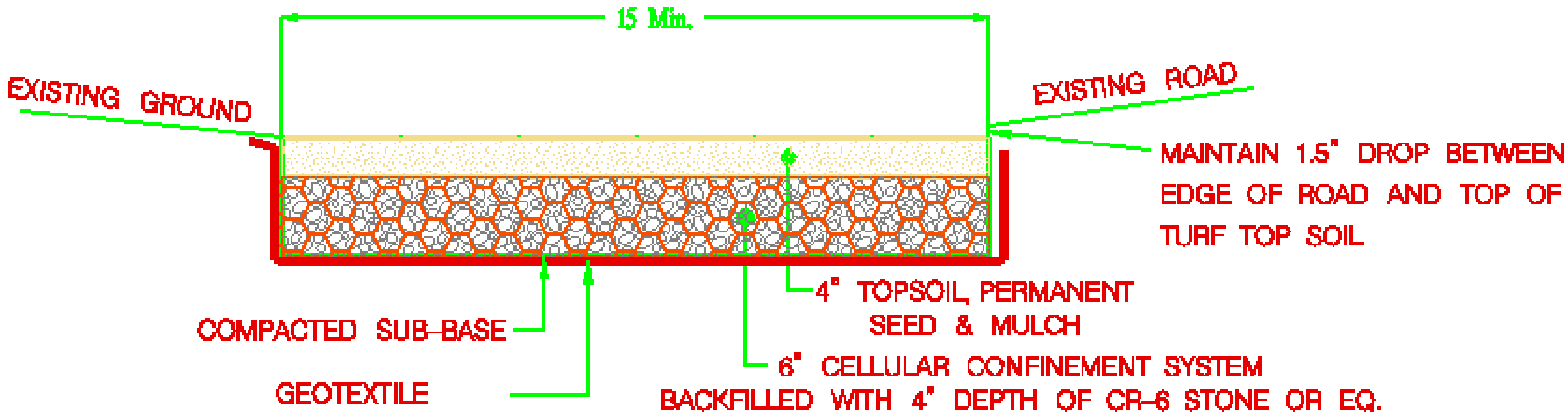
Preliminary Cost Estimate

Preliminary construction estimates for each the proposed retrofit measure is provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed.

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$500	$500.00
Reinforced Turf including excavation, placement, aggregate, top soil, and seed and mulch	2,250	square yard	$25	$56,250.00
MOT	1	lump sum	$5,000	$5,000.00
Total				$61,750.00
Contingency and Incidental Costs (15%)				$9,262.50
Total Cost				**$71,012.50**

RETROFIT SITE – R1A

RETROFIT SITE – R1A



NOTE: PAYMENT FOR GEOTEXTILE SHALL BE INCIDENTAL TO THE CONTRACT UNIT PRICE FOR CR-6 STONE

REINFORCED TURF

R1b/R2a/R2d: SOUTH PA AVE: DITCH TO WET SWALE AND FOREBAY/ SEA COLONY: DITCH TO WET SWALE

Description

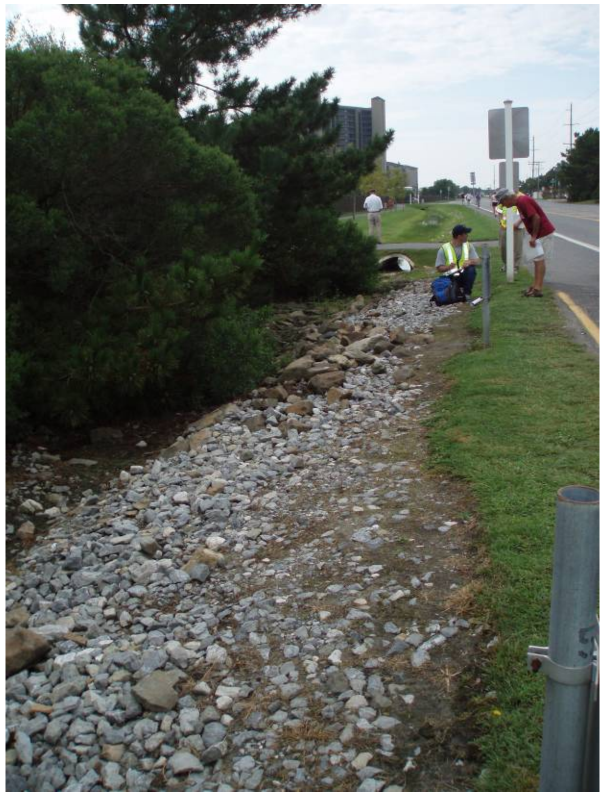
The retrofit site is located along, and to the east of South Pennsylvania Avenue, immediately south of Cedarwood Street. At this location there exists a riprap ditch that receives runoff from Cedarwood Street and South Pennsylvania Avenue. The riprap ditch flows into the vegetated ditch adjacent to Sea Colony Development. The retrofit site is bounded to the north by Sea Colony North Entrance.

Existing Conditions

The riprap channel conveys runoff from the surrounding area (via sheet flow surface runoff) including runoff from development along Cedarwood Street, Ashwood Street, partially from development along Maplewood Street and the eastern side of South Pennsylvania Avenue. The drainage area to the riprap ditch is approximately 14.0 Ac. The area draining to the riprap ditch consists mostly of houses and streets, with approximately 85% of impervious cover.

The riprap ditch is approximately eight-feet wide at the bottom, and one-foot deep and 95 feet long.

The riprap ditch flows into vegetated ditch (Ditch 1) to the east of Sea Colony, and along South Pennsylvania Avenue. The Ditch 1 is 360 feet long trapezoidal ditch. The drainage area to Ditch 1 consists of part of Sea Colony Development (6.0 Ac. approx.), part of South Pennsylvania Avenue (0.23 Ac), and the upstream area that flows into the riprap ditch (14 Ac.). This ditch flows via culverts at the intersection of Jefferson Bridge Road into a vegetated ditch (Ditch 2) downstream. The 800 feet ditch (Ditch 2) extends from North Bridge Road up to the Sea Colony North Entrance. The drainage area to the Ditch 2 consists of part of South Pennsylvania Avenue (0.7 Ac). Stormwater management (SWM) pond at Sea Colony discharges into the Ditch 2. The existing drainage area to the Sea Colony SWM pond is approximately 10.0 Ac.



Figures 1&2: Existing Riprap Ditch to be converted into a Forebay

Figure 3: Existing Vegetated Ditch

Figure 4: Existing Vegetated Ditch showing the side slopes that are proposed to be converted into filter strip

Figure 5: Sea Colony SWM Facility that discharges into vegetated Ditch along South Pennsylvania Avenue.

Proposed Conditions

Under the existing condition, the connected ditches convey runoff from 31 Ac. of developed area. In order to improve the quality of runoff it is proposed to construct a forebay, filter strips and convert the existing ditch into a wet swale. These measures will incrementally improve the water quality of the runoff to the downstream ditch (Ditch 3). The above-mentioned retrofit measures are discussed below:

Forebay:

As a pretreatment measure for the runoff conveyed to the vegetated swale, it is proposed to replace the existing riprap ditch with a sediment forebay. A sediment forebay is a small pool located upstream of a Stormwater management pond or swales. These devices are designed as initial storage areas to trap and settle out sediment and heavy pollutants before they reach the main basin. The sediment forebay is designed to typically store 25% of Water Quality volume (WQv).

To create the sediment forebay, the following activities are necessary:

- Remove the riprap lining from the bottom of the existing ditch.
- Excavate sediment forebay. The forebay shall be trapezoidal with minimum two-foot bottom, minimum depth of one-foot and side slopes no steeper than 3:1.
- The forebay should have a zero-percent longitudinal slope.
- Install a fixed vertical sediment depth marker to measure sediment deposition over time.
- Install a gabion weir structure just upstream of the culvert pipes. The weir should be sized to safely pass water quality storm.

- Plant the forebay with appropriate species that are salt, water and drought tolerant. These could include alkali grass, bermuda grass, and others.

The primary pollutant removal mechanisms operating in the forebay will be settling. With this design, the sediments transferred to the downstream wet swale will be significantly reduced.

Preliminary Hydrologic Conditions

Preliminary sizing of the forebay is provided in the table below:

Parameter	Value
Drainage Area, A	14.0 acres
Imperviousness, I	85%
Runoff Coefficient, R_v	0.815
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	41,418 cu.ft.
Pretreatment Volume (10% WQv)	10,354 cu.ft.
Minimum forebay volume provided (cu ft)	500 cu.ft
Minimum percent of pretreatment volume treated provided	0.5%

Minimum surface area created by forebay: 800 square feet.

Filter strip along South Pennsylvania Avenue:

Under existing conditions, the runoff from part of the south Pennsylvania Avenue sheet flows into the adjacent to Ditch 1 and 2. Due to the availability of area between the edge of road and the top of channel, it is proposed that the side slope on the east of the channel be flattened and used as a filter strip. Filter strips provide reduction of pollutant loads through filtration by vegetation and infiltration.

To create a filter strip along the side slope of the existing swale, the following activities are necessary:

- Excavate and flatten the side slope to maximum of twenty-five percent slope and a minimum width of five feet.
- Place six inches of top soil
- Seed and mulch the side slope.

Preliminary Hydrologic Conditions

Preliminary sizing of the filter strip is provided in the table below:

Parameter	Value
Drainage Area, A (South Penn. Ave. draining to the swale)	1.0 acres
Imperviousness, I	71%
Length of Filter Strip (ft)	1160

Parameter	Value
Minimum Width (ft)	5
Maximum Slope	25%
TSS Removal (DURMM)	72 %

Wet swale:

The existing Ditch1 and 2 along South Pennsylvania conveys runoff from approximately 30 Ac. of developed area. To improve the water quality of the runoff in the ditches, it is proposed that the ditches be converted into wet swales. Wet swales store the water quality volume within a series of cells within the channel, which may be formed by berm or check dams and may contain wetland vegetation. The pollutant removal mechanisms in wet swales rely on sedimentation, adsorption, and microbial breakdown. A well designed wet swale is capable of removing 50-80% of Total Suspended Solids, 15-30% of phosphorus and 25-35% of total nitrogen from the runoff.

To create the wet swale, the following activities are necessary:

- Remove existing stone from the ditch bottom.
- Install rock check dams. The check dams should be 18 inches high with overflow points in the center a maximum of 12 inches high. This will create a maximum ponding depth of 12 inches. At the least, one check dam should be placed in each section of the swale, specifically upstream of culvert crossing.
- Plant the swale with appropriate species that are both water-tolerant and drought-tolerant. These could include turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

Additional design Criteria:

- Wet swales should be designed to temporarily retain the water quality volume for 24 hours
- Hydraulic analysis will need to be performed to assure that tailwater elevations created by wet swale do not adversely affect storm drain system that tie into them.

Preliminary Hydrologic Conditions

Preliminary sizing of the wet swale is provided in the table below:

Parameter	Value
Drainage Area, A	31 acres
Imperviousness, I	85%
Runoff Coefficient, R_v	0.815
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQv to be treated*	62,128 cu.ft
Minimum WQv stored in Ditch 1 and 2	4640 cu ft

Parameter	Value
Minimum percent of pretreatment volume treated provided	7.5%
Total Phosphorous Removal, TPr	0.78 lbs/yr
Total Nitrogen Removal, TNr	12.24 lbs/yr

* Water quality runoff from Sea Colony that is being treated in the SWM facility at Sea Colony has been neglected from the above calculations.
* The water quality improvements due to the forebay (72% TSS removal) are not quantified in terms of Phosphorous and Nitrate removal due to unavailability of these removal rates in the literature.

Site Constraints

Several site constraints exist for this location, and should be further investigated as a part of this project:

- Utilities: No utility conflicts were observed on site, but utility locations have not been researched.
- Safety: Care must be taken to ensure that any re-graded slopes to not pose a danger to pedestrians and bicyclists using the shoulder along South Pennsylvania Avenue.

Sizing Calculations and Assumptions

In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

$Rv = 0.05 + 0.009 \times I$

$WQ_v = P/12 \times Rv \times A$

$PV = (PA_{top} + PA_{bottom})/2 \times 0.5'$

$SV = PA_{bottom} \times 0.25 \times 1.5$

$TV = PV + SV$

$\%WQv = TV / WQ_v \times 100$

$TPr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

$TNr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

Where:

Removal % = Total nutrient removal percentage for wet swale = 25% for phosphorous, 55% for nitrogen

P_{annual} = average annual rainfall depth (inches) = 46 inches

P_j = fraction of rainfall events that produce runoff = 0.9

C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen

2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Preliminary Plans

Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction.

Next Steps

- Discuss the project proposal with appropriate City of South Bethany and DelDOT representatives.
- Collect additional information needed to further develop the forebay design, including a topographic survey.
- Hold a pre-application meeting with permitting representatives from City of South Bethany to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the forebay according to the guidance provided in the Delaware & Maryland Stormwater Design Manual.
- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities are summarized in Appendix D.

Preliminary Cost Estimate

Preliminary construction estimates for each of the above-mentioned pretreatment and treatment alternatives are provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed.

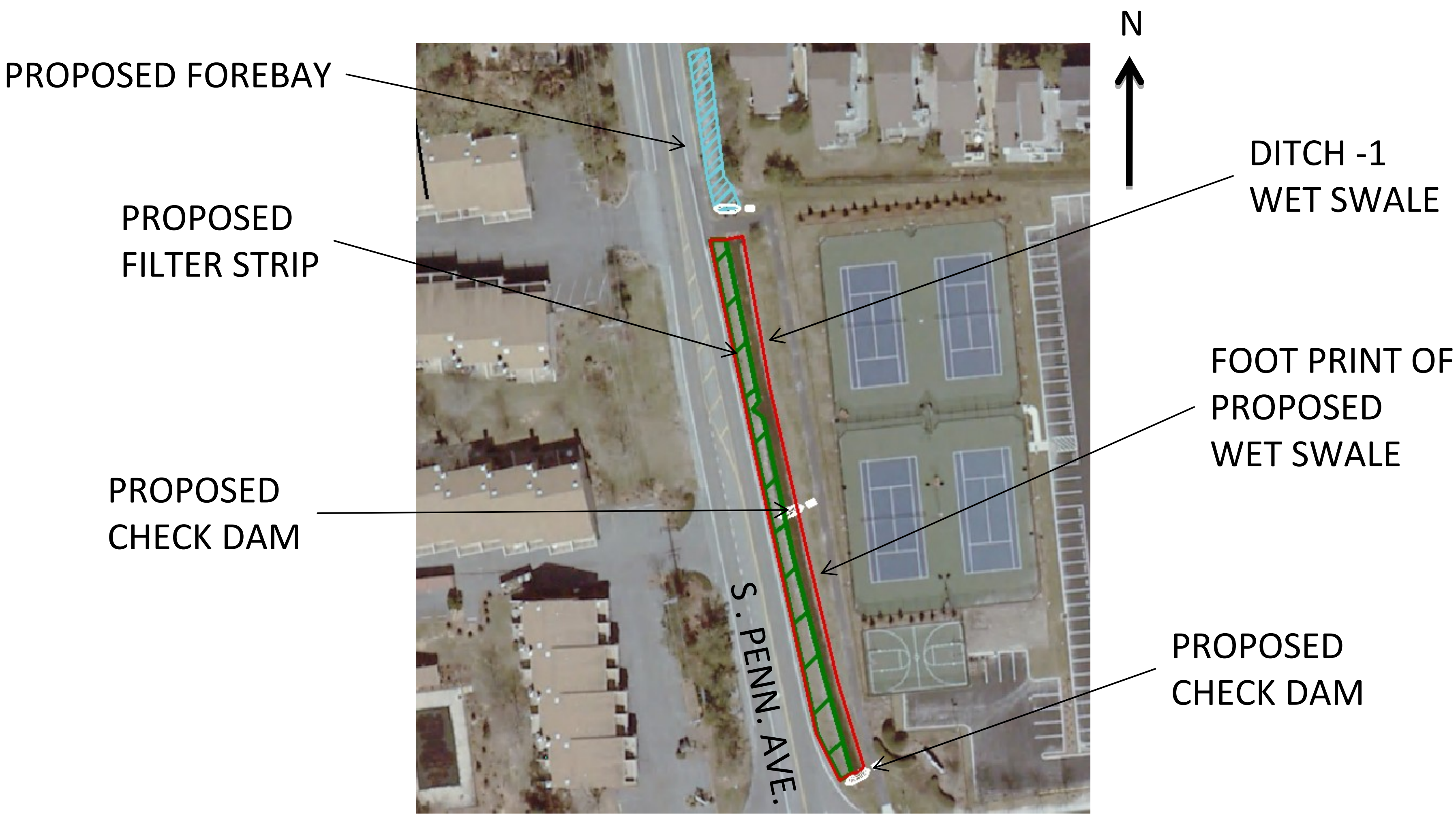
Forebay (R1b):

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$500	$500.00
Safety Fence	250	linear feet	$5.00	$1,250.00
Excavation and Embankment Required	9.5	cubic yards	$20.00	$180.00
Permanent site stabilization w/ seeding & mulching	90	square yard	$5.50	$495.00
Gabion Weir Structure	1	each	$2,000.00	$2,000.00
6” Topsoil	90	square yard	$5.00	$450.00
			Total	$4,875.00
Contingency and Incidental Costs (25%)				$1,218.75
Total Cost				**$6,093.755**

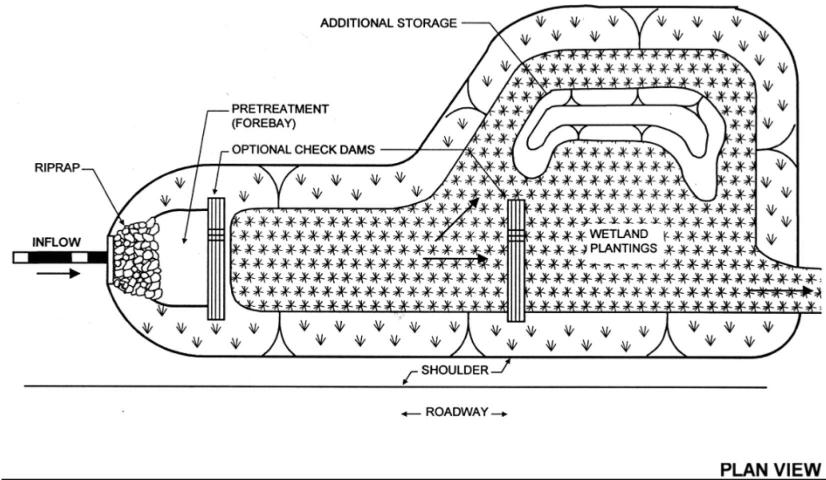
Filter Strip & Wet Swale (R2a):

