Carolina Beach

Nine Elements

Watershed Restoration Plan

TOWN OF CAROLINA BEACH | North Carolina

Contributing Partners

Town of Carolina Beach
Cape Fear Council of Governments
North Carolina Coastal Federation

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Table of Contents

Guide to Nine Minimum Elements

This table serves as a quick reference guide to where the Environmental Protection Agency (EPA) Nine Minimum Elements are located within this watershed management plan.

	EPA Nine Minimum Elements	Section of Plan
1	Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.	Section 1 Introduction Section 2 Watershed Characterization and Conditions
2	An estimate of the load reductions expected from management measures.	Section 3 Reduction Load Target
3	A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan.	Section 4 Goals Section 4 Management Strategies
4	Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.	Section 5 Funding Cost and Technical Needs
5	An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	Section 6 Education and Outreach Program
6	Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.	Section 7 Implementation Schedule
7	A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.	Section 8 Milestones
8	A set of criteria that can be used to determine whether load reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.	Section 9 Evaluation
9	A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the established criteria.	Section 10 Monitoring

1 Introduction

1.1 Plan Introduction

This Watershed Restoration Plan provides a voluntary management framework to address water quality impairments in six Carolina Beach watersheds. The watersheds have experienced increased volumes of stormwater runoff from land use activities. This increased runoff transports bacteria and other pollutants causing surface water quality impairments. This plan includes strategies for restoring or mimicking the natural, pre-development hydrology of the watersheds prior to water quality impairment. Mimicking natural drainage processes can reduce runoff and nuisance flooding and help restore water quantity and quality requirements of receiving water bodies.

This restoration plan will be the beginning of a multi-year process to implement and maintain, manage, and mitigate stormwater runoff pollution. This plan combines low-cost, high-yield strategies such as community outreach initiatives and targeted retrofit projects aimed at reducing the impact of impervious surface by mimicking natural hydrology to reduce flooding, protect water quality, and provide the community with clean, usable waters. The non-regulatory *Carolina Beach Watershed Restoration Plan* includes all Nine Minimum Elements of a watershed management plan as recommended by the EPA to qualify to be eligible to apply for federal 319 Grant funding opportunities. The information provided in this plan enables the participating partners to easily source technical information necessary to apply for other state and national grant opportunities.

This plan seeks to:

1. Restore and maintain the water quality of six Carolina Beach Watersheds;
2. Reduce instances of localized flooding to improve safety and protect property;
3. Identify and prioritize cost effective Low Impact Development and stormwater retrofit techniques to address stormwater management.

The Carolina Beach watersheds have tremendous recreational and tourism value. Significant recreational and habitat areas surround the watersheds, including Carolina Beach State Park, MOTSU Buffer Zone Natural Area, and surrounding beaches. The Cape Fear River borders these watersheds to the west, Snows Cut and the Intracoastal Waterway borders to the north, and the Atlantic Ocean borders to the east. In recent years, the increase in stormwater runoff following large rain events has resulted in an increase in the frequency of water quality impairments, indicating that stormwater runoff transports impairments downstream.

Improvements in water quality can be achieved by using stormwater reduction techniques that reduce the volume of stormwater runoff thereby effectively treating stormwater runoff from existing and new developments. This plan combines low-cost, high-yield strategies such as community outreach initiatives and lot level retrofit projects aimed at reducing the impact of impervious surface by mimicking natural hydrology to reduce flooding, protect water quality, and provide the community with clean, usable waters. By focusing on techniques that reduce, slow, and treat stormwater runoff, the plan can mimic the natural hydrology of the area before urban expansion and development. This document provides a framework for the restoration of Carolina Beach Watersheds' water quality, by reducing the volume of stormwater runoff.

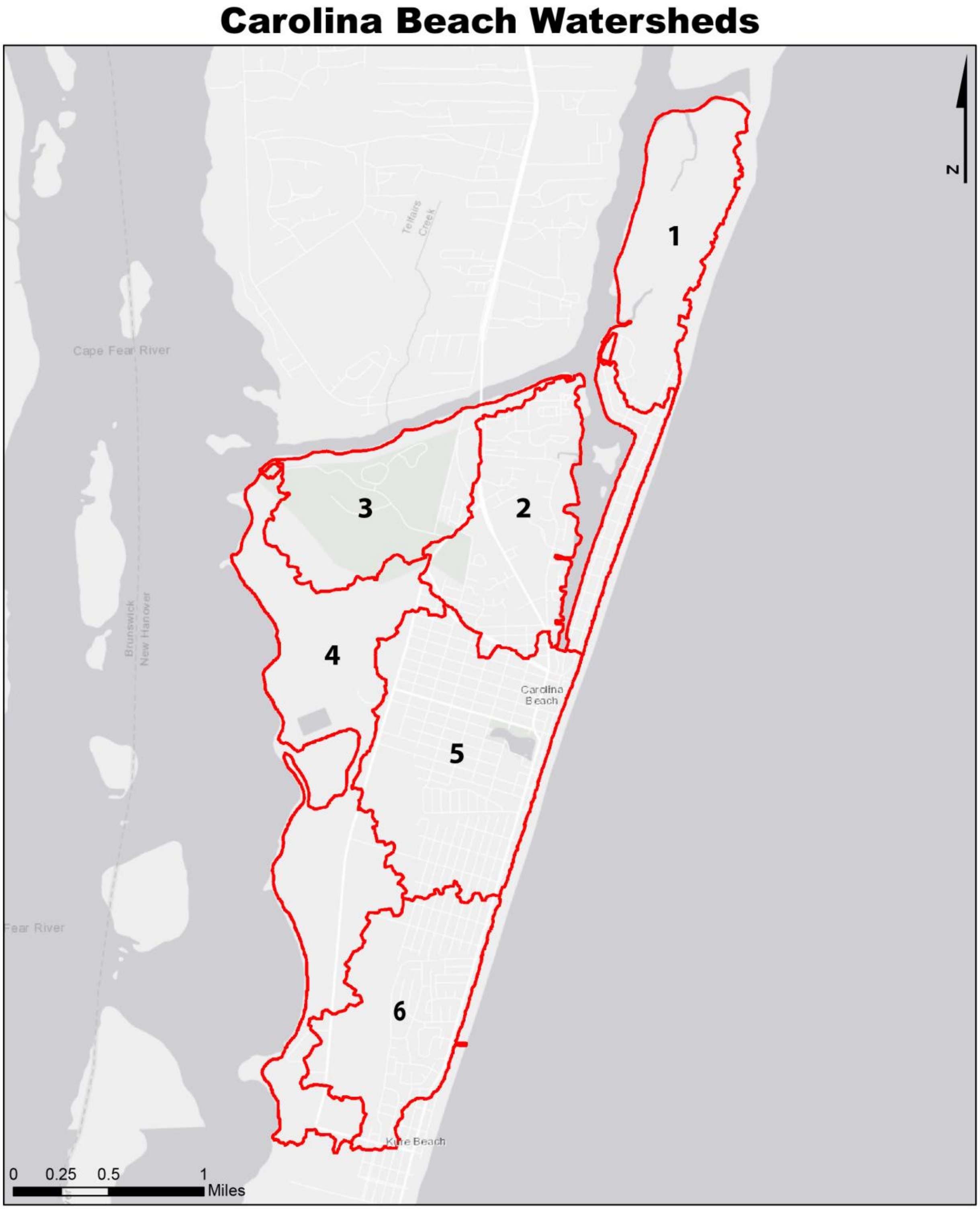

Figure 1-1. Map of Carolina Beach Watersheds with numerical identification.

1.2 Plan Rationale

Conventional management approaches rely on peak flow storage and attempt to manage onsite flooding by collecting and conveying stormwater from a site as quickly as possible. In this approach, stormwater is often directed to curb and gutter systems, where the untreated runoff is conveyed to the nearest receiving water. This approach can deter onsite, localized flooding but the downstream effects result in an increase in the magnitude and frequency of flooding. Conventional efforts to manage runoff throughout the coast have failed to prevent polluted stormwater from discharging contaminants into waterways. Shellfish closures and swimming advisories are a result of increased surface runoff. Restoration of water quality in tidal waters depends upon reducing the volume of stormwater.

A stormwater volume reduction strategy recognizes that:

(1) Sources of fecal bacteria are widespread. Bacteria come from wildlife, pets, and other warm-blooded animals. While this is a human health problem and such sources should be removed, it is not feasible to reduce all sources significantly enough to improve degraded water quality.

(2) Improving shellfish and swimming waters by treating runoff to levels that comply with water quality standards for bacteria is not practical. While technology is available to treat stormwater runoff, tying in an already developed urban area with a stormwater treatment facility can be cost prohibitive to achieve sufficiently high removal rates necessary to meet designated water quality standards.

(3) Recontamination of treated runoff is extremely problematic. Even if it were cost effective to treat runoff to remove bacteria, any “clean” runoff discharged back onto the landscape would then become a vehicle to transport downstream bacteria, lessening the overall benefits of treatment.