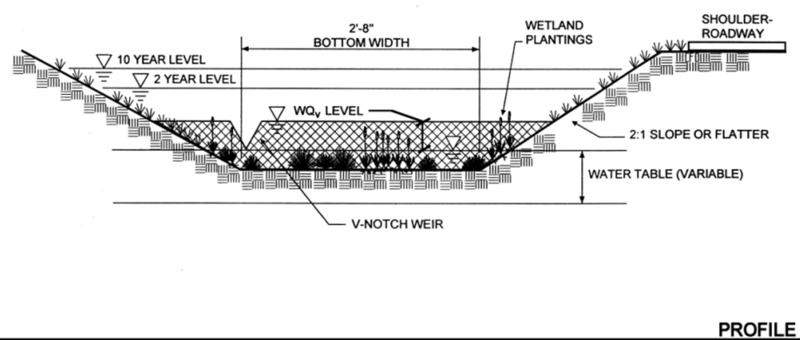
Material item (furnish and install)	**Amount**	**Unit**	**Cost/unit**	**Cost**
A. General				
Mobilization	1	lump sum	$ 3,900	$3,900.00
B. Filter Strip				
Safety Fence	1160	linear feet	$5.00	$5,800.00
Traffic Control	1	lump sum	$2,500.00	$2,500.00
Excavation Required	33	cubic yards	$20.00	$660.00
Permanent site stabilization w/ seeding & mulching	580	square yard	$5.50	$3,190.00
6" Topsoil	580	square yard	$5.00	$2,900.00
			Total	$15,050.00
C. Wet Swale				
Excavation and Embankment Required	19	cubic yards	$20.00	$380.00
Permanent site stabilization w/ seeding & mulching	900	square yard	$5.50	$4,950.00
Gabion Weir Structure	2	each	$2,000.00	$4,000.00
Planting (material only)	386	square yard	$10.00	$3,860.000
6" Topsoil	386	square yard	$5.00	$1,934.00
E&S Control (Pumping and Dewatering)	1	lump sum	$2,000.00	$2,000.00
			Total	$17,124.00
Total Cost for (A,B & C)				$32,834.00
Contingency and Incidental Costs (25%)				$8,208.50
Total Cost				**$41,042.50**

RETROFIT SITE – 1b

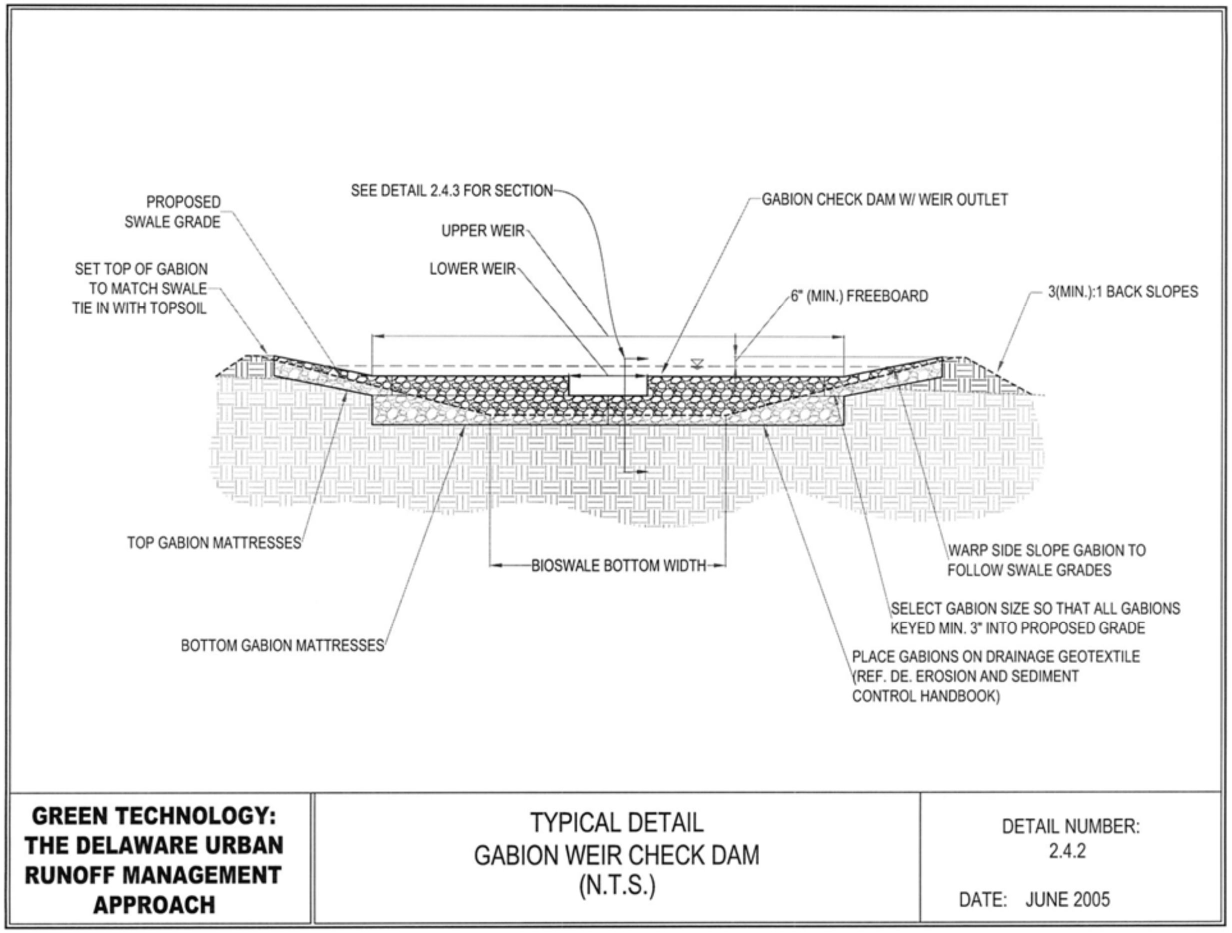


RETROFIT SITE – R1b

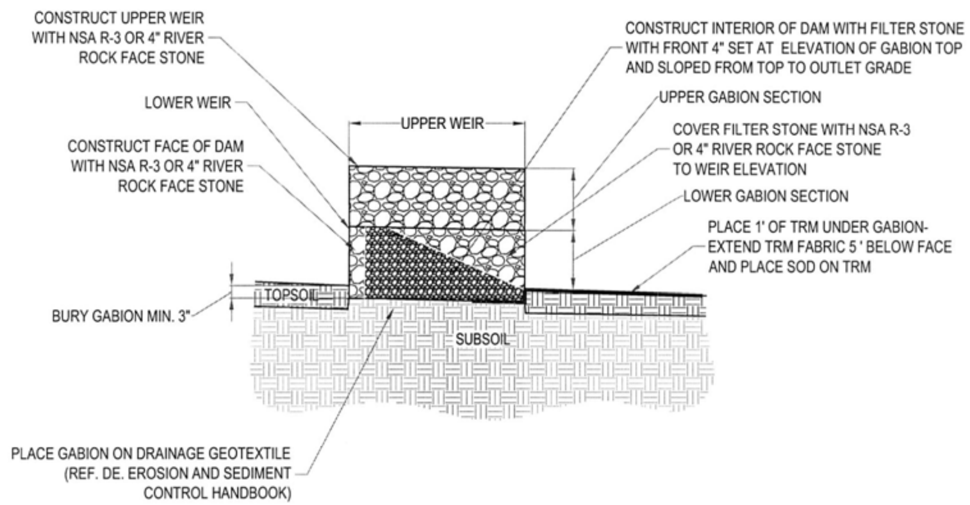




RETROFIT SITE – R1b

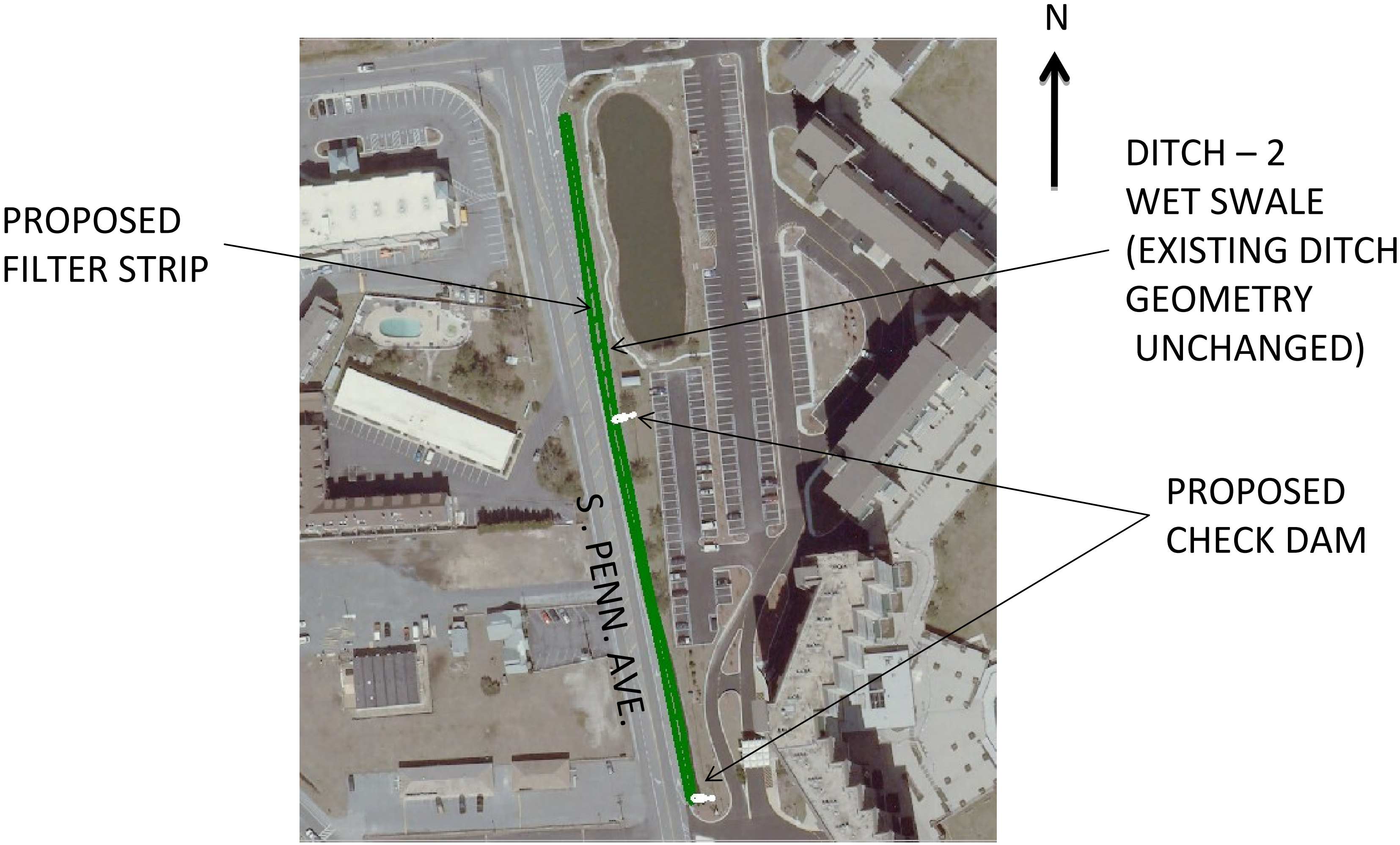


RETROFIT SITE – R1b



GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL GABION WEIR CHECK DAM - SECTION (N.T.S.)	DETAIL NUMBER: 2.4.3 DATE: JUNE 2005

RETROFIT SITE – 2a



R2b: FOREBAY AND BAFFLE WALL FOR WET POND AT SEA COLONY

Description

The retrofit site is located at the Sea Colony. The wet pond at Sea Colony Property collects runoff from Chesapeake and Dover House, and parking area in front of Chesapeake and Dover House.

Existing Conditions

Under existing conditions, the Chesapeake and Dover House, and the parking area to the east of the property drain to the wet pond. There are six catch basins in the parking area that drain via three outfalls in to the wet pond. Drainage area to the wet pond is approximately 5.0 acres with approximately 70% impervious cover.

Figure 1&2: Existing wet pond at Sea Colony

Figure 3: Parking Area discharging to the wet pond

Proposed Conditions

Under the existing condition, Chesapeake and Dover House, and the parking area to the west of Chesapeake and Dover House, at the Sea Colony property discharges via network of storm drain pipes to the wet pond. In order to better capture the pollutant load in the wet pond, it is proposed to provide forebays at outfalls to the wet pond. These devices are designed as initial storage areas to trap and settle out sediment and heavy pollutants before they reach the main basin. The sediment forebay is designed to typically store 25% of Water Quality volume (WQv). In order to maintain existing aesthetic value of the pond and minimize disturbances around the pond, it is proposed to install gabion walls around the outfalls, with enclosed area acting as forebay. Also, under the existing conditions, the placement of the outlet structure is such that the runoff in to the wet pond from southern outfalls has a short residence time. In order to eliminate the possibility of short-circuiting, and to increase runoff residence time, a gabion baffle wall is proposed along the partial length of the pond.

To create the sediment forebay and baffle wall, the following activities are necessary:

- Install gabion walls around the outfalls to the wet pond. In order to maintain the aesthetics of the pond, it is recommended to use 2"-4" washed gravel for gabion walls. 3'x 3' gabion boxes shall placed over each other in two layers to create the forebay.
- Install gabion baffle wall along the partial length of the pond. The baffle wall should extend beyond the outlet structure. 3'x 3' gabion boxes shall placed over each other in two layers to create the baffle wall.
- Provide weir on the forebay. The weir should be sized to safely pass water quality storm. The weir should discharge east of the baffle wall (behind the proposed baffle wall).

The primary pollutant removal mechanisms in the forebay will be settling. With this design, the sediments transferred to the wet pond will be significantly reduced. The baffle walls will allow increase settling of pollutants, thereby reducing the pollutant load on the downstream wet swale.

Preliminary Hydrologic Conditions

Preliminary sizing of the forebay is provided in the table below:

Parameter	Value
Drainage Area, A	5 acres
Imperviousness, I	70%
Runoff Coefficient, R_v	0.68
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	12,342 cu.ft
Pretreatment Volume (25% WQv)	3,085 cu ft
Minimum percent of pretreatment volume treated provided	100 %

Additional design requirements:

- As-built design of the wet pond needs to be obtained to finalize the final foot print of forebay.

Site Constraints

Site constraints to be further investigated for this location are:

- Safety: Care must be taken to ensure that visitors using the sidewalk around the pond do not walk on top of the gabion walls.

Sizing Calculations and Assumptions

In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

$Rv = 0.05 + 0.009 \times I$

$WQ_v = P/12 \times Rv \times A$

Preliminary Plans

Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction.

Next Steps

- Discuss the project proposal with appropriate City of South Bethany and DelDOT representatives.
- Collect additional information needed to further develop the forebay design, including a topographic survey.
- Hold a pre-application meeting with permitting representatives from City of South Bethany and Sea Colony representatives to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the forebay according to the guidance provided in the Delaware & Maryland Stormwater Design Manual.
- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

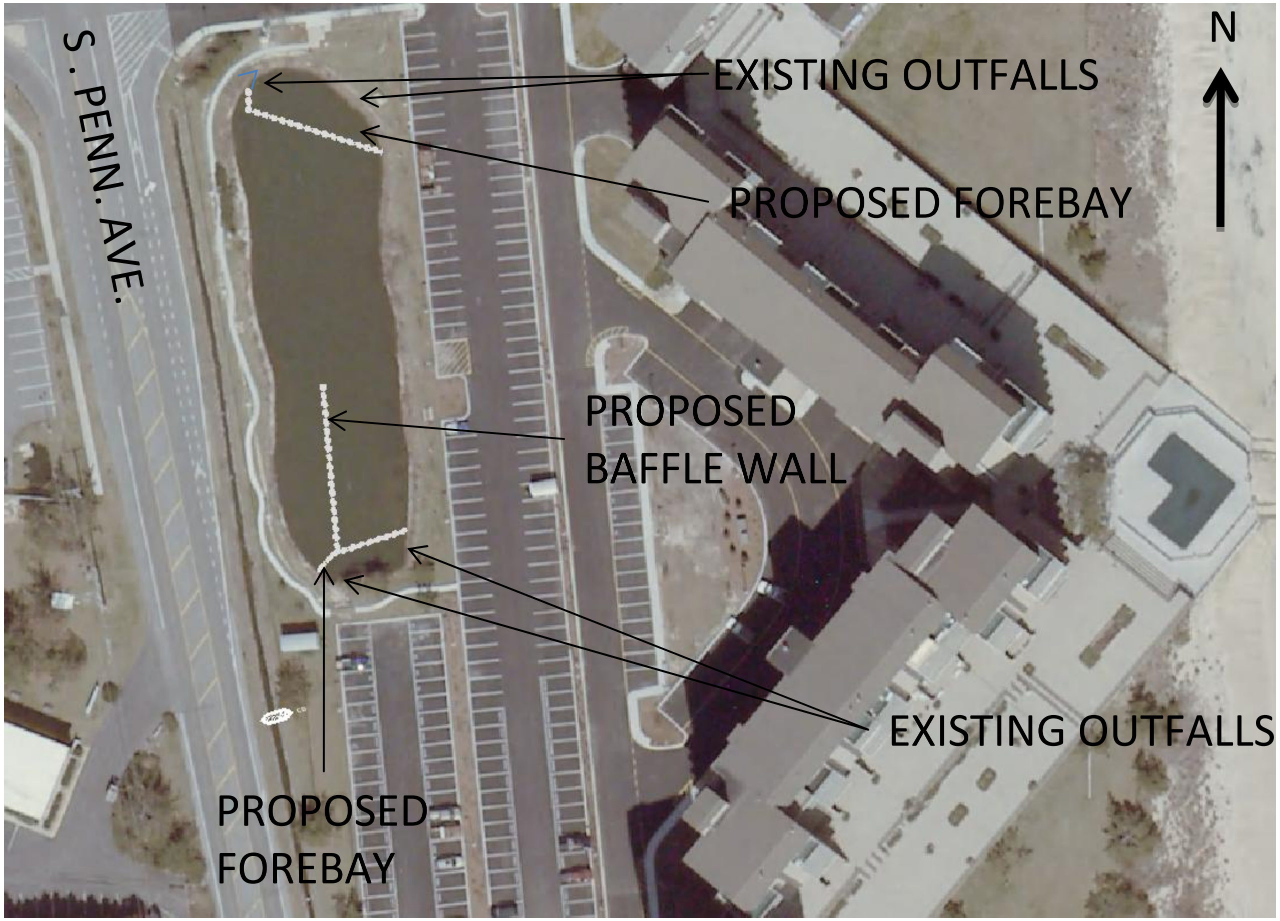
Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities typically associated with forebays are summarized in Appendix D.

Preliminary Cost Estimate

Preliminary construction estimates for each of the above-mentioned pretreatment alternative is provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed.

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$500	$500.00
Gabion Wall forebay and Baffle Wall	166	cubic yard	$100	$16,600.00
Erosion and Sediment Control	90	lump sum	$5,000	$5,000.00
			Total	$21,100.00
Contingency and Incidental Costs (15%)				$3,315.00
Total Cost				**$24,415.00**

RETROFIT SITE – R2B



R2c: SEA COLONY PROMENADE: IMPERVIOUS DISCONNECTION, INSTALLATION OF FILTER STRIP

Description
The retrofit site is located to the east end of the Sea Colony, specifically to the north-east of Edgewater House. The site includes open green space adjacent to the promenade.

Existing Conditions
Under the existing condition, runoff from part of Edgewater House, promenade, and parking areas under the promenade is piped to a sump inlet. This runoff is pumped to the inlet in the open space downstream. The runoff is eventually discharged in to the wet swale along South Pennsylvania Avenue. The drainage area to the inlet is approximately 1.1 Ac. The area draining to the inlets consists mostly of roof tops and wooden deck, with 54% of impervious cover.

Figure 1: Available open space adjacent to the Edgewater House parking lot

Figure 2: Drainage pipes collecting runoff from the promenade

Figure 3: Receiving inlet located in the open space

Proposed Conditions

In order to improve runoff quality discharging to downstream swale, it is proposed to disconnect the pipe draining into the sump inlet, and allowing runoff to sheet flow over the open green space to the inlet. The existing inlet in the open field is proposed to be lowered, and the area between the inlet and edge of parking area is proposed to be graded to facilitate gravity flow. The area between the inlet and the existing inlet will serve as a filter strip, improving the quality of runoff discharging to the inlet. Pollutant removal mechanism for the proposed retrofit measure is predominantly filtration and runoff reduction.

To create a filter strip adjacent to the parking area under the promenade, the following activities are necessary:

- Lower the existing inlet by approximately 6”.
- Disconnect the conveyance pipes carrying runoff from the promenade to the sump inlet. Install downspout. Install gravel/rip rap pad at the end of downspout.
- Grade the area edge of the parking area and existing inlet to facilitate gravity flow. Please top soil and seed and mulch the disturbed areas.

Preliminary Hydrologic Conditions

Preliminary sizing of the filter strip is provided in the table below:

Parameter	Value
Drainage Area, A	1 acres
Imperviousness, I	50%
Runoff Coefficient, R_v	0.5
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQv to be treated*	1,851 cu.ft
Length of Filter Strip	170
Minimum Width	40
Maximum Slope	5%
TSS Removal (DURMM)	95%
Total Phosphorous Removal, TPr	0.24 lbs/yr
Total Nitrogen Removal, TNr	1.78 lbs/yr

Additional design requirements:

- Existing survey plans of the open space with inlet elevation are needed to determine the proposed slope of the filter strip area.

Site Constraints

- None.

Sizing Calculations and Assumptions

In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.
Calculations:

$Rv = 0.05 + 0.009 \times I$
$WQ_v = P/12 \times Rv \times A$
$PV = (PA_{top} + PA_{bottom})/2 \times 0.5'$
$SV = PA_{bottom} \times 0.25 \times 1.5$
$TV = PV + SV$
$\%WQv = TV / WQ_v \times 100$

$TPr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)
$TNr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

Where:

Removal % = Total nutrient removal percentage for filter strip = 20% for phosphorous, 20% for nitrogen
P_{annual} = average annual rainfall depth (inches) = 46 inches
P_j = fraction of rainfall events that produce runoff = 0.9
C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Preliminary Plans

Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction.

Next Steps

- Discuss the project proposal with appropriate City of South Bethany and DelDOT representatives.
- Collect additional information needed to further develop the final design, including a topographic survey.
- Hold a pre-application meeting with permitting representatives from City of South Bethany to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the filter strip according to the guidance provided in the Delaware & Maryland Stormwater Design Manual.

- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities typically associated with filter strip are summarized in Appendix D.

Preliminary Cost Estimate

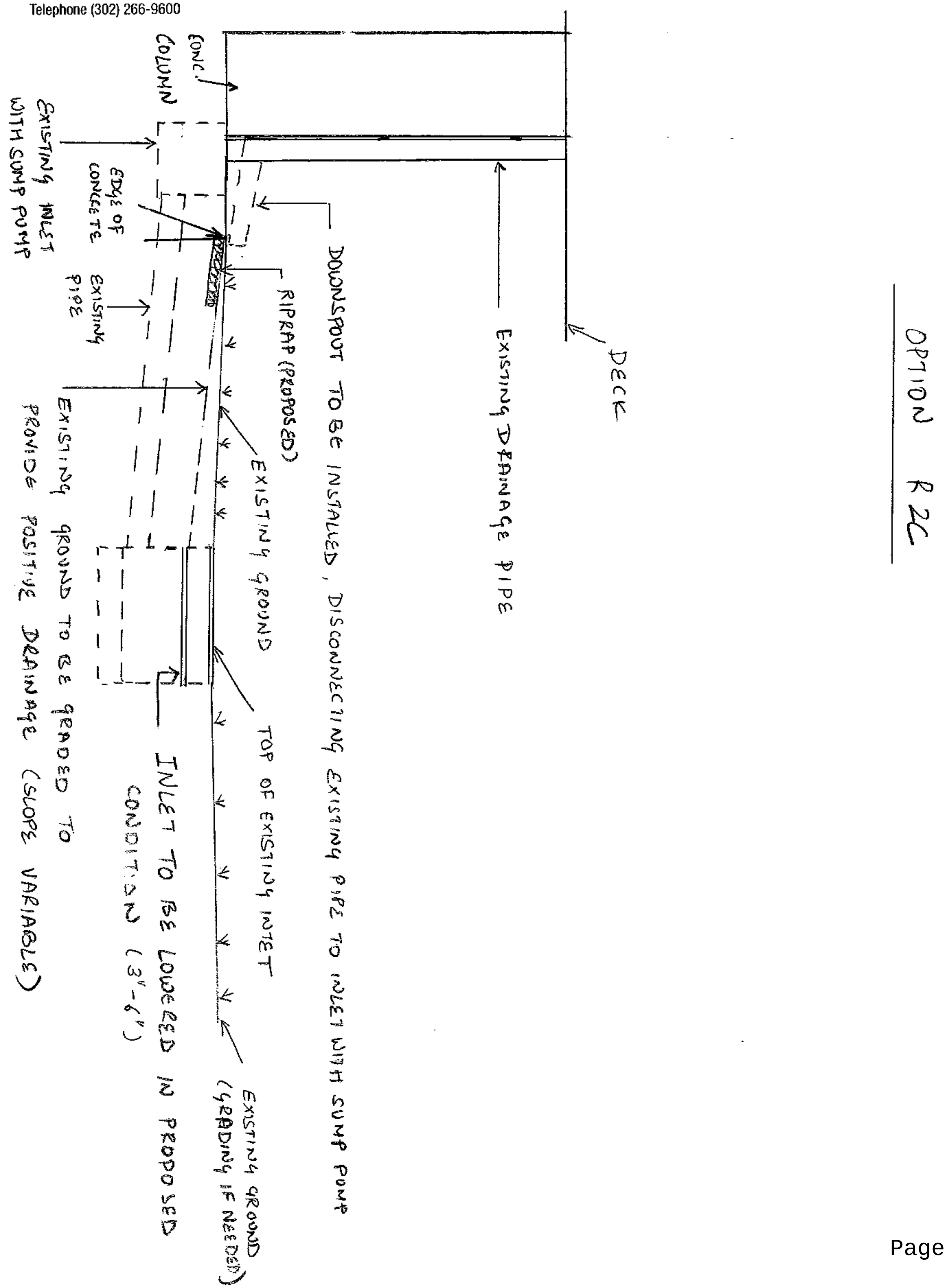
Preliminary construction estimates for each of the above-mentioned pretreatment and treatment alternatives are provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed.

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
A. General				
Mobilization	1	lump sum	$500	$500
B. Filter Strip				
Safety Fence	170	linear feet	$5.00	$850
Inlet Adjustment, Downspout and Riprap Installation	1	lump sum	$3,500.00	$3,500.00
Excavation Required	300	cubic yards	$20.00	$6,000.00
Permanent site stabilization w/ seeding & mulching	950	square yard	$5.50	$5,225.00
6” Topsoil	150	square yard	$5.00	$750.00
			Total	$16,825.00
Contingency and Incidental Costs (15%)				$2,523.75
Total Cost				**$19,348.75**

RETROFIT SITE – R2C

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
131 Continental Drive Suite 109 Newark, Delaware 19713
Telephone (302) 266-9600

Project: ANCHORAGE CANAL
Subject: OPTION R-2C
Job No.:
Sheet No. 1 of 1
Computed By: AMP Date: 4/27/10 Checked By: Date:



R2e/R2f/R2g/R2i: CONVERT EXISTING DITCH TO WET SWALE AND CONSTRUCT CURB OPENINGS AT SEA COLONY

Description

The retrofit site is located along, and to the east of South Pennsylvania Avenue, immediately south of Sea Colony South Entrance. At this location there exists a vegetated ditch that receives runoff from part of South Pennsylvania Avenue, Sea Colony and the upstream areas including developments along Cedarwood Street, Ashwood Street and Maplewood Street. The vegetated ditch flows into a storm sewer system that ultimately discharges into the Anchorage Canal.

Existing Conditions

The vegetated ditch (Ditch 3) is a 960 feet trapezoidal ditch. A part of South Pennsylvania Ave (1.16 Ac.) sheet flows into the ditch. Stormwater from a part of the Sea Colony is discharged via pipe network also into Ditch 3 (10.5 Ac.). The runoff carried by upstream ditches (Ditch 1 and 2) is discharged in to Ditch 3. The total drainage area to Ditch 3 is 42.50 Ac. There exist multiple curb openings along the Sea Colony Parking lot to facilitate sheet flow in to Ditch 3. Downstream of the curb opening is stone line swale that drains to the ditch along east side of South Pennsylvania Avenue.

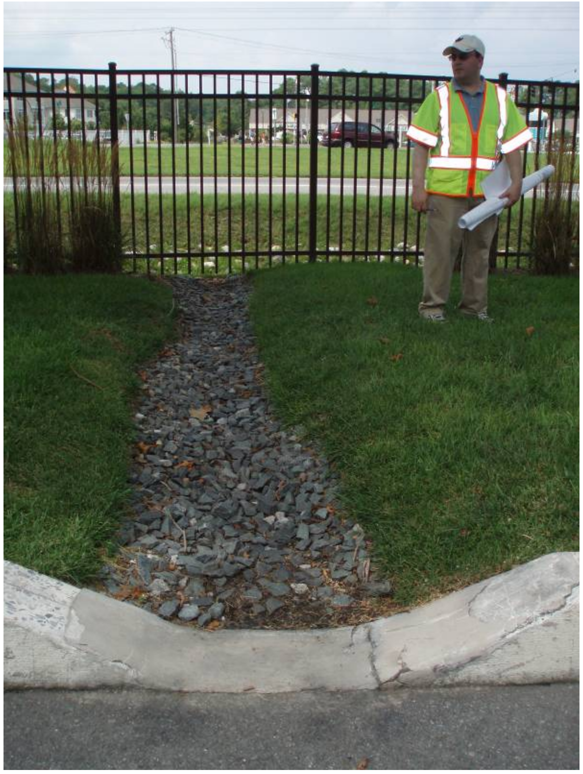



Figure 1&2: Curb Openings at Sea Colony Parking Lot

Figure 3&4: Existing Vegetated Ditch (Ditch 3)

Proposed Conditions

Under the existing condition, Ditch 3 conveys runoff from a 42.5 Ac. of developed area. In order to improve the quality of runoff it is proposed to convert the existing ditch in to a wet swale. Also, it is proposed to construct additional curb openings along the Sea Colony parking lot to facilitate sheet flow and distribute the pollutant load through the entire length of the Ditch 3 (in contrast to concentrated pollutant load discharge through the existing curb openings). These measures will incrementally improve the water quality of the runoff to the receiving water body. The above-mentioned retrofit measures are discussed below:

Curb Openings along Sea Colony parking Lot:

Under existing conditions, the runoff from part of the Sea Colony parking Lot flows via existing curbs openings in to Ditch 3. The outlets of the curb openings are stone-lined ditches. It is proposed that the bottoms be replaced with grass surface, and additional curb openings with vegetated ditch outlets be installed at intervals of 50 feet. This will allow the pollutant load to be distributed along the length of the ditch and thereby improving the pollutant removal efficiency.

To create the curb openings, the following activities are necessary:

- Remove the existing stone from the ditches, and replace with topsoil, seed and soil retention blanket mulch.
- Construct additional openings at approximately 50 feet intervals along parking lot curb. Place topsoil, seed and mulch, as needed, behind the openings up to the bottom of Ditch 3.
- Place appropriate soil retention blanket mulch behind the opening, and up to the bottom of the ditch, if the deemed necessary

Wet swale:

The existing Ditch 3 along South Pennsylvania conveys runoff from approximately 41.5 Ac. of developed area. To improve the water quality of the runoff in the ditch, it is proposed that the ditches be converted into wet swale. Wet swales store the water quality volume within a series of cells within the channel, which may be formed by berm or check dams and may contain wetland vegetation. The pollutant removal mechanisms in wet swales rely on sedimentation, adsorption, and microbial breakdown. A well designed wet swale is capable of removing 50-80% of Total Suspended Solids, 15-30% of phosphorus and 25-35% of total nitrogen from the runoff.

To create the wet swale, the following activities are necessary:

- Remove existing stone from the ditch bottom.
- Install rock check dams. The check dams should be 18 inches high with overflow points in the center a maximum of 12 inches high. This will create a maximum

ponding depth of 12 inches. At the least, one check dam should be placed in each section of the swale, specifically upstream of culvert crossing.

- Plant the swale with appropriate species that are both water-tolerant and drought-tolerant. These could include turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

Additional design Criteria:

- Wet swales should be designed to temporarily retain the water quality volume for 24 hours
- Hydraulic analysis will need to be performed to assure that tailwater elevations created by wet swale do not adversely affect storm drain system that tie into them.

<u>Preliminary Hydrologic Conditions</u>

Preliminary sizing of the wet swale is provided in the table below:

Parameter	Value
Drainage Area, A	41.5 acres
Imperviousness, I	85%
Runoff Coefficient, R_v	0.815
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQv to be treated*	90652cu.ft
Minimum WQv stored in Ditch 1 and 2	3840cu ft
Minimum percent of pretreatment volume treated provided	4.5%
Total Phosphorous Removal, TPr	0.68 lbs/yr
Total Nitrogen Removal, TNr	10.76 lbs/yr

* Water quality runoff from Sea Colony that is being treated in the SWM facility at Sea Colony and the volume treated in proposed Ditch 1 and 2 has been neglected from the above calculations.
* For simplicity, the water quality improvements resulting from the construction of curb openings and grassed channels are neglected.

<u>Site Constraints</u>

Several site constraints exist for this location, and should be further investigated as a part of this project:

- Utilities: No utility conflicts were observed on site, but utility locations have not been researched.
- Safety: Care must be taken to ensure that any re-graded slopes to not pose a danger to pedestrians and bicyclists using the shoulder along South Pennsylvania Avenue.

Sizing Calculations and Assumptions
In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

$Rv = 0.05 + 0.009 \times I$

$WQ_v = P/12 \times Rv \times A$

$PV = (PA_{top} + PA_{bottom})/2 \times 0.5'$

$SV = PA_{bottom} \times 0.25 \times 1.5$

$TV = PV + SV$

$\%WQv = TV / WQ_v \times 100$

$TPr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

$TNr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

Where:

Removal % = Total nutrient removal percentage for wet swale = 25% for phosphorous, 55% for nitrogen

P_{annual} = average annual rainfall depth (inches) = 46 inches

P_j = fraction of rainfall events that produce runoff = 0.9

C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen

2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Preliminary Plans
Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction.

Next Steps
- Discuss the project proposal with appropriate City of South Bethany and DelDOT representatives.
- Collect additional information needed to further develop the forebay design, including a topographic survey.
- Hold a pre-application meeting with permitting representatives from City of South Bethany to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the forebay according to the guidance provided in the Delaware & Maryland Stormwater Design Manual.
- Submit final design to appropriate agencies for review and approval.

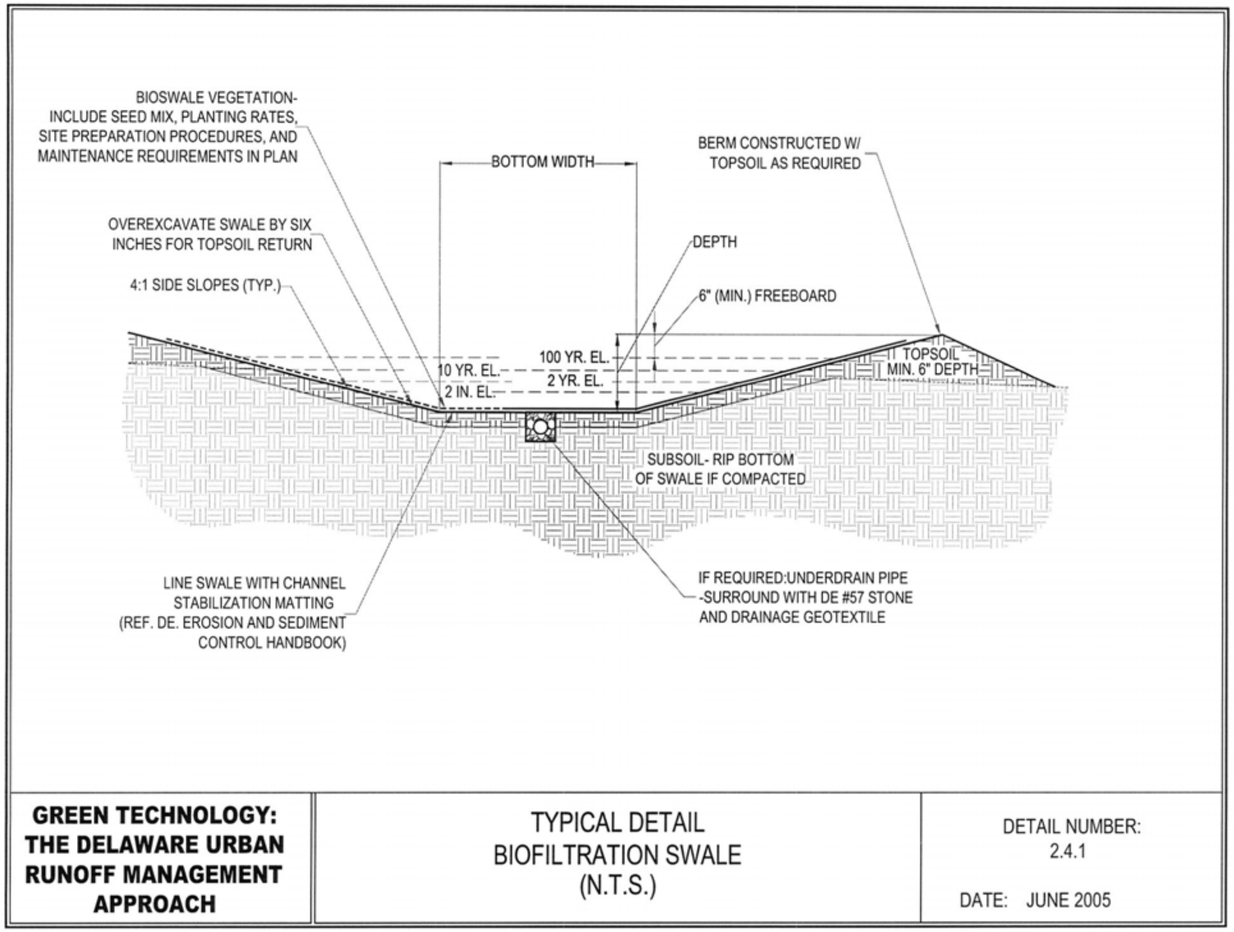
Maintenance Considerations
Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities are summarized in Appendix D.