Additionally, conventional stormwater control systems are often designed to manage peak flow during a singular major designed storm event, such as flood prone areas. These systems are often designed with the intent that large amounts of stormwater is quickly moved downstream into the receiving waterways slowing the impact of flooding in major storm events. Due to this, conventional stormwater control systems can degrade natural stream systems by causing bank erosion. Control systems that focus on larger storms are often overdesigned and do not address the management of runoff caused by smaller storm events or water quality. The proactive use of Low Impact Development (LID) and stormwater retrofits throughout an area can manage both small and larger storms by restoring an area’s natural hydrology.

2 Watershed Characterization and Conditions

The Carolina Beach watersheds are located within the Town of Carolina Beach and surrounding areas. These watersheds span across **2,741.47** acres. Residential and commercial development over the past decades has resulted in an increase in impervious surfaces throughout the watershed, which has increased the amount of flooding and stormwater runoff that is transported to the Cape Fear River, Intracoastal Waterway, Snows Cut and the Atlantic Ocean.

2.1 Watershed Locations

Carolina Beach watersheds are located in southern New Hanover County. The Carolina Beach watersheds are surrounded by the Cape Fear River, Intracoastal Waterway, Snow's Cut and the Atlantic Ocean. There are three major watersheds within this area with their 12-digit HUCs: Everett Creek-Carolina Beach Inlet **030203020501**, Wrightsville Beach-Mason Inlet **030203020503**, and Town of Kure Beach-Cape Fear River **030300050704** (Table 2-1).

Table 2-1. Watershed 12-HUC codes (United States Geologic Survey, n.d.)

Watershed ID	12-HUC	12-HUC Formal Subwatershed Name
1	030203020501 030203020503	Everett Creek-Carolina Beach Inlet Wrightsville Beach-Mason Inlet
2	030300050704 030203020501 030203020503	Town of Kure Beach-Cape Fear River Everett Creek-Carolina Beach Inlet Wrightsville Beach-Mason Inlet
3	030300050704 030203020501	Town of Kure Beach-Cape Fear River Everett Creek-Carolina Beach Inlet
4	030300050704	Town of Kure Beach-Cape Fear River
5	030300050704 030203020501 030203020503	Town of Kure Beach-Cape Fear River Everett Creek-Carolina Beach Inlet Wrightsville Beach-Mason Inlet
6	030300050704 030203020503	Town of Kure Beach-Cape Fear River Wrightsville Beach-Mason Inlet

2.2 NATURAL CHARACTERISTICS

The North Carolina Natural Heritage Program (NCNHP) of the Department of Environmental Quality (DEQ) has identified areas that are of biodiversity significance. These are often areas where rare or significant species and significant natural communities occur (Figure 2-1)[1]. The identified areas contain both terrestrial and aquatic habitats. The boundaries of these areas are based on field surveys by NCNHP staff and other professional biologists. The intent of the NCNHP data was to assist government agencies and others in developing management strategies. DEQ targeted these conservation areas when planning for restoration projects. As Figure 2-1 shows, the Carolina Beach watersheds contain two natural areas, Carolina Beach State Park and the MOTSU Buffer Zone Natural Area. Water quality of these watersheds affect these tidal areas, particularly aquatic and shoreline habitat. Identifying the location of critical habitat areas is relevant for planning, and this information can be used to develop projects that can positively enhance these areas, in turn leading to potential funding opportunities.

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[1] North Carolina OneMap. (2013, July). Biodiversity/Wildlife habitat assessment. *N.C. Natural Heritage Program, N.C. Department of Environment and Natural Resources, N.C. OneMap*. Retrieved from http://data.nconemap.com/geoportal/catalog/search/resource/details.page?uuid=%7BE85829D4-4D5F-4203-BCB3-D5A6346E7BC3%7D

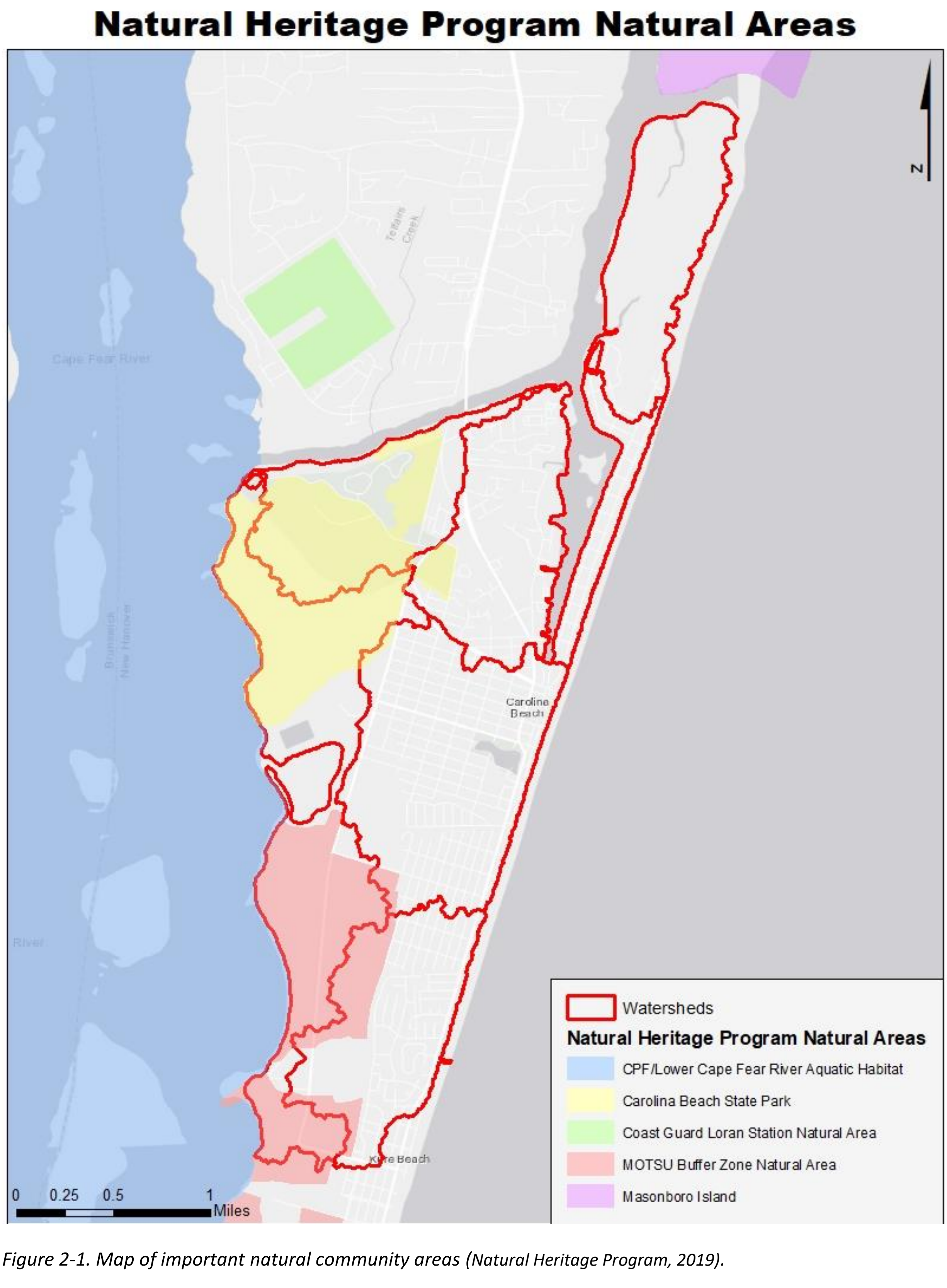
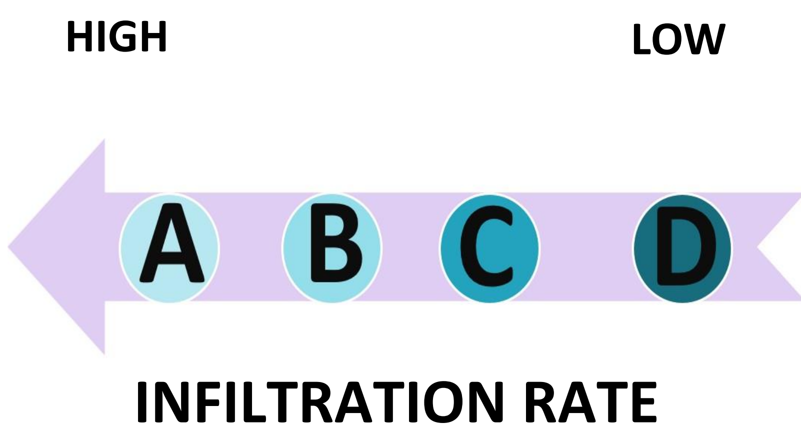


Figure 2-1. Map of important natural community areas (Natural Heritage Program, 2019).