Preliminary Cost Estimate
Preliminary construction estimates for each of the above-mentioned pretreatment and treatment alternatives are provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed.

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
A. General				
Mobilization	1	lump sum	$2,500	$2,500
B. Curb Openings				
Saw cut, concrete curb	45	linear feet	$20.00	$900
Excavation and Embankment Required	10	cubic yards	$25.00	$250
SRBM, Type 4	60	square yard	$5.00	$300
Permanent site stabilization w/ seeding & mulching	60	square yard	$5.50	$330
6” topsoil	60	square yard	$5.00	$300
			Total	$2,080
C. Wet Swale				
Excavation and Embankment Required	115	cubic yards	$20	$2,300
Permanent site stabilization w/ seeding & mulching	335	square yard	$5.50	$1,842.50
Gabion Weir Structure	3	each	$2,000.00	$6,000
Planting (material only)	350	square yard	$10.00	$3,500
6” topsoil	350	square yard	$5.00	$1,750
E&S Control (Pumps, Dewatering Device)	1	Lump Sum	$2,000	$2,000
MOT	1	Lump Sum	$3,000	$3,000
			Total	$20,392.50
			Cost (A, B &C)	$24,972.50
			Contingency and Incidental Costs (25%)	$6,243.15
			Total Cost	**$31,215.63**

RETROFIT SITE – 2e

RETROFIT SITE – R2e



R2h: SEA COLONY: WET POND ON LAND-LOCKED PARCEL

Description

The retrofit site is a land-locked area where Coastal Highway splits into South Pennsylvania Avenue. The triangular piece of land of approximately 0.28 Ac. is currently vacant and covered with grass. It is bounded on two sides by north bound traffic lanes on Coastal highway and South Pennsylvania Avenue and on the third side by south bound traffic lane on South Pennsylvania Avenue. There are some utility poles on the parcel, and underground utilities cross the parcel including water and sanitary sewer. A pedestrian cross walk with access to Sea Colony Development also crosses the parcel.

Existing Conditions

Under the existing conditions, the site is currently vacant, with utility poles and traffic signs placed on the site. There are no hydrologic features (ditches, ponds, etc) on the site.

Figure 1&2: Retrofit Site as viewed from Sea Colony Entrance

Figure 3: Retrofit Site as viewed from south-side of north-bound lane of South Pennsylvania Avenue

Figure 4: Retrofit Site as viewed from pedestrian cross walk connecting Sea Colony

Figure 5: Retrofit Site as viewed from pedestrian cross walk connecting Sea Colony

Proposed Conditions

Under the existing condition, stormwater runoff from developments along Ashwood Street, Maplewood Street and Cedarwood Lane and Sea Colony is conveyed by the ditches along the south Pennsylvania Avenue into the storm drain system, ultimately discharging into Anchorage Canal. Although a part of the runoff from the Sea Colony Development is managed for water quality in the on-site stormwater management (SWM) facility, the majority of the runoff that discharges into the storm drain system is untreated. The existing ditches, if modified, can provide water quality treatment for a small percentage of the runoff.

It is proposed that a wet pond be constructed on land-locked parcel, and divert the existing ditches to the proposed wet pond. The wet pond will receive runoff from 37.8 Ac. of the upstream area. The treated runoff would flow into the existing storm drain system that discharges into the Anchorage Canal.

This retrofit measure would involve closing the north-bound lane of South Pennsylvania Avenue, constructing a new north-bound right-turn lane along Coastal Highway, and relocating above-ground and underground utility structures on the site.

Wet Pond:

The existing ditches along South Pennsylvania convey runoff from approximately 41.5 Ac. of developed area. To improve the water quality of the runoff, it is proposed that a wet pond shall be constructed in the land-locked parcel and ditches be diverted to the wet pond. Based on the location of the retrofit site, it is possible to runoff from Ditch1, Ditch 2 and part of Ditch 3 in to the proposed wet pond, totaling to runoff from 36.5 Ac. of drainage area.

Wet ponds consist of a permanent pool of standing water that promotes a better environment for gravitational settling, biological uptake and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a residence time that ranges from many days to several weeks, which allows numerous pollutant removal mechanisms to operate. A well designed wet pond is capable of removing 60-90% of Total Suspended Solids, 40-75% of phosphorus and 15-40% of total nitrogen from the runoff.

To create the wet pond, the following activities are necessary:

- Excavate the pond to the designed depth with maximum side slopes of 4:1.
- Install 10-feet wide benches, one foot below and above the normal pool elevation.
- Install outlet structure.
- Construct access path to the pond and/or outlet structure.
- Seed and mulch the area.

- Plant the pond with appropriate species that are both water-tolerant and drought-tolerant. These could include turf grass, alkali grass, tall meadow grasses, decorative herbaceous cover, or trees.
- Install safety fence around the pond if needed.

Additional design Criteria:
- Wet ponds shall provide for extended detention volume, over and above wet pool volume.
- Hydraulic analysis will need to be performed to assure that tailwater elevations created by wet pond do not adversely affect storm drain system that tie into them.
- Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack.

Preliminary Hydrologic Conditions
Preliminary sizing of the wets pond is provided in the table below:

Parameter	Value
Drainage Area, A	36.5 acres
Imperviousness, I	85%
Runoff Coefficient, R_v	0.815
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQv to be treated*	94369 cu.ft
Minimum WQv stored in Wet Pond	14850 cu ft
Minimum percent of pretreatment volume treated provided	16%
Total Phosphorous Removal, TPr	5.05 lbs/yr
Total Nitrogen Removal, TNr	21.60 lbs/yr

* Water quality runoff from Sea Colony that is being treated in the SWM facility at Sea Colony and the volume treated in proposed Ditch 1, 2 and part of Ditch 3 has been neglected from the above calculations.

Site Constraints
Several site constraints exist for this location, and should be further investigated as a part of this project:
- Utilities: Underground and above-ground utilities are present on the site. This retrofit measure needs relocation of utilities including water, sanitary sewer and traffic signal poles.
- Traffic: This retrofit measure will require closing the north-bound lane of Coastal Highway that merges into the South Pennsylvania Avenue, constructing a north-bound right-turn lane on Coastal Highway
- Safety: Care must be taken to ensure that any re-graded slopes to not pose a danger to pedestrians and bicyclists using the shoulder along South Pennsylvania Avenue.

Sizing Calculations and Assumptions

In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

$Rv = 0.05 + 0.009 \times I$

$WQ_v = P/12 \times Rv \times A$

$PV = (PA_{top} + PA_{bottom})/2 \times 0.5'$

$SV = PA_{bottom} \times 0.25 \times 1.5$

$TV = PV + SV$

$\%WQv = TV / WQ_v \times 100$

$TPr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

$TNr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

Where:

- Removal % = Total nutrient removal percentage for wet pond = 50% for phosphorous, 30% for nitrogen
- P_{annual} = average annual rainfall depth (inches) = 46 inches
- P_j = fraction of rainfall events that produce runoff = 0.9
- C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen
- 2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Preliminary Plans

Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction.

Next Steps

- Discuss the project proposal with appropriate City of South Bethany and DelDOT representatives.
- Collect additional information needed to further develop the forebay design, including a topographic survey.
- Hold a pre-application meeting with permitting representatives from City of South Bethany to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the forebay according to the guidance provided in the Delaware & Maryland Stormwater Design Manual.
- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities are summarized in Appendix D.

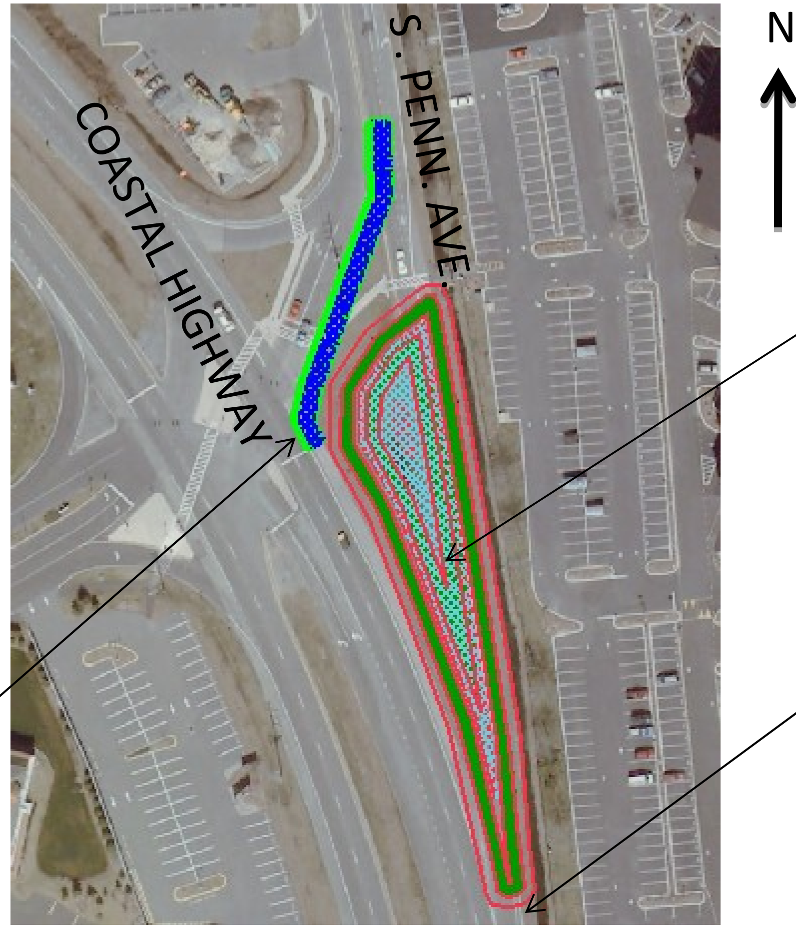
Preliminary Cost Estimate

Preliminary construction estimates for each of the above-mentioned treatment alternatives are provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed.

Wet Pond(R2h):

Material item (furnish and install)	**Amount**	**Unit**	**Cost/unit**	**Cost**
A. General				
Mobilization	1	lump sum	$23,000	$23,000.00
Clearing & Grubbing	1	lump sum	$2,000	$2,000.00
B. Stormwater Management				
Excavation	2165	cubic yard	$20	$43,300.00
Top soil, 6”	1121	square yard	$5	$5,605.00
Seeding & mulching	1121	square yard	$5.50	$6,165.50
Outlet structure	1	each	$3,950	$3,950.00
Planting	1121	square yard	$10.00	$11,210.00
Safety Fence	700	linear feet	$5.00	$5,800.00
C. Right Turn Lane & Utilities				
10” GABC , Type B	82	cubic yard	$50	$2,500.00
12” Superpave	200	ton	$100	$660.00
Excavation	180	cubic yard	$20	$3,190.00
Signing & striping	1500	linear feet	$5	$7,500.00
Construction Phasing/MOT	1	lump sum	$5,000	$5,000.00
Modifying existing traffic signal	1	lump sum	$30,000	$30,000.00
Relocation of Utilities (Sewer & Water)	1000	linear feet	$100	$100,000.00
D. Erosion & Sediment Control				
Stabilized Construction Entrance	150	ton	$25	$3,750.00
Silt Fence	700	linear feet	$3	$2,100.00
Pumping & Dewatering Device	1	Lump Sum	$2,500	$2,500.00
			Total	$258,053.55
Contingency and Incidental Costs (30%)				$77,416.06
Total Cost				**$335,469.62**

RETROFIT SITE – 2h



PROPOSED WET POND

NORTH BOUND LANE TO BE CLOSED

PROPOSED RIGHT TURN LANE

R3, R4b, R5b, R6b, R7b, R8b: COASTAL HIGHWAY MEDIANS

Description

Coastal Highway and its drainage system make up the majority of the Anchorage Canal Watershed. Where the highway runs through the community of Middlesex Beach, potential retrofit locations exist in the median.

Existing Conditions

Coastal Highway is a four-lane road, including wide shoulders and turn lanes in both directions. Northbound and southbound traffic is separated by a series of uncurbed medians between each intersection, generally ranging from 30 to 34 feet wide. The highway is crowned to drain runoff from the inside lanes (both northbound and southbound) to the medians. One drop inlet is located in the center of each median, with shallow grass swales conveying water to them. The drop inlets connect to a storm sewer running along the west side of the highway.

Figure 1: Coastal Highway median. Top left: Looking north in site R7. Top right: Drop inlet in site R5. Bottom: Looking south in site R4.

Proposed Conditions

There is ample room for construction of a bioretention area in each of the medians. The bioretention areas would be narrow and long, with uniformly flat, safe, slopes from the outer edge to the center. Due to the presence of sandy soils on site, underdrains and replacement soil media will not be necessary, and construction of the bioretention areas will be relatively simple:

- Maintain a 6'wide undisturbed grass strip along the road edges of the median. (Site R3 can only accommodate a 4' side undisturbed strip as the width of the median is narrower than other sites.)
- Excavate a 6' wide strip in the center of the median to a depth at least fifteen inches below the road elevation and nine inches below the existing drop inlet grate elevation. (It may be necessary to raise the drop inlet grate if the existing elevation is too low.) (Site R3 can only accommodate a 4'wide excavation.)
- Keep slopes from the undisturbed grass strip to the bottom of the bioretention at 6:1 or flatter.
- Vegetate the slopes and bottom of the bioretention area using one of the following strategies:

  Strategy 1, Cool Season Turf – Cool season turf – Plant cool season turf grass and mow routinely.

  Kill existing vegetation with a non-selective herbicide (glyphosate) in late August and reseed with turf type tall fescue between August 15 and September 30. Mow the median on a routine mowing schedule to a height of 4-6 inches. *This strategy provides a highly maintained traditional median and would be acceptable where neat, controlled vegetation is desired.*

  Strategy 2, Meadow – Discontinue mowing and allow existing vegetation to grow. Mow annually to prevent shrubs from developing.

  Allow new vegetation to seed in. Maintain meadow by mowing annually. If invasive species develop, spot spray with herbicides to control. *This strategy will allow native and naturalized plants to develop and a mixed meadow will be created. Most likely the meadow will be dominated by panic grass, seaside goldenrod and thoroughwort. It will look highly naturalized. The mowed edge will provide a sense of maintenance and control, but most of the median will be a loose mix of plants. This will be appropriate where a more natural look is acceptable.*

  Strategy 3, Meadow and Shrubs – Discontinue mowing and allow existing vegetation to grow.

  Allow new vegetation to seed in. Allow shrubs to grow. Maintain median by mowing only when shrubs become overgrown and too large for the median (every 5-7 years). If invasive species develop, spot spray with herbicides to control. *This strategy will allow native and naturalized plants to develop and a mixed shrubby meadow will be created. Most likely the meadow will be dominated by panic grass, seaside goldenrod, thoroughwort, groundsel bush, bayberry and sumac. It will look highly naturalized. The mowed edge will provide a sense of maintenance and control, but most of the median will be a loose mix of plants. This will be appropriate where a more natural look is acceptable.*

Strategy 4, Planted Meadow – – Plant the bioretention area with appropriate species that are both water-tolerant and drought-tolerant. These could include warm season meadow grasses, herbaceous perennials, or shrubs. Add a 3-inch layer of mulch at establishment but allow plants to grow together such that routine mulching is no longer necessary.

Kill existing vegetation with a non-selective herbicide (glyphosate) in late spring. Cut dead vegetation as close to the ground as possible. Seed a mix of warm season grasses and herbaceous perennials to provide a meadow cover in late May or June. Mix seed with compost (moist sawdust or yard waste compost—avoid high nitrogen compost such as poultry manure or mushroom compost) and spread compost over site to a depth of 1" using a manure spreader. Recommended species include *Panicum virgatum, Rudbeckia hirta, Aesclepias tuberosa* and *Elymus canadensis.* Spot treat to control undesirable tall weeds (such as mare's tail and wild lettuce) and invasive species. Mow the planting annually to maintain an herbaceous meadow planting. Herbaceous annuals that flower throughout the summer can be added to the edges of the median by planting plugs in May to increase the ornamental value of this meadow. Plugs to enhance the median include *Aster laevis* 'Bluebird'*, Eupatorium dubium, Hibiscus moscheutos, Rudbeckia laciniata* and *Lobelia cardinalis*. *This strategy will result in a highly floriferous meadow for the first 2-3 years. Ultimately the warm season grasses will dominate and a grassy meadow will be sustained. The mowed edge will provide order and by controlling tall broadleaved weeds an attractive more ornamental meadow will exist. This planting is appropriate for any median along Route 1 unless a highly managed ornamental gateway planting is desired.*

Strategy 5, Planted Meadow with Shrubs –Plant a highly ornamental mix of perennials and shrubs that is managed routinely as a beautification planting. Add a 3-inch layer of mulch and re-mulch yearly.
–

Kill existing vegetation with a non-selective herbicide (glyphosate) in late spring. Cut dead vegetation as close to the ground as possible. Seed a mix of warm season grasses and herbaceous perennials to provide a meadow cover as the ground layer in late May or June. Mix seed with compost (moist sawdust or yard waste compost—avoid high nitrogen compost such as poultry manure or mushroom compost) and spread compost over site to a dept of 1" using a manure spreader. Recommended species include (*Panicum virgatum, Rudbeckia hirta*, *Aesclepias tuberosa* and *Elymus canadensis).* Spot treat to control undesirable tall weeds (such as mare's tail and wild lettuce) and invasive species. Plant shrubs (*Baccharis halmifolia, Cephalanthus occidentalis, Myrica cerifera*, *Myrica pensylvanica*, *Rhus copallina*,) to provide more structure and interest to the median planting. Manage this median by cutting back every 5-7 years when shrubs become overgrown and leggy. *This strategy is similar to Strategy 5,but the addition of shrubs will provide more structure and ornamental value from flowering, fall foliage color and fruit. This planting is appropriate for any* *median along Route 1 unless a highly managed ornamental gateway planting is desired.*

Strategy 6 – Planted Ornamental Traffic Island – Plant a highly ornamental mix of perennials that is managed routinely as a beautification planting. Add a 3-inch layer of mulch and re-mulch yearly.