2.3 SOILS

Carolina Beach Watersheds are predominated by Group A hydrologic soil per the United States Department of Agriculture Natural Resource Conservation Service (NRCS) data collected from Web Soil Survey (Figure 2-2). However, Group D hydrologic soil group predominates within the Town of Carolina Beach. Soil Group A/D occurs primarily within low lying areas, such as tidal creeks and marshes. Four hydrologic groups (HSG; Groups: A, B, C, D) exist with progressively decreased infiltration potential characteristics; soils classified under Group A have the highest infiltration potential and are often the quickest draining soils, while soils classified under Group D have the lowest infiltration potential. It is possible to have a soil type that has characteristics from two hydrologic groups; for example, a soil can be designated as Group A/D, which means it has characteristics of both Group A and Group D (wetland type conditions). This is because of the changing nature of the soils when they are fully saturated by water. Once a hydraulic threshold is reached, the soil type converts to another hydrologic group because of the change of the available water capacity of the soil. In these instances, if a soil needs to be characterized by one soil group, the lowest infiltration rating should be used as this represents the likely infiltration performance in these areas during significant rain events. NRCS soil surveys are ideal for watershed scale analysis and determining runoff volume rates. These data are used to calculate the runoff volume rates in this plan.



The following is the NRCS summary description for each soil group[2]:

- **Group A** soils are sands, loamy sands, or sandy loams. These soils have high infiltration rates even when thoroughly saturated. These soils consist of deep, well to excessively drained sands or gravels and have a high rate of water transmission.
- **Group B** soils are silt loams or loams. These soils have moderate infiltration rates when thoroughly saturated and consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
- **Group C** soils are sandy clay loams. These soils have low infiltration rates when thoroughly saturated and consist of soils with a horizon that impedes downward movement of water and possess moderately fine to fine texture.
- **Group D** soils are clay loams, silty clay loams, sandy clays, silty clays, or clay. These soils have the highest runoff potential. These soils have very low infiltration rates when thoroughly saturated and consist of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material.

Soil survey data can be used when trying to determine which areas have the most ideal combined characteristics for retrofit projects. HSG, as with any characteristic, should always be tested through field surveys to determine the extent of characteristics at a project site. The partners' previous experiences installing retrofits along the coast have shown that a simple handheld auger tool samples to assess soils may not be sufficient and it may be necessary to take a deeper sample to break through a confining layer of Group D soil covering Group A soils. Refer to Appendix A for the list of soils and their associated HSG.

[2] Natural Resources Conservation Service. (n.d.). Updated Hydrologic Soil Group. *United States Department of Agriculture Natural Resource Conservation Service*.