Kill existing vegetation with a non-selective herbicide (glyphosate) in late spring. Cut dead vegetation as close to the ground as possible. Plant a combination of 2-3 herbaceous perennials in large masses to create a simple ornamental pattern. Use plugs or quarts and space on approximately 18 inch centers. Some effective species combinations include (*Aster oblongifolius 'Raydon's* Favorite' and *Solidago sempervirens; Amsonia hubrichtii* and *Panicum virgatum 'Northwind'; Aster laevis 'Bluebird'* and *Asclepias tuberosa; Rudbeckia laciniata* and *Vernonia novaborensis; Schizachyrium scoparium* and *Eupatorium serotinum*). Mulch at planting and for 1-2 years until vegetation forms a solid ground layer. Spot treat or hand pull undesirable weeds. Mow the planting annually in the spring to remove dead perennial vegetation. Treat with a preemergent herbicide in April to reduce weed problems each year. *This strategy is the most expensive and most ornamental planting option. It should be reserved for high visibility gateway or intersection sites.*

With this design, during all rain events, stormwater runoff from the highway will be directed to the bioretention area. Water will then pond to a depth of at least six inches. Excess runoff during larger storm events will overflow into the existing drop inlet. The ponded water will slowly infiltrate into the soil media and underlying soils. The primary pollutant removal mechanisms operating in the bioretention area will be settling, infiltration, and plant uptake.

Additional Design Considerations and Site Constraints

Several difficult issues exist for this location, and should be further investigated as a part of this project:

- Since the medians do not have curbs, care must be taken to ensure that any re-graded slopes do not pose a danger to vehicle traffic. The elevation of existing drop inlet grates may have to be raised in order to allow for sufficient ponding depth and safe slopes.
- It may be necessary to maintain a minimum cover depth above the existing storm sewers. This will not adversely affect the retrofit designs, but may require additional care during construction.
- While other underground utilities, including sanitary sewer, gas, telephone, cable, and electric lines were not observed in the field, they may be present, and their location and depth must be verified.
- In several locations, small sinkholes were observed above the storm sewer. This may be a sign or a crack or other problem with the storm sewer, which should be corrected before completion of a bioretention area.

Preliminary Plans
Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction. The plans include a general drawing for all of the sites, and a depiction of each bioretention area's contributing drainage area.

Unique Site Characteristics
While each median retrofit has similar design features, the length of the medians and the corresponding drainage areas differ. In each case, the median area is considerably larger than the area needed to treat the water quality volume from the drainage area. The list below indicates the approximate surface area which will be required for excavation of the bioretention areas.

- R3: Median Area: 24' x 440' Bioretention Area: 16' x 430'
- R4: Median Area: 30' x 260' Bioretention Area: 18' x 170'
- R5: Median Area: 30' x 320' Bioretention Area: 18' x 210'
- R6: Median Area: 30' x 250' Bioretention Area: 18' x 160'
- R7: Median Area: 30' x 320' Bioretention Area: 18' x 200'
- R8: Median Area: 30' x 220' Bioretention Area: 18' x 130'

*Note: The areas utilized for hydrologic calculations below are slightly smaller than those indicated in this list, due to the need to account for freeboard space above the overflow elevation.

Preliminary Hydrologic Conditions
Preliminary sizing of each bioretention area is provided in the tables below.

R3:

Parameter	Value
Drainage Area, A	1.01 ac
Imperviousness, I	60%
Runoff Coefficient, R_v	0.59
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	2163 cf
Top of Ponding Area, PA_{top}	4260 sf
Bottom of Ponding Area, PA_{bottom}	1680 sf
Ponding Volume, PV	1485 cf
Soil Storage Volume, SV	630 cf
Total Volume Available, TV	2115 cf
% of Water Quality Volume Treated, %WQv	98%
Total Phosphorous Removal, TPr	0.39 lbs/yr
Total Nitrogen Removal, TNr	3.25 lbs/yr

R4:

Parameter	Value
Drainage Area, A	0.51 ac
Imperviousness, I	55%
Runoff Coefficient, R_v	0.55
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	1018 cf
Top of Ponding Area, PA_{top}	1944 sf
Bottom of Ponding Area, PA_{bottom}	936 sf
Ponding Volume, PV	720 cf
Soil Storage Volume, SV	351 cf
Total Volume Available, TV	1071 cf
% of Water Quality Volume Treated, %WQv	105%
Total Phosphorous Removal, TPr	0.19 lbs/yr
Total Nitrogen Removal, TNr	1.57 lbs/yr

R5:

Parameter	Value
Drainage Area, A	0.65 ac
Imperviousness, I	55%
Runoff Coefficient, R_v	0.55
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	1298 cf
Top of Ponding Area, PA_{top}	2424 sf
Bottom of Ponding Area, PA_{bottom}	1176 sf
Ponding Volume, PV	900 cf
Soil Storage Volume, SV	441 cf
Total Volume Available, TV	1341 cf
% of Water Quality Volume Treated, %WQv	103%
Total Phosphorous Removal, TPr	0.24 lbs/yr
Total Nitrogen Removal, TNr	2.00 lbs/yr

R6:

Parameter	Value
Drainage Area, A	0.48 ac
Imperviousness, I	55%
Runoff Coefficient, R_v	0.55
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	958 cf
Top of Ponding Area, PA_{top}	1884 sf
Bottom of Ponding Area, PA_{bottom}	906 sf
Ponding Volume, PV	698 cf
Soil Storage Volume, SV	340 cf
Total Volume Available, TV	1038 cf
% of Water Quality Volume Treated, %WQv	108%
Total Phosphorous Removal, TPr	0.18 lbs/yr
Total Nitrogen Removal, TNr	1.47 lbs/yr

R7:

Parameter	Value
Drainage Area, A	0.58
Imperviousness, I	55%
Runoff Coefficient, R_v	0.55
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	1158 cf
Top of Ponding Area, PA_{top}	2304 sf
Bottom of Ponding Area, PA_{bottom}	1116 sf
Ponding Volume, PV	855 cf
Soil Storage Volume, SV	419 cf
Total Volume Available, TV	1274 cf
% of Water Quality Volume Treated, %WQv	110%
Total Phosphorous Removal, TPr	0.21 lbs/yr
Total Nitrogen Removal, TNr	1.78 lbs/yr

R8:

Parameter	Value
Drainage Area, A	0.39 ac
Imperviousness, I	55%
Runoff Coefficient, R_v	0.55
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	779 cf
Top of Ponding Area, PA_{top}	1464 sf
Bottom of Ponding Area, PA_{bottom}	696 sf
Ponding Volume, PV	540 cf
Soil Storage Volume, SV	261 cf
Total Volume Available, TV	801 cf
% of Water Quality Volume Treated, %WQv	103%
Total Phosphorous Removal, TPr	0.14 lbs/yr
Total Nitrogen Removal, TNr	1.20 lbs/yr

*Notes:

- These bioretention areas were designed with very flat side slopes (6:1). If steeper side slopes are permitted, treatment capacity will increase.
- Pollutant removal values shown are 50% less than would be typical for these practices due to the assumption that the existing conditions provide pollutant removal benefits similar to a grass filter strip.

<u>Sizing Calculations and Assumptions</u>

In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

$Rv = 0.05 + 0.009 \times I$

$WQ_v = P/12 \times Rv \times A$

$PV = (PA_{top} + PA_{bottom})/2 \times 0.5'$

$SV = PA_{bottom} \times 0.25 \times 1.5$

$TV = PV + SV$

$\%WQv = TV / WQ_v \times 100$

$TPr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

$TNr = Removal\% \times P_{annual} \times P_j \times [WQv/43{,}560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

Where:

Removal % = Total nutrient removal percentage for bioretention areas = 55% for phosphorous, 64% for nitrogen

P_{annual} = average annual rainfall depth (inches) = 46 inches

P_j = fraction of rainfall events that produce runoff = 0.9

C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen

2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Assumptions:

- The existing drop inlet grate is located (or will be adjusted to) 6” below the road elevation. This allows 6” of freeboard for the overflow.
- The top of the bioretention area will be set six inches below the grate elevation, creating a 0.5’ ponding depth.
- The median bioretention areas will be designed with a 4’ flat grass strip at the road edge, followed by a 6 foot wide, 1 foot deep grass slope slope (6:1) to the bottom of the bioretention area.
- Where appropriate, the length and/or width of the bioretention area was decreased and the grass strip width increases as necessary to match the total volume available to the water quality volume.
- Soil storage volume is calculated using a filter bed depth of 18” with 0.25 void space ratio.

Recommended Plant List

See Appendix A for a planting plan description, including appropriate plant species.

Next Steps

- Discuss the project proposal with appropriate community, county, and state staff.
- Collect additional information needed to further develop the bioretention design, including utility verification and a survey of key elevations (road elevation, drop inlet grate elevation, etc.).
- Hold a pre-application meeting with permitting representatives from community, county, and state staff to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the bioretention area.
- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities typically associated with bioretention areas are summarized in Appendix D.

Preliminary Cost Estimate

Preliminary construction estimates for each of these projects are provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed. Monitoring wells are included in the preliminary cost estimate. Although they are not essential, they can be beneficial in determining the water table elevation, as well as infiltration rate in the proposed bioretention areas.

R3:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$1,700	$1,700.00
Safety Fence	928	linear feet	$5.00	$4,640.00
Traffic Control	1	lump sum	$3,000.00	$3,000.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Required	159	cubic yards	$15.00	$2,386.67
Hauling	159	cubic yards	$10.00	$1,591.11
Site stabilization w/ seeding & mulching	987	square yard	$1.00	$986.67
Mulch	187	square yard	$5.70	$1,064.00
Bioretention Plants (materials only)	187	square yard	$10.00	$1,866.67
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$18,535.11
Contingency and Incidental Costs (25%)				$4,633.78
Total Cost				**$23,169**

R4:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$1,000	$1,000.00
Safety Fence	420	linear feet	$5.00	$2,100.00
Traffic Control	1	lump sum	$3,000.00	$3,000.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Req'd	73	cubic yards	$15.00	$1,100.00
Hauling	73	cubic yards	$10.00	$733.33
Site stabilization w/ seeding & mulching	496	square yard	$1.00	$496.00
Mulch	104	square yard	$5.70	$592.80
Bioretention Plants (materials only)	104	square yard	$10.00	$1,040.00
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$11,362.13
Contingency and Incidental Costs (25%)				$2,840.53
Total Cost				**$14,203**

R5:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$1,200	$1,200.00
Safety Fence	500	linear feet	$5.00	$2,500.00
Traffic Control	1	lump sum	$3,000.00	$3,000.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Req'd	91	cubic yards	$15.00	$1,366.67
Hauling	91	cubic yards	$10.00	$911.11
Site stabilization w/ seeding & mulching	603	square yard	$1.00	$602.67
Mulch	131	square yard	$5.70	$744.80
Bioretention Plants (materials only)	131	square yard	$10.00	$1,306.67
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$12,931.91
Contingency and Incidental Costs (25%)				$3,232.98
Total Cost				**$16,165**

R6:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$1,000	$1,000.00
Safety Fence	410	linear feet	$5.00	$2,050.00
Traffic Control	1	lump sum	$3,000.00	$3,000.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Req'd	71	cubic yards	$15.00	$1,066.67
Hauling	71	cubic yards	$10.00	$711.11
Site stabilization w/ seeding & mulching	483	square yard	$1.00	$482.67
Mulch	101	square yard	$5.70	$573.80
Bioretention Plants (materials only)	101	square yard	$10.00	$1,006.67
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$11,190.91
Contingency and Incidental Costs (25%)				$2,797.73
Total Cost				**$13,989**

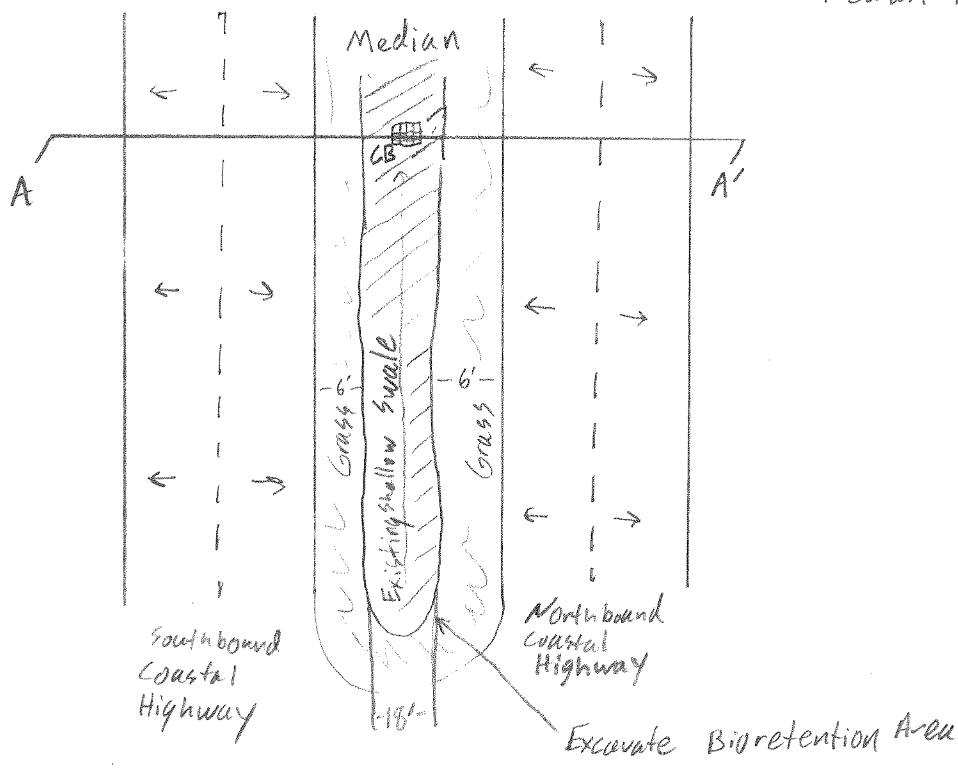
R7:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$1,100	$1,100.00
Safety Fence	480	linear feet	$5.00	$2,400.00
Traffic Control	1	lump sum	$3,000.00	$3,000.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Req'd	87	cubic yards	$15.00	$1,300.00
Hauling	87	cubic yards	$10.00	$866.67
Site stabilization w/ seeding & mulching	576	square yard	$1.00	$576.00
Mulch	124	square yard	$5.70	$706.80
Bioretention Plants (materials only)	124	square yard	$10.00	$1,240.00
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$12,489.47
Contingency and Incidental Costs (25%)				$3,122.37
Total Cost				**$15,612**

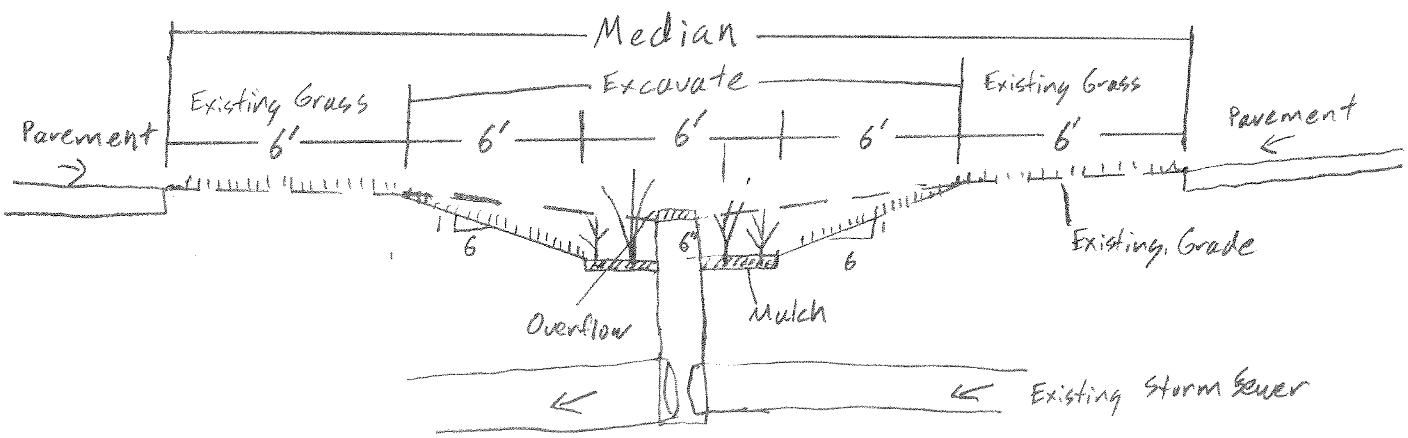
R8:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$900	$900.00
Safety Fence	340	linear feet	$5.00	$1,700.00
Traffic Control	1	lump sum	$3,000.00	$3,000.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Req'd	56	cubic yards	$15.00	$833.33
Hauling	56	cubic yards	$10.00	$555.56
Site stabilization w/ seeding & mulching	400	square yard	$1.00	$400.44
Mulch	77	square yard	$5.70	$440.80
Bioretention Plants (materials only)	77	square yard	$10.00	$773.33
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$9,903.47
Contingency and Incidental Costs (25%)				$2,475.87
Total Cost				**$12,379**

Greg Hoffmann
8/19/09
Coastal Highway
Median Retrofit



Plan View



Cross Section A-A'

R4a, R5a, R6a, R7a, R8a: COASTAL HIGHWAY WEST RIGHT-OF-WAY

Description

Coastal Highway and its drainage system make up the majority of the Anchorage Canal Watershed. Along the west side of the highway a grass strip, located within the right-of-way, separates the commercial properties from the highway. There are several opportunities for bioretention area retrofits in this space.

Existing Conditions

Stormwater runoff from approximately one half of the south bound lanes of Coastal Highway and much of the commercial properties on the west side of the highway drains to the grass strip within the right of way. A storm sewer runs along this right-of-way with periodic drop inlets located to collect the runoff. The grassed area is at least 20 feet wide in most areas.

Figure 1: Coastal Highway median. Top left: Looking north at drop inlet in site R5. Top right: Looking north in site R7. Bottom: Looking south in site R8.

Proposed Conditions

There is ample room for construction of bioretention areas along the grassed right of way of the highway. The bioretention areas would be narrow and long, with uniformly flat, safe, slopes from the outer edge to the center. Due to the presence of sandy soils on site, underdrains and replacement soil media will not be necessary, and construction of the bioretention areas will be relatively simple:

- Maintain a 4’wide undisturbed grass strip along the pavement edge.
- Excavate the center of the bioretention area to a depth at least fifteen inches below the road elevation and nine inches below the existing drop inlet grate elevation. (It may be necessary to raise the drop inlet grate if the existing elevation is too low.) The width of the bottom of the bioretention area will vary depending on the space available.
- Keep slopes from the undisturbed grass strip to the bottom of the bioretention at 6:1 or flatter.
- Vegetate the slopes and bottom of the bioretention area using one of the following strategies:

  Strategy 1, Cool Season Turf – Plant cool season turf grass and mow routinely.

  Kill existing vegetation with a non-selective herbicide (glyphosate) in late August and reseed with turf type tall fescue between August 15 and September 30. Mow the median on a routine mowing schedule to a height of 4-6 inches. *This strategy provides a highly maintained traditional median and would be acceptable where neat, controlled vegetation is desired.*

  Strategy 2, Tree and Shrub Masses – Plant the bioretention area with appropriate species that are both water-tolerant and drought-tolerant. These could include warm season meadow grasses, herbaceous perennials, or shrubs. Add a 3-inch layer of mulch at establishment but allow plants to grow together such that routine mulching is no longer necessary.

  Kill existing vegetation with a non-selective herbicide (glyphosate) in late spring. Cut dead vegetation as close to the ground as possible. Plant several trees as the backbone of the biotention planting. Species to be planted should stay relatively small and should not grow to a caliper of larger than 4 inches. Suggested tree species include *Amelanchier canadensis, Cercis canadensis, Chionanthus virginicus, Juniperus virginiana* ‘Emerald Sentinnel’, Plant shrubs (*Baccharis halmifolia,Cephalanthus occidentalis, Clethra alnifolia, Ilex verticillata, Myrica cerifera, Myrica pensylvanica, Rhus copallina*) in clusters of at least 5-7 in the bioretention planting. Use a ground layer of several species of herbaceous perennials in front of and in between the shrub masses. Use plugs or quarts and space on approximately 18 inch centers. Suggested herbaceous ground layers include *Aster oblongifolius* ‘Raydon’s Favorite,’ *Eupatorium coelestinum, Euthamia graminifolia, Hibiscus moscheutos, Rudbeckia laciniata, Solidago caesia, Solidago sempervirens.* Grasses or sedges such as *Carex stricta, Chasmanthium latifolium, Deschampsia flexuosa, Muhlenbergia capillaris, Panicum amarum, Panicum virgatum, Schizachyrium scoparium, Sporobolis heterolepis* are also suggested for use in masses in front of or between shrub masses. Mulch at planting and for 1-2 years until vegetation forms a solid ground layer. Spot treat or hand pull undesirable weeds. Cut back herbaceous plants and grasses to the ground annually in the spring. Treat with a preemergent herbicide in April to reduce weed problems each year. *This strategy will result in an ornamental planting buffer between the roadway and commercial lots. Ornamental value can be increased by increasing the density of plants in the bioretention swales.*

Strategy 3. Planted Ornamental Bed – Plant a highly ornamental mix of perennials and shrubs that is managed routinely as a beautification planting. Add a 3-inch layer of mulch and re-mulch yearly.

Kill existing vegetation with a non-selective herbicide (glyphosate) in late spring. Cut dead vegetation as close to the ground as possible. Plant a combination of 2-3 herbaceous perennials in large masses to create a simple ornamental pattern. Use plugs or quarts and space on approximately 18 inch centers. Some effective species combinations include (*Aster oblongifolius* 'Raydon's Favorite' and *Solidago sempervirens; Amsonia hubrichtii* and *Panicum virgatum 'Northwind'; Aster laevis 'Bluebird'* and *Asclepias tuberosa; Rudbeckia laciniata* and *Vernonia novaborensis; Schizachyrium scoparium* and *Eupatorium serotinum*). Mulch at planting and for 1-2 years until vegetation forms a solid ground layer. Spot treat or hand pull undesirable weeds. Mow the planting annually in the spring to remove dead perennial vegetation. Treat with a preemergent herbicide in April to reduce weed problems each year. *This strategy is the most expensive and most ornamental planting option. It should be reserved for high visibility gateway or intersection sites.*

With this design, during all rain events, stormwater runoff from the highway and commercial properties will be directed to the bioretention area. Water will then pond to a depth of at least six inches. Excess runoff during larger storm events will overflow into the existing drop inlet. The ponded water will slowly infiltrate into the soil media and underlying soils. The primary pollutant removal mechanisms operating in the bioretention area will be settling, infiltration, and plant uptake.

<u>Additional Design Considerations and Site Constraints</u>

Several difficult issues exist for this location, and should be further investigated as a part of this project:

- Since most of these areas do not have curbs, care must be taken to ensure that any re-graded slopes do not pose a danger to vehicle traffic. The elevation of existing drop inlet grates may have to be raised in order to allow for sufficient ponding depth and safe slopes.
- Areas with curbing may require curb cuts to allow runoff to enter the bioretention areas.
- The top of the storm sewer that runs underneath each of these proposed bioretention areas is very near to the ground surface. If the proposed bottom of the bioretention area will be too near the top of the pipe, it may be necessary to adjust either the location or the elevation of the bioretention area.
- Plans for Middlesex Beach indicate an 8" and a 6" force main running along the west side of Coastal Highway. The 8" force main appears to be under the pavement, but

- o While other underground utilities, including gas, telephone, cable, and electric lines were not observed in the field, telephone lines are also shown in some areas on the Middlesex Beach drawings, and others may be present. All utilities' location and depth must be verified. Overhead are also present, and will have to be avoided.
- o Road signs and mailboxes may need to be relocated in some cases.
- o In several locations, small sinkholes were observed above the storm sewer. This may be a sign or a crack or other problem with the storm sewer, which should be corrected before completion of a bioretention area.

Preliminary Plans

Please see the attachments for preliminary plans for the proposed stormwater retrofit. These preliminary plans will need to be further refined as this project proceeds toward construction. The plans include a general drawing for all of the sites, and a depiction of each bioretention area's contributing drainage area.

Unique Site Characteristics

While each right-of-way retrofit has similar design features, the area available for construction of bioretention, the contributing drainage areas, and the existing vegetation differ significantly. Important features of each site are provided below.

- R4: Grass strip area utilized: 25' x 160'. This includes approximately 12' of the ROW and 13' on private land. Some of the existing plantings in parking lot islands can remain, but Miscanthus (invasive plant) should be removed.
- R5: Grass strip area utilized: 23' x 150' This includes approximately 20' in the ROW and 3' on private land. This bioretention area must be extended to the north beyond its drainage area to provide sufficient capacity. Also, a shrub mass would work well as a boomerang-shaped bed on the north end of this area.
- R6: Grass strip area utilized: 19' x 270'. This appears to be entirely in the ROW. The pruned junipers, Japanese privet (invasive plant) and stunted sycamores in the existing planting bed should be removed.
- R7: Grass strip area utilized: 20' x 150'. This appears to be entirely in the ROW. In order to collect as much runoff as possible from the adjacent private property, it may be necessary to remove, or at least re-grade one parking space at the south end of the Long and Foster parking lot. Plants (crape myrtle, barberry—invasive plant, miscellaneous annuals) and mulch (dyed mulch) in the existing landscape bed adjacent to the parking lot should be removed and bioretention planting continued to the edge of the parking area.
- R8 north: Grass strip area utilized: 20' x 100'. This appears to be entirely in the ROW. Curb cuts would be necessary on the McDonald's parking lot to direct water into the bioretention area.
- R8 south: Grass strip area utilized: 20' x 90'. This appears to be entirely in the ROW.

*Note: All estimates of private versus public land requirements were based upon property lines shown on the aerial photo, and should be field verified before construction proceeds or cooperative agreements are signed.

Preliminary Hydrologic Conditions

Preliminary sizing of each bioretention area is provided in the tables below.

R4:

Parameter	Value
Drainage Area, A	0.84
Imperviousness, I	65%
Runoff Coefficient, R_v	0.635
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	1936
Top of Ponding Area, PA_{top}	2310
Bottom of Ponding Area, PA_{bottom}	1332
Ponding Volume, PV	911
Soil Storage Volume, SV	500
Total Volume Available, TV	1410
% of Water Quality Volume Treated, %WQv	73%
Total Phosphorous Removal, TPr	0.26 lbs/yr
Total Nitrogen Removal, TNr	2.17 lbs/yr

R5:

Parameter	Value
Drainage Area, A	0.56
Imperviousness, I	50%
Runoff Coefficient, R_v	0.5
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	1016
Top of Ponding Area, PA_{top}	1872
Bottom of Ponding Area, PA_{bottom}	966
Ponding Volume, PV	710
Soil Storage Volume, SV	362
Total Volume Available, TV	1072
% of Water Quality Volume Treated, %WQv	105%
Total Phosphorous Removal, TPr	0.19 lbs/yr
Total Nitrogen Removal, TNr	1.56 lbs/yr

R6:

Parameter	Value
Drainage Area, A	1.11
Imperviousness, I	85%
Runoff Coefficient, R_v	0.815
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	3284
Top of Ponding Area, PA_{top}	2376
Bottom of Ponding Area, PA_{bottom}	774
Ponding Volume, PV	788
Soil Storage Volume, SV	290
Total Volume Available, TV	1078
% of Water Quality Volume Treated, %WQv	33%
Total Phosphorous Removal, TPr	0.20 lbs/yr
Total Nitrogen Removal, TNr	1.66 lbs/yr

R7:

Parameter	Value
Drainage Area, A	1.55
Imperviousness, I	60%
Runoff Coefficient, R_v	0.59
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	3320
Top of Ponding Area, PA_{top}	1440
Bottom of Ponding Area, PA_{bottom}	552
Ponding Volume, PV	498
Soil Storage Volume, SV	207
Total Volume Available, TV	705
% of Water Quality Volume Treated, %WQv	21%
Total Phosphorous Removal, TPr	0.13 lbs/yr
Total Nitrogen Removal, TNr	1.08 lbs/yr

R8 north:

Parameter	Value
Drainage Area, A	0.24
Imperviousness, I	80%
Runoff Coefficient, R_v	0.77
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	671
Top of Ponding Area, PA_{top}	940
Bottom of Ponding Area, PA_{bottom}	352
Ponding Volume, PV	323
Soil Storage Volume, SV	132
Total Volume Available, TV	455
% of Water Quality Volume Treated, %WQv	68%
Total Phosphorous Removal, TPr	0.08 lbs/yr
Total Nitrogen Removal, TNr	0.70 lbs/yr

R8 south:

Parameter	Value
Drainage Area, A	0.28
Imperviousness, I	40%
Runoff Coefficient, R_v	0.41
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	417
Top of Ponding Area, PA_{top}	840
Bottom of Ponding Area, PA_{bottom}	312
Ponding Volume, PV	288
Soil Storage Volume, SV	117
Total Volume Available, TV	405
% of Water Quality Volume Treated, %WQv	97%
Total Phosphorous Removal, TPr	0.07 lbs/yr
Total Nitrogen Removal, TNr	0.62 lbs/yr

*Notes:

- These bioretention areas were designed with very flat side slopes (6:1). If steeper side slopes are permitted, treatment capacity will increase.
- Pollutant removal values shown are 50% less than would be typical for these practices due to the assumption that the existing conditions provide pollutant removal benefits similar to a grass filter strip.

Sizing Calculations and Assumptions

In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

$Rv = 0.05 + 0.009 \times I$

$WQ_v = P/12 \times Rv \times A$

$PV = (PA_{top} + PA_{bottom})/2 \times 0.5'$

$SV = PA_{bottom} \times 0.25 \times 1.5'$

$TV = PV + SV$

% of Water Quality Volume Treated = $TV / WQ_v \times 100$

TPr = Removal% x P_{annual} x P_j x [WQv/43,560/P] x C x 2.72 x %WQv (if less than 100)

TNr = Removal% x P_{annual} x P_j x [WQv/43,560/P] x C x 2.72 x %WQv (if less than 100)

Where:

Removal % = Total nutrient removal percentage for bioretention areas = 55% for phosphorous, 64% for nitrogen

P_{annual} = average annual rainfall depth (inches) = 46 inches

P_j = fraction of rainfall events that produce runoff = 0.9

C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen

2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Assumptions:

- The existing drop inlet grate is located (or will be adjusted to) 6” below the road elevation. This allows 6” of freeboard for the overflow.
- The top of the bioretention area will be set six inches below the grate elevation, creating a 0.5’ ponding depth.
- The median bioretention areas will be designed with a 4’ flat grass strip at the road edge, followed by a 6 foot wide, 1 foot deep grass slope slope (6:1) to the bottom of the bioretention area.
- Where appropriate, the length and/or width of the bioretention area was decreased and the grass strip width increases as necessary to match the total volume available to the water quality volume.
- Soil storage volume is calculated using a filter bed depth of 18” with 0.25 void space ratio.

<u>Next Steps</u>

- Discuss the project proposal with appropriate community, county, and state staff.
- Collect additional information needed to further develop the bioretention design, including utility verification and a survey of key elevations (road elevation, drop inlet grate elevation, etc.).
- Hold a pre-application meeting with permitting representatives from community, county, and state staff to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the bioretention area.

- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities typically associated with bioretention areas are summarized in Appendix D.

Preliminary Cost Estimate

Preliminary construction estimates for each of these projects are provided below. These costs are intended only as an estimate. Unforeseen additional costs or savings may arise as the final designs are completed.

R4:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$900	$900.00
Safety Fence	370	linear feet	$5.00	$1,850.00
Traffic Control	1	lump sum	$1,500.00	$1,500.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Required	87	cubic yards	$15.00	$1,303.33
Hauling	87	cubic yards	$10.00	$868.89
Site stabilization w/ seeding & mulching	296	square yard	$1.00	$296.44
Mulch	148	square yard	$5.70	$843.60
Bioretention Plants (materials only)	148	square yard	$10.00	$1,480.00
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$10,342.27
Contingency and Incidental Costs (25%)				$2,585.57
Total Cost				**$12,928**

R5:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$800	$800.00
Safety Fence	346	linear feet	$5.00	$1,730.00
Traffic Control	1	lump sum	$1,500.00	$1,500.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Required	71	cubic yards	$15.00	$1,060.00
Hauling	71	cubic yards	$10.00	$706.67
Site stabilization w/ seeding & mulching	276	square yard	$1.00	$276.00
Mulch	107	square yard	$5.70	$611.80
Bioretention Plants (materials only)	107	square yard	$10.00	$1,073.33
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$9,057.80
Contingency and Incidental Costs (25%)				$2,264.45
Total Cost				**$11,322**

R6:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$900	$900.00
Safety Fence	578	linear feet	$5.00	$2,890.00
Traffic Control	1	lump sum	$1,500.00	$1,500.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Required	85	cubic yards	$15.00	$1,270.00
Hauling	85	cubic yards	$10.00	$846.67
Site stabilization w/ seeding & mulching	512	square yard	$1.00	$512.00
Mulch	58	square yard	$5.70	$330.60
Bioretention Plants (materials only)	58	square yard	$10.00	$580.00
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$10,129.27
Contingency and Incidental Costs (25%)				$2,532.32
Total Cost				**$12,662**

R7:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$800	$800.00
Safety Fence	340	linear feet	$5.00	$1,700.00
Traffic Control	1	lump sum	$1,500.00	$1,500.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Required	55	cubic yards	$15.00	$820.00
Hauling	55	cubic yards	$10.00	$546.67
Site stabilization w/ seeding & mulching	272	square yard	$1.00	$272.00
Mulch	61	square yard	$5.70	$349.60
Bioretention Plants (materials only)	61	square yard	$10.00	$613.33
Pavement removal	1	lump sum	$500.00	$500.00
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$8,401.60
Contingency and Incidental Costs (25%)				$2,100.40
Total Cost				**$10,502**

R8 north:

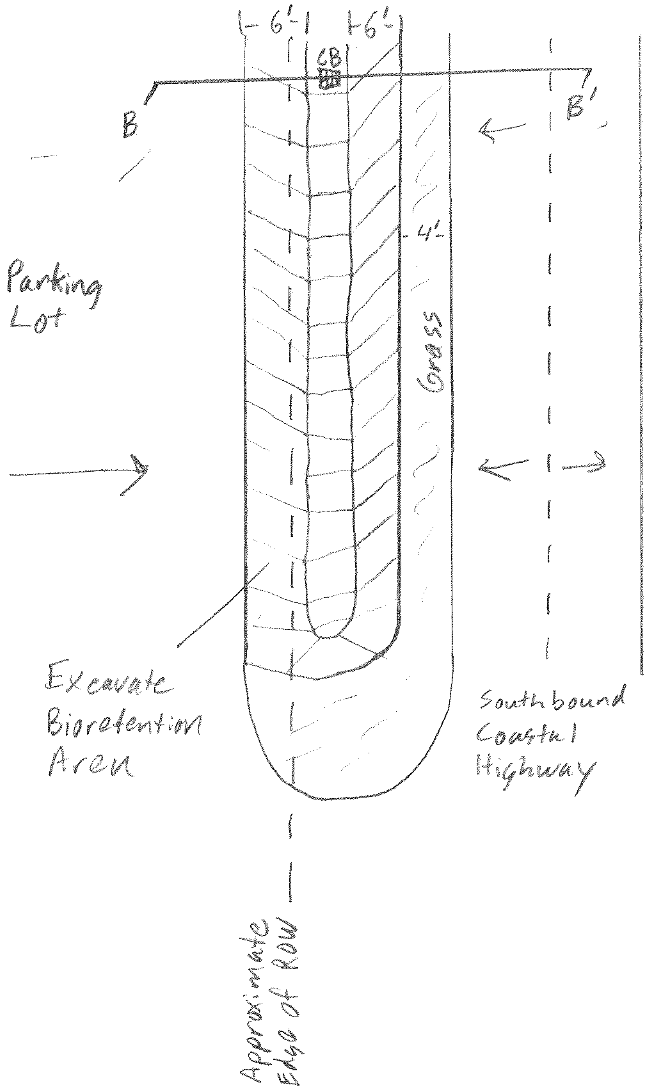
Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$600	$600.00
Safety Fence	240	linear feet	$5.00	$1,200.00
Traffic Control	1	lump sum	$1,500.00	$1,500.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Required	36	cubic yards	$15.00	$542.22
Hauling	36	cubic yards	$10.00	$361.48
Site stabilization w/ seeding & mulching	183	square yard	$1.00	$183.11
Mulch	39	square yard	$5.70	$222.93
Bioretention Plants (materials only)	39	square yard	$10.00	$391.11
Curb cuts	4	each	$100.00	$400.00
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$6,700.86
Contingency and Incidental Costs (25%)				$1,675.21

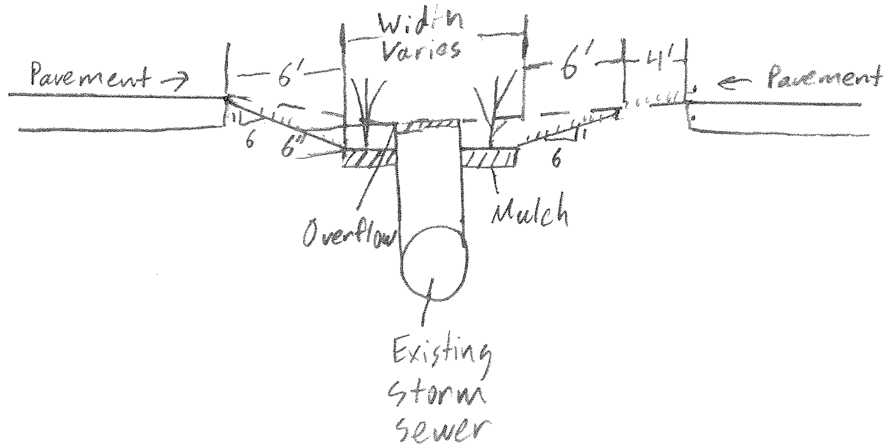
Total Cost	**$8,376**

R8 south:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$500	$500.00
Safety Fence	220	linear feet	$5.00	$1,100.00
Traffic Control	1	lump sum	$1,500.00	$1,500.00
Erosion and Sediment Control	1	lump sum	$1,000.00	$1,000.00
Excavation Required	32	cubic yards	$15.00	$486.67
Hauling	32	cubic yards	$10.00	$324.44
Site stabilization w/ seeding & mulching	165	square yard	$1.00	$165.33
Mulch	35	square yard	$5.70	$197.60
Bioretention Plants (materials only)	35	square yard	$10.00	$346.67
Monitoring Well	1	lump sum	$300.00	$300.00
			Total	$5,920.71
Contingency and Incidental Costs (25%)				$1,480.18
Total Cost				**$7,401**

Greg Hoffmann
8/19/09
Coastal Highway
West Right-of-Way
Retrofit





Cross Section B-B'

R4c AND EAST COASTAL HIGHWAY: COASTAL HIGHWAY ADDITIONAL OPPORTUNITIES

Description

Coastal Highway and its drainage system make up the majority of the Anchorage Canal Watershed. While many of the common and consistent retrofit opportunities along the highway were identified in other documents, a few unique opportunities remain, and are described here.