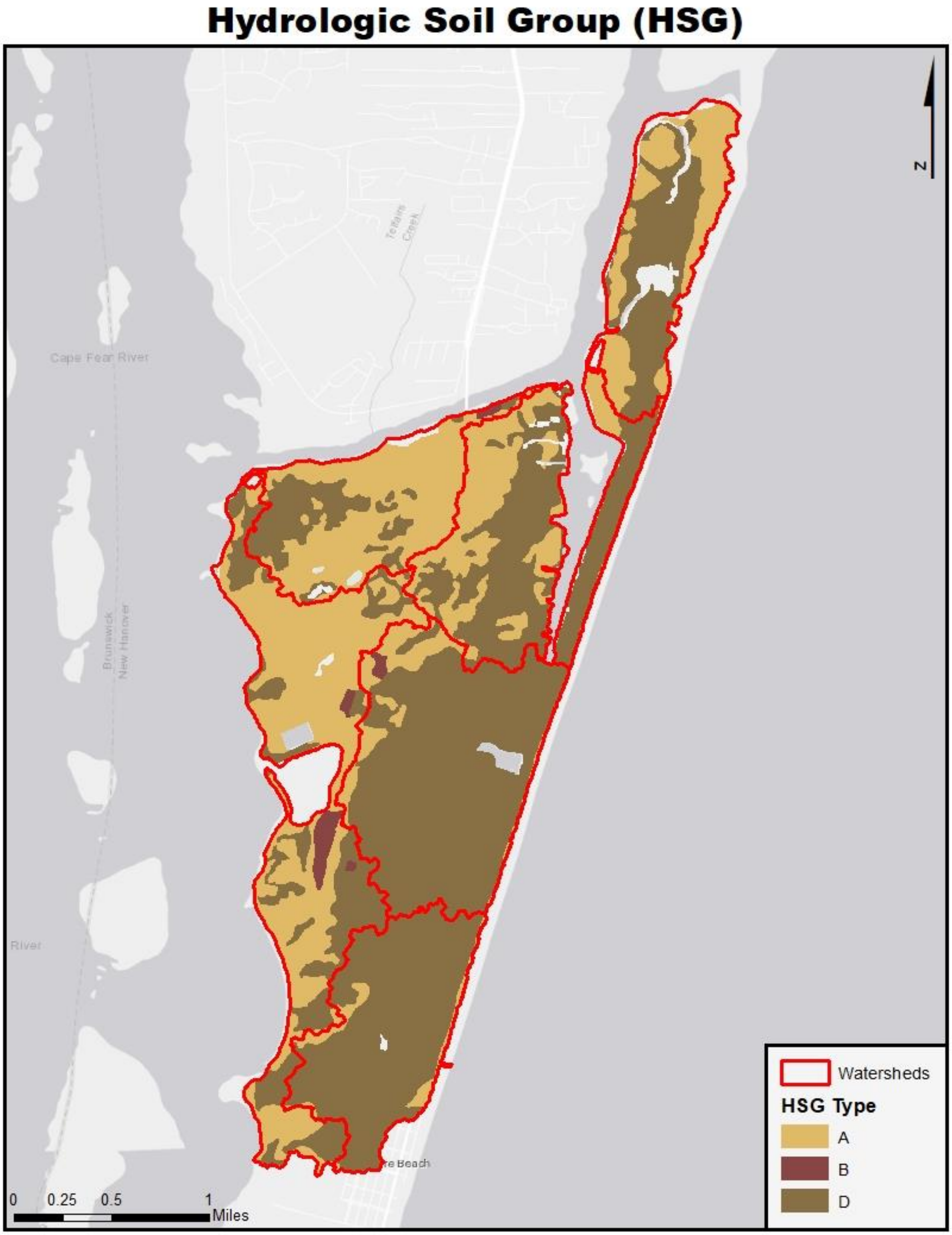


Figure 2-2. Hydrologic soil group map of Carolina Beach watersheds (Data Source: Natural Resources Conservation Service, 2017).

2.4 LAND USE

The Carolina Beach watersheds encompass parts of the following municipalities (Figure 2-3):