R4 at Short Road

Existing Conditions

Between Short Road and the law office to the south, is an existing small bioretention area. The bioretention area collects water from the law office and most of its parking lot. It is planted with turf grass, and appears to include an underdrain approximately six inches below the bottom.

Figure 1: Bioretention area between Short Road and law office.

Proposed Conditions

The underdrain may not be deep enough to provide an effective filtering depth for the stormwater runoff that the bioretention area receives. Further, it appears that the existing soil is sandy enough to allow infiltration, rather than just filtration. This could be accomplished by simply capping the underdrain at the outlet. Capping the underdrain would force water in the bioretention area to infiltrate into the soil, rather than entering the storm sewer via the underdrain.

Converting this bioretention area into an infiltration-based practice may lead to increased periods of standing water after rain events, but this should not be a problem, as the adjacent building does not appear to have a basement. Additional plantings could be added to increase evapotranspiration as well. . To tolerate periodic standing water, a native water-loving plant such as marshmallow (*Hibiscus moscheutos*) could be planted as a mass to take up water and provide showy pink/white flowers during August. If standing water becomes a problem, the cap on the underdrain could simply be removed, and the system would be quickly returned to existing conditions.

While plans are not necessary for this retrofit, an aerial photo indicating the practice's contributing drainage area has been included.

Preliminary Hydrologic Conditions
Estimated sizing of for the bioretention area is provided in the tables below.

R4:

Parameter	Value
Drainage Area, A	0.39 ac
Imperviousness, I	100%
Runoff Coefficient, R_v	0.95
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	1346 cu. ft.
Top of Ponding Area, PA_{top}	500 sq. ft
Bottom of Ponding Area, PA_{bottom}	200 sq. ft
Ponding Volume, PV	525 cu. ft
Soil Storage Volume, SV	75 cu. ft
Total Volume Available, TV	600cu. ft.
% of Water Quality Volume Treated, WQv%	45%
Total Phosphorous Removal, TPr	0.22 lbs/yr
Total Nitrogen Removal, TNr	1.85 lbs/yr

Next Steps

- Discuss the project proposal with the property owners and community staff.
- Cap the underdrain.
- Observe the site for several days after rain events to determine the feasibility of infiltration in the practice.
- Plant bioretention plants in the practice if desired.

<u>East side of Coastal Highway</u>

Existing Conditions
Grass swales run along most of the east side of Coastal Highway. These swales collect stormwater runoff from a portion of the highway as well as the residential neighborhoods to the east. Runoff is conveyed through these swales to storm sewer inlets that connect to the storm sewer on the west side of the road.

Figure 2: East side of Coastal Highway. Left: Partially filled stormwater inlet in Site R8. Right: Stormwater inlet and shallow swale in Site R5.

Proposed Conditions

These grass swales provide minimal water quality treatment, and could be improved to function more like an engineered dry swale or bioretention area, promoting greater infiltration.

While keeping safe slopes adjacent to the highway, the swales can be excavated wider and deeper, with a nearly flat profile slope. This would provide greater ponding volume and reduce the speed at which runoff is conveyed through the swale. Stone check dams should be added on either side of the stormwater inlets and further up the swales as needed. The check dams will hold water temporarily, encouraging infiltration, but will allow the water to slowly drain out, so excessive ponding should not be a problem.

In some locations, shrub removal may be necessary to accommodate expansion of the swales. The expanded swales can be planted with bioretention plants similar to those to be used for the median and west side of Coastal Highway. Large masses of one or two species per area should be repeated in multiple locations to unify the roadside and provide a neater consistency to the town plantings.

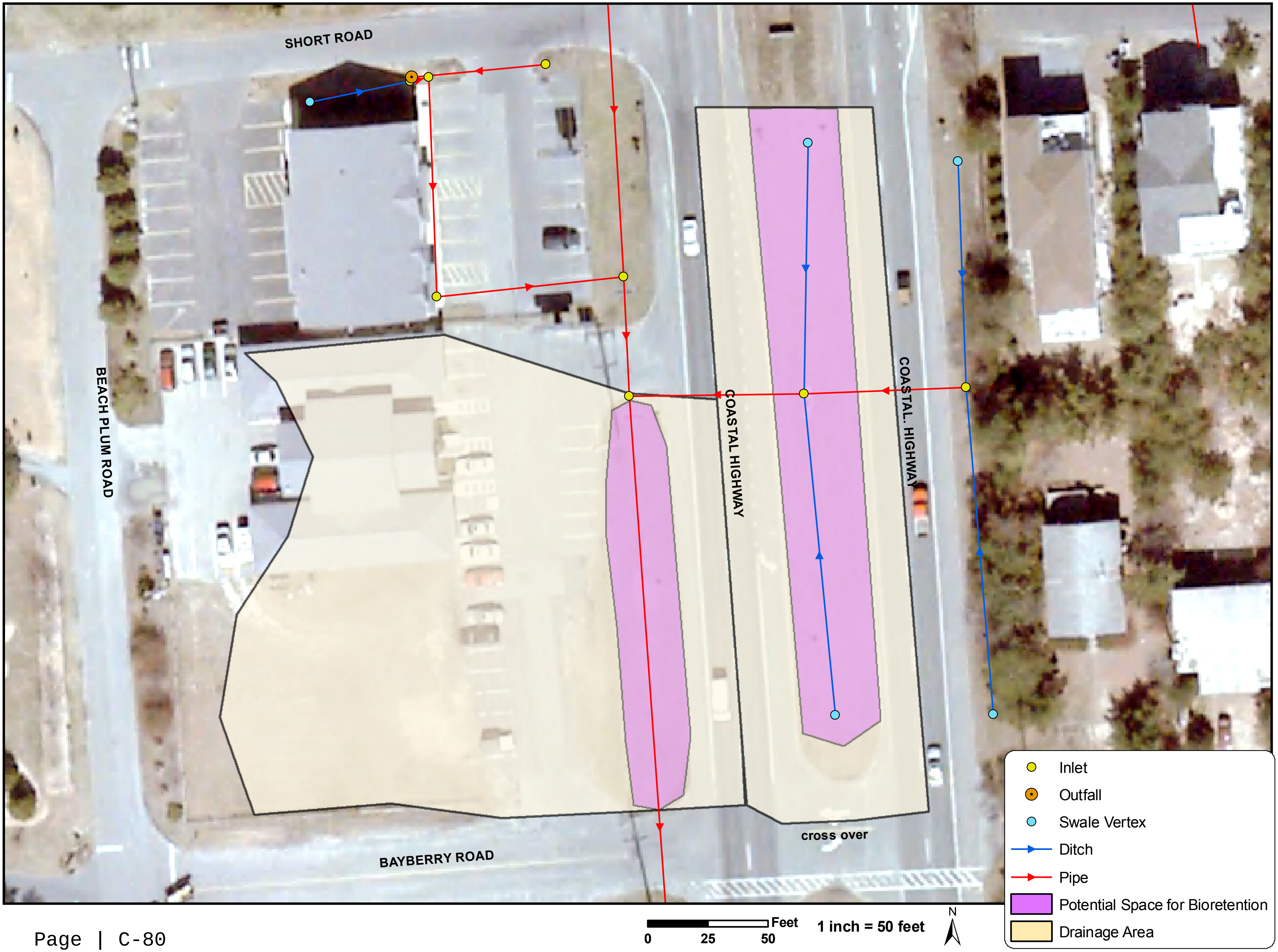
Next Steps

- Delineate drainage areas to each practice to determine the size, feasibility, and cost effectiveness of each practice.
- Discuss the project proposal with appropriate community, county, and state staff.
- Collect additional information needed to further develop the design, including utility verification and a survey of key elevations (road elevation, stormwater inlet elevation, etc)
- Hold a pre-application meeting with permitting representatives from community, county, and state staff to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the bioretention area.
- Submit final design to appropriate agencies for review and approval.

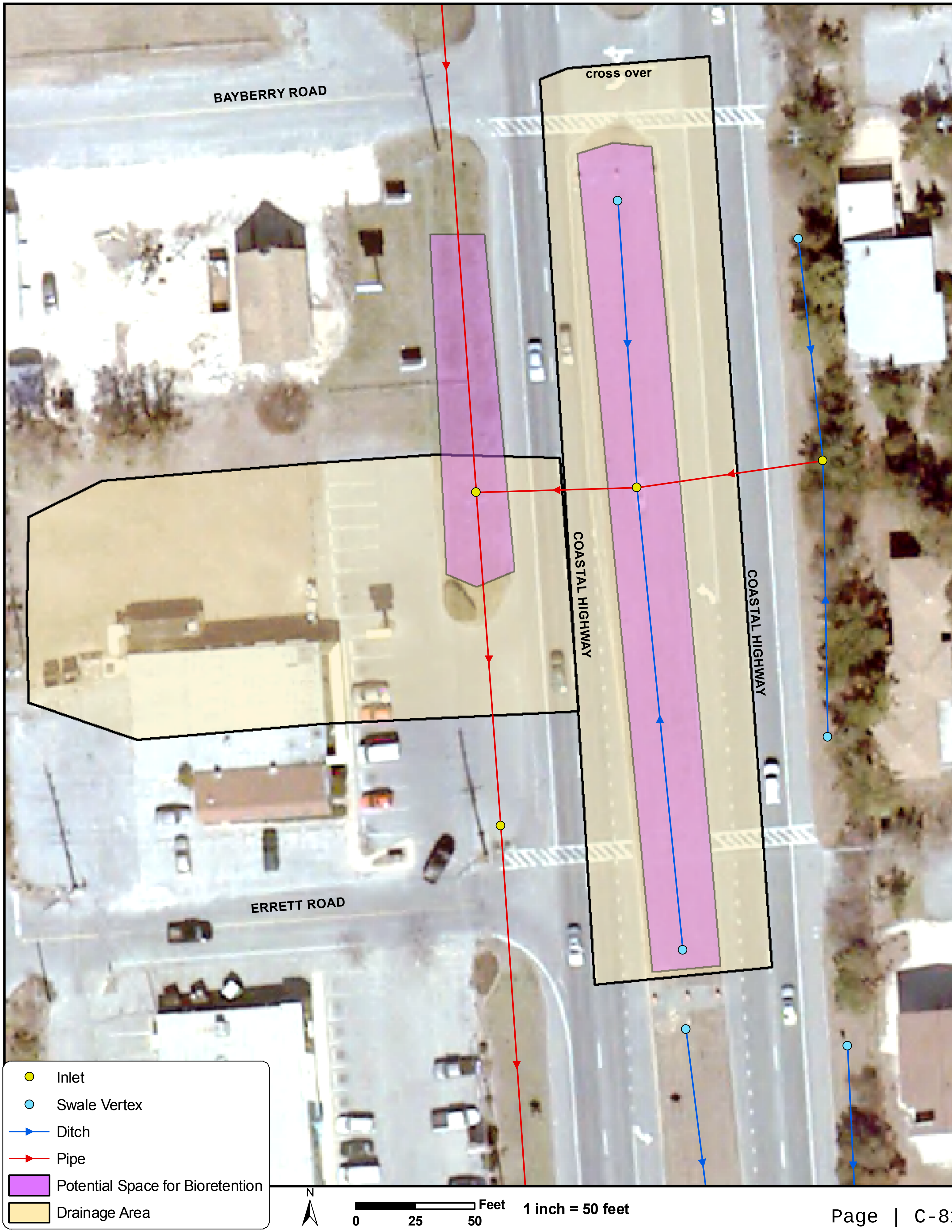
Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities typically associated with bioretention areas are summarized in Appendix D.