- New Hanover County
- The Town of Carolina Beach
- The Town of Kure Beach

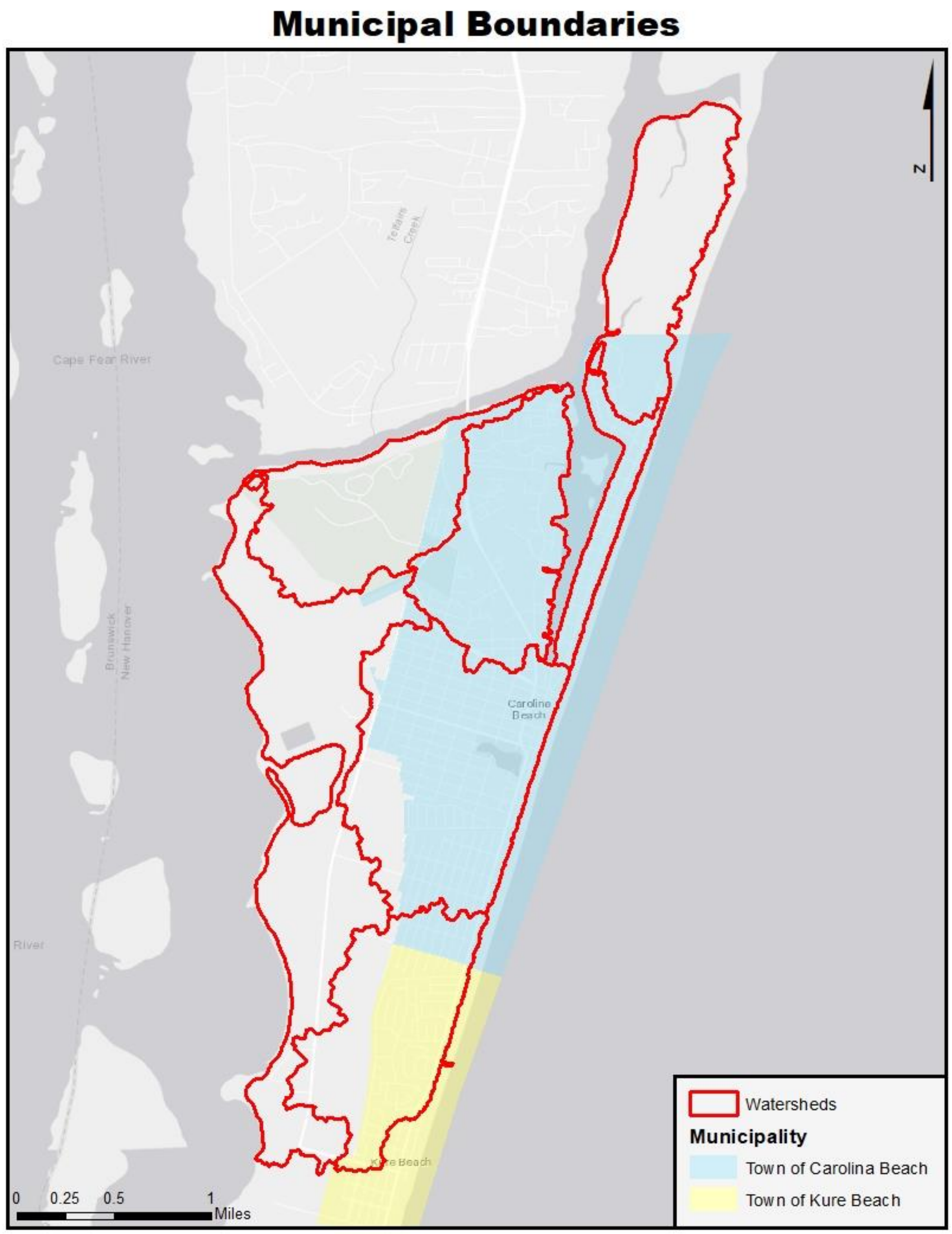


Figure 2-3. Political boundaries map of Carolina Beach Watersheds (Data Source: North Carolina OneMap, 2019).

The Carolina Beach Watersheds are located in southern New Hanover County. Only one watershed is shared with another municipality, the Town of Kure Beach. Watersheds 1-5 have the Town of Carolina Beach as the only municipality within them but are shared with Carolina Beach State Park (CBSP) and Military Ocean Terminal Sunny Point (MOTSU).

The Carolina Beach area has been inhabited for centuries, with the earliest known inhabitants being the Tuscarora Indians. In the early 1700s, these Native Americans were forcefully expelled from the region shortly after the arrival of English Settlers. As Wilmington grew into a strategically located port town, Carolina Beach remained largely undeveloped during the following century. When civil war broke out in 1861, Carolina Beach consisted of only 72 residents. As the war progressed the significance of Carolina Beach increased as the Cape Fear River became an important route for delivering supplies to the Confederate southern states. After the civil war ended, interest in the rich history, beaches, and abundant fishing of the area made Carolina Beach a popular destination. By the 1890's Carolina Beach had a ferry service, hotel, 10-pin bowling alley, grocery store, and train. Carolina Beach experienced more substantial growth in the early 1900's as the iconic boardwalk was built and services for tourists were greatly expanded. In 1946 Carolina Beach opened its first fishing pier. Soon after a steel swing bridge was constructed to allow for easier access to the beach town. The town experienced a period of slow growth in the 1970s and 1980s but experienced a significant surge of development during the 1990s, a trend which continues today.

Understanding the past and present land uses of the watersheds enhances this plan's ability to address education and outreach and to tailor stormwater reduction techniques that address community needs. For example, a watershed is predominately residential would benefit from stormwater management strategies and planning targeted for single lot, residential land uses.

Land uses within the Carolina Beach watersheds are varied, but are predominated by residential, business/commercial, conservation (aims to preserve natural resource assets of the land and allows for single family residential development), mixed use, and industrial. Residential represents the highest percentage of land use in Carolina Beach, but conservation land occupies a considerable amount of acreage as well, as seen in Table 2-2. Figure 2-4 provides a visual depiction of the land uses in Carolina Beach. Land use data was not able to be obtained for the Town of Kure Beach, which is located in the southern area of the Carolina Beach watersheds.

Table 2-2. Simplified land use categories by acreages of the Carolina Beach Watersheds as of 2016 (Town of Carolina Beach, 2019).

Watersheds	Residential (acres)	Commercial (acres)	Conservation (acres)	Industrial (acres)	Mixed Use (acres)
1 (425 acres)	42	3	365	-	-
2 (630 acres)	381	211	29	4	-
3 (455 acres)	37	32	380	3.92	-
4 (849 acres)	8	-	538	56	-
5 (771 acres)	72	64	145	16	43
6 (496 acres)	54	-	7	-	8

Note: These numbers include conservation areas that may have an HSG category of "water" because they are part of a waterbody, wetland, or have intertidal (area that is covered by water during high tide and uncovered during low tide) acreage that is designated as "water." As such, these totals will vary from other acreages listed within this plan, particularly with the acreage totals listed in Section 3 Runoff Calculations.