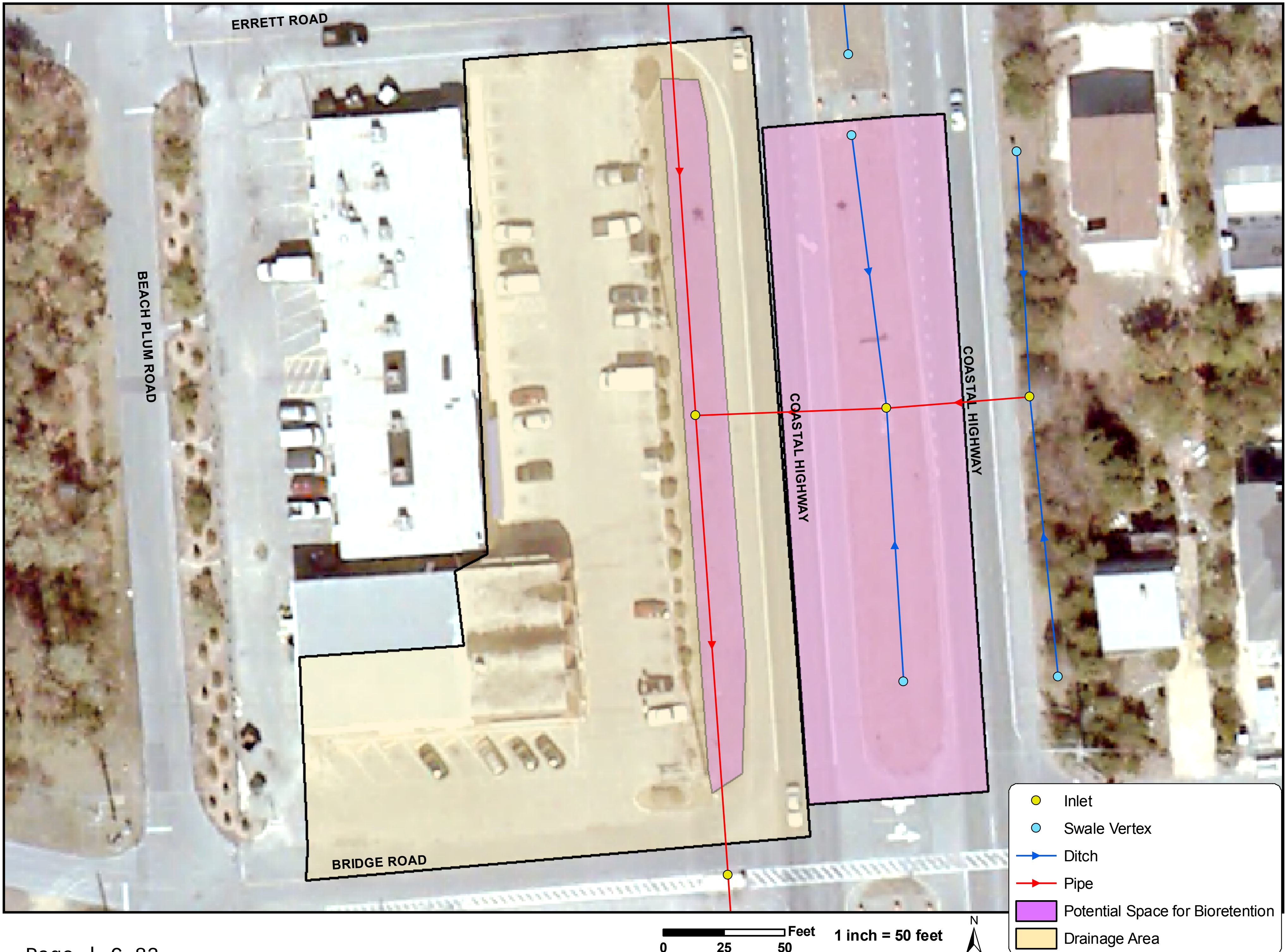
Anchorage Canal - Drainage Area for R4



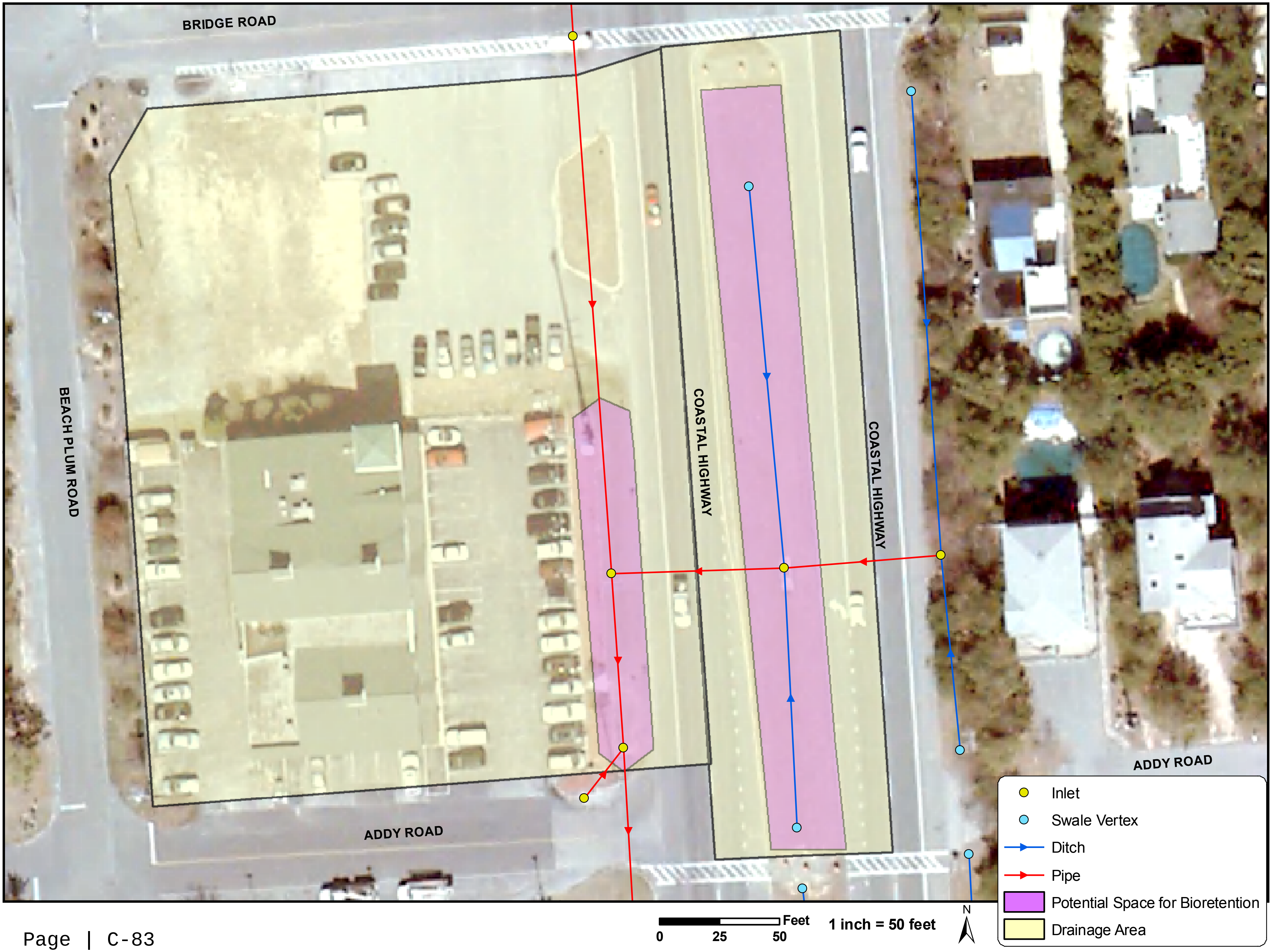
Anchorage Canal - Drainage Area for R5



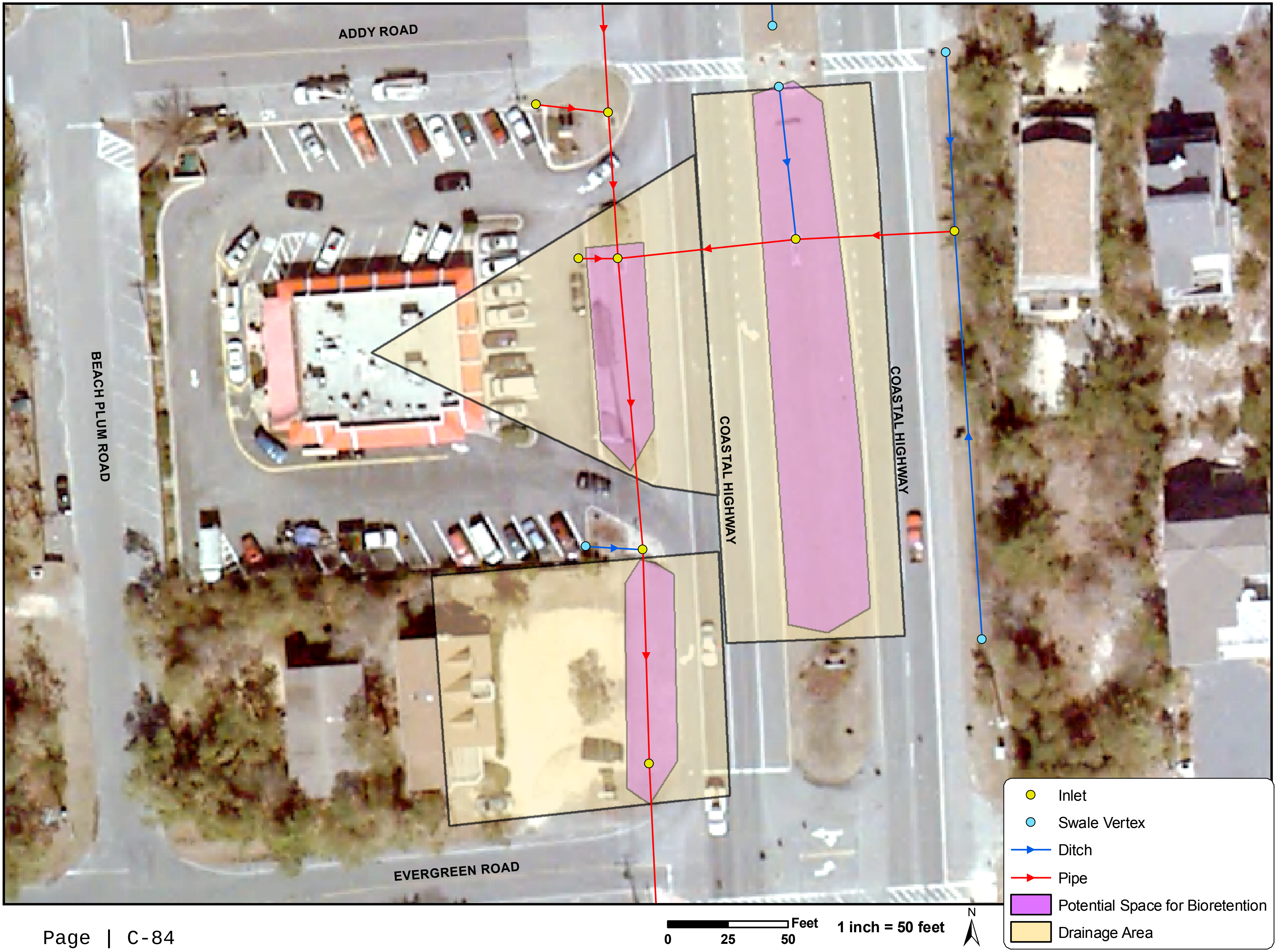
Anchorage Canal - Drainage Area for R6



Anchorage Canal - Drainage Area for R7



Anchorage Canal - Drainage Area for R8

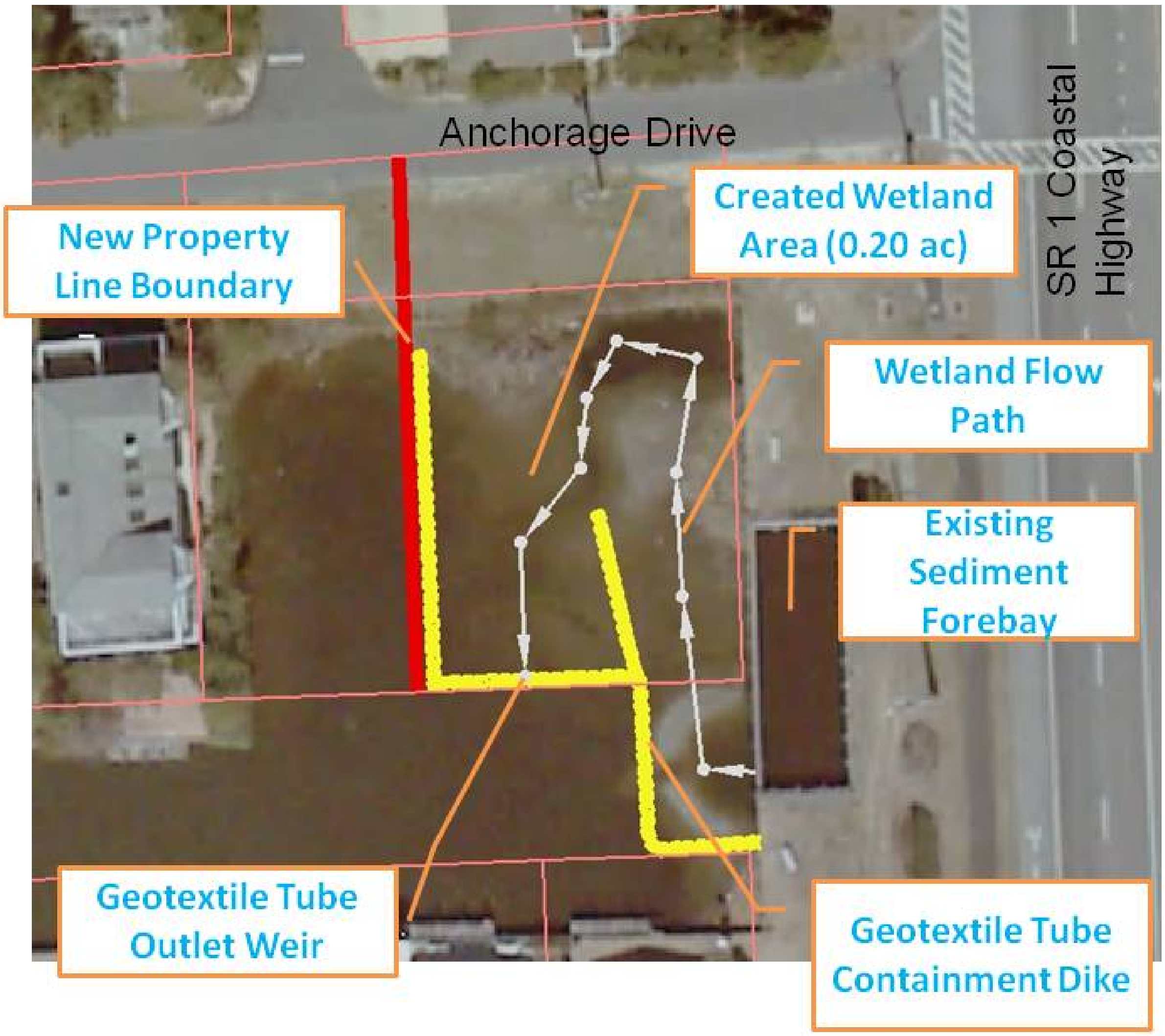


R9: CONSTRUCTED WETLAND AT DELDOT SEDIMENT FOREBAY

At the termination of Anchorage Canal exists two privately owned parcels that could be used to create a stormwater wetland to treat flows that exit the DelDOT sediment forebay. It is recommended that the two parcels first be recreated in order to provide a more developable lot for the owner of the two lots and provide space for the creation of the wetland. Geotextile tubes (see below) would be used as dikes to create a containment area that separates the created wetland from the canal. Dredge spoils from the canal as well as sediment that is captured in the sediment forebay could be used to both fill the geotextile tubes as well as place inside the wetland creation area in order to create high marsh areas within the wetland where wetland vegetation can become established and help to remove nutrients prior to entering the canal. The geotextile tubes and sediment would be placed so as to create a sinuous route through the wetland in order to provide maximum residence time for settling of particles. A lower geotextle tube weir would be located at the end of the sinuous route to allow treated flow out of the wetland and into the canal. The elevation of the outlet weir would likely be set around 1.0 above sea level as is the sediment forebay outflow spillway. The length of the weir would be longer than the 12’ used for the sediment forebay in order to reduce velocities and scour affects. Approximately 0.20 acres of wetland could be created to provide treatment. The treatment volume provided would depend on the depths provided within the wetland. An average depth of 12” would provide approximately 8,712 cubic feet of storage volume.

Geotextile Tube Containment

Stormwater Wetland Creation at DelDOT Sediment Forebay



Preliminary Hydrologic Conditions
Preliminary sizing of the constructed wetland area is provided in the table below.

R9:

Parameter	Value
Drainage Area, A	85 ac
Imperviousness, I	55%
Runoff Coefficient, R_v	0.55
Rainfall Depth Treated, P	1.0 in.
Water Quality Volume, WQ_v	169,703 cf
Top of Ponding Area, PA_{top}	7500 sf
Bottom of Ponding Area, PA_{bottom}	4200 sf
Ponding Volume, PV	11,700 cf
Soil Storage Volume, SV	0 cf
Total Volume Available, TV	11,700 cf
% of Water Quality Volume Treated, %WQv	7%
Total Phosphorous Removal, TPr	3.99 lbs/yr
Total Nitrogen Removal, TNr	14.28 lbs/yr

Sizing Calculations and Assumptions
In order to obtain the hydrologic values reported above, the following calculations and assumptions were used.

Calculations:

$Rv = 0.05 + 0.009 \times I$
$WQ_v = P/12 \times Rv \times A$
$PV = (PA_{top} + PA_{bottom})/2 \times 2.0'$
$SV = 0$
$TV = PV + SV$
$\%WQv = TV / WQ_v \times 100$

$TPr = Removal\% \times P_{annual} \times P_j \times [WQv/43,560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)
$TNr = Removal\% \times P_{annual} \times P_j \times [WQv/43,560/P] \times C \times 2.72 \times \%WQv$ (if less than 100)

Where:

Removal % = Total nutrient removal percentage for constructed wetland areas = 50% for phosphorous, 25% for nitrogen
P_{annual} = average annual rainfall depth (inches) = 46 inches
P_j = fraction of rainfall events that produce runoff = 0.9
C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus, 1.86 mg/L for total nitrogen
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Assumptions:

- The combination of deeper pools, high and low marsh will provide an average depth of 2’.
- The width of the geotextile tubes will be approximately 16’.

Next Steps

- Discuss the project proposal with appropriate community, county, and state staff.
- Collect additional information needed to further develop the constructed wetland design, including utility verification and a survey of key elevations (forebay, canal bottom elevations, wooden bulkhead elevations, etc.).
- Hold a pre-application meeting with permitting representatives from community, county, and state staff to discuss the proposed retrofit and the project review and approval process.
- Use information gathered from the pre-application meeting and additional information about site characteristics and constraints to perform final design of the wetland creation area.
- Submit final design to appropriate agencies for review and approval.

Maintenance Considerations

Maintenance of all stormwater retrofits is necessary to ensure that they continue to provide stormwater management and aesthetic benefits over time. The routine maintenance activities typically associated with wetland creation areas are summarized in Appendix D.

Preliminary Cost Estimate

Preliminary construction estimates for each of these projects are provided below. Preliminary construction estimates for each of these projects are provided below. These costs are intended only as an estimate. These costs do not include any property acquisition costs. Unforeseen additional costs or savings may arise as the final designs are completed.

R9:

Material item (furnish and install)	Amount	Unit	Cost/unit	Cost
Mobilization	1	lump sum	$17,000	$17,000
Safety Fence	150	linear feet	$5.00	$750
Traffic Control	1	lump sum	$1000.00	$1000.00
Hydraulic Dredging	1500	cubic yards	$100.00	$150,000
Geotextile Tubes (6.5 high x 16 wide)	280	linear feet	$55	$15,400
Wetland Plants (materials only)	450	square yard	$10.00	$4,500
			Total	$188,650.00
			Contingency and Incidental Costs (25%)	$47,162.50
			Total Cost	**$235,812.50**

Appendix D: Routine Maintenance Activities Typically Associated with Stormwater Retrofit Practices

Stormwater Practice	Activity	Schedule
Bioretention	• Water to promote plant growth and survival. • Inspect site following rainfall events. Plant replacement vegetation in any eroded areas.	As Needed (Following Construction)
Bioretention	• Prune and weed swale to maintain appearance. • Remove accumulated trash and debris. • Replace mulch as needed.	Regularly (Monthly)
Bioretention	• Inspect inflow area for sediment accumulation. Remove any accumulated sediment or debris. • Inspect site for erosion and the formation of rills and gullies. Plant replacement vegetation in any eroded areas. • Inspect bioretention area for dead or dying vegetation. Plant replacement vegetation as needed. • Test planting bed for pH. If the pH is below 5.2, limestone should be applied. If the pH is above 8.0, iron sulfate and sulfur should be applied.	Annually (Semi-Annually During First Year)
Bioretention	• Replace mulch.	Every 2 to 3 Years
Curb Openings	• Inspect curb openings for trash and debris.	Monthly
Curb Openings	• Inspect the grass strip behind the openings after intense rainfall and runoff events of long duration. Small small erosion channels quickly become large problems.	As needed Following storm event
Filter Strip	• Mow and remove hay as required to maintain moderate vegetation height. The vegetation should not be mowed closer than 6 inches.	Every 4 months

Stormwater Practice	Activity	Schedule
	• Inspect the filter strip after intense rainfall events and runoff events of long duration. Small breaks in the sod and small erosion channels quickly become large problems.	As needed Following storm event
	• Inspect the filters for formation of erosion channels within the filter. Even small channels may allow much of the runoff from the field to bypass the filter. These areas should be repaired and reseeded immediately to help ensure proper flow of runoff through the filter	As Needed Following storm event
Forebay	• Inspect forebay for trash and debris, and the check dam, which acts as the outlet structure for inspected for stability	Monthly
	• Sediment removal in the forebay shall occur when 50% of the total forebay capacity has been exhausted	Monthly
Reinforced Turf	• Inspect for clogging, damage by vehicular or pedestrian traffic, excessive accumulations and channelization,	Every 4 Months
	• Remove sediments and debris	At least bi-annually or upon observation, when buildup exceeds 2” of depth
Wet Pond (source: WMI, 1997)	• Inspect for damage. • Note signs of hydrocarbon build-up, and deal with appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational	Annual Inspection
	• Repair undercut or eroded areas	As Needed
	• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Monthly
	• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic...	5-7 Years

Stormwater Practice	Activity	Schedule
Wet Swale	• Water to promote plant growth and survival. • Inspect swale following rainfall events. Plant replacement vegetation in any eroded areas.	As Needed (Following Construction)
	• Prune and weed swale to maintain appearance. • Remove accumulated trash and debris. • Replace mulch as needed.	Regularly (Monthly)
	• Inspect inflow area for sediment accumulation. Remove any accumulated sediment or debris. • Inspect swale for erosion and the formation of rills and gullies. Plant replacement vegetation in any eroded areas. • Inspect swale for dead or dying vegetation. Plant replacement vegetation as needed. • Test planting bed for pH. If the pH is below 5.2, limestone should be applied. If the pH is above 8.0, iron sulfate and sulfur should be applied.	Annually (Semi-Annually During First Year)
	• Replace mulch.	Every 2 to 3 Years