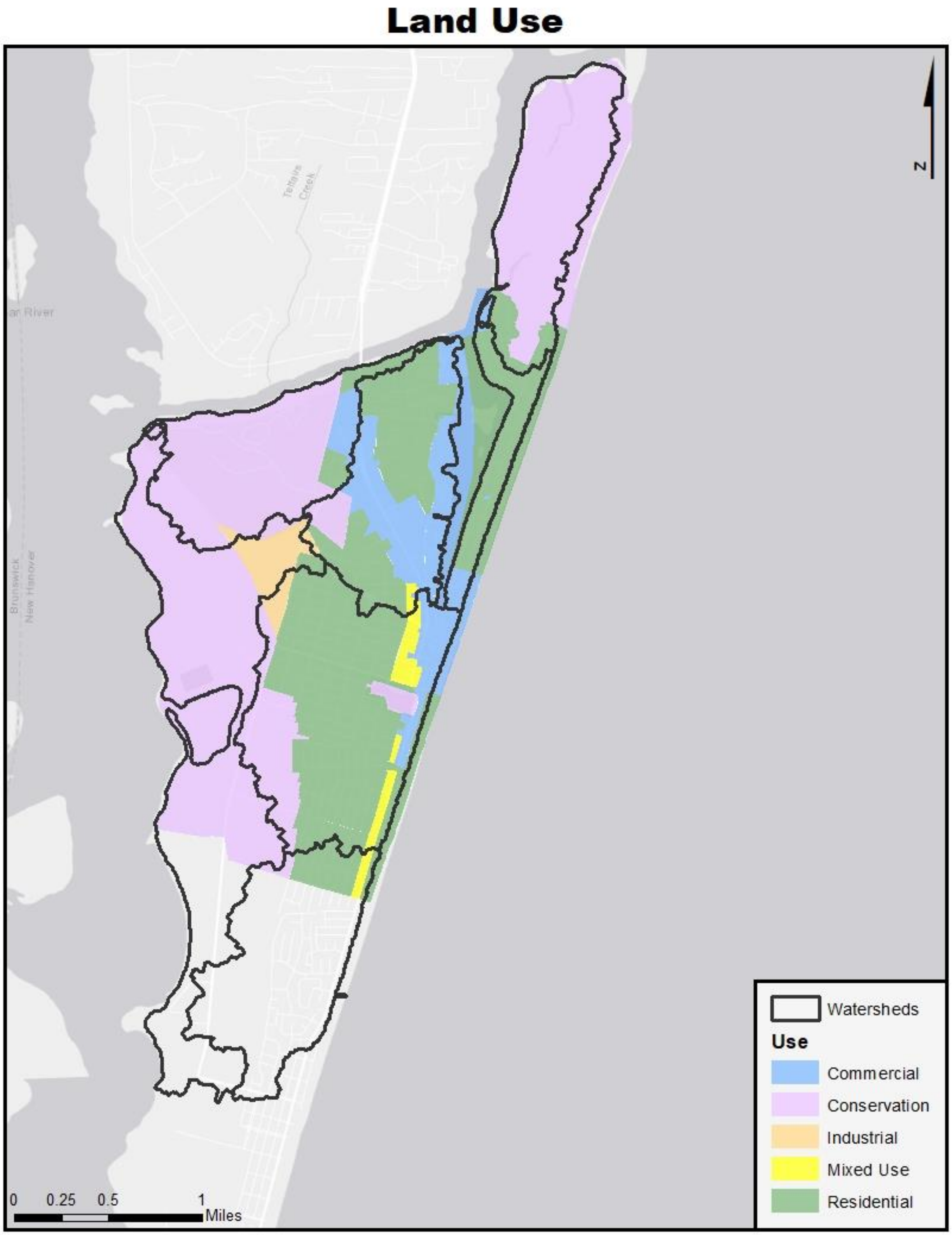


Figure 2-4. Land usage categories of Carolina Beach Watersheds (Data Source: Town of Carolina Beach, 2019)

2.5 WATER QUALITY

North Carolina uses various methods to measure water quality. This plan uses three: the state's water classification system, which is reported on the 303(d) and 305(b) list, shellfishing water classifications, and the swimming usage tier scale system (refer to Appendix B for detailed guide of water quality classifications). Water quality Use Classifications are presented in Figure 2-5, and water quality monitoring station locations are shown in Figure 2-6.

The 303(d) and 305(b) lists are released by the EPA and reports if waters are meeting their designated usage. If the water quality standards are being met for the assigned usage, the water body is assigned a supporting status. If the area's water quality falls below the assigned usage water quality standards, the water body is designated as impaired.

The shellfishing water classifications were created and are managed by the NC Shellfish Sanitation Program within the NC Division of Marine Fisheries. These classifications show which areas are open or closed to shellfishing based on the amount of fecal coliform present in the water.

The tier scale effects the prioritization of sampling and the minimum water quality in swimming waters with Tier 1 being the highest priority and are locations that are used daily. Tier 2 sites are not used as heavily and see the most use on the weekend, and Tier 3 sites are used less frequently (refer to Table 2-3). These tiers coincide with sampling requirements and maximum observation of bacteria. There are 8 N.C. Recreational Water Quality Monitoring Stations that are in close proximity to the Carolina Beach Watersheds (15A NCAC 18A .3400, 2004).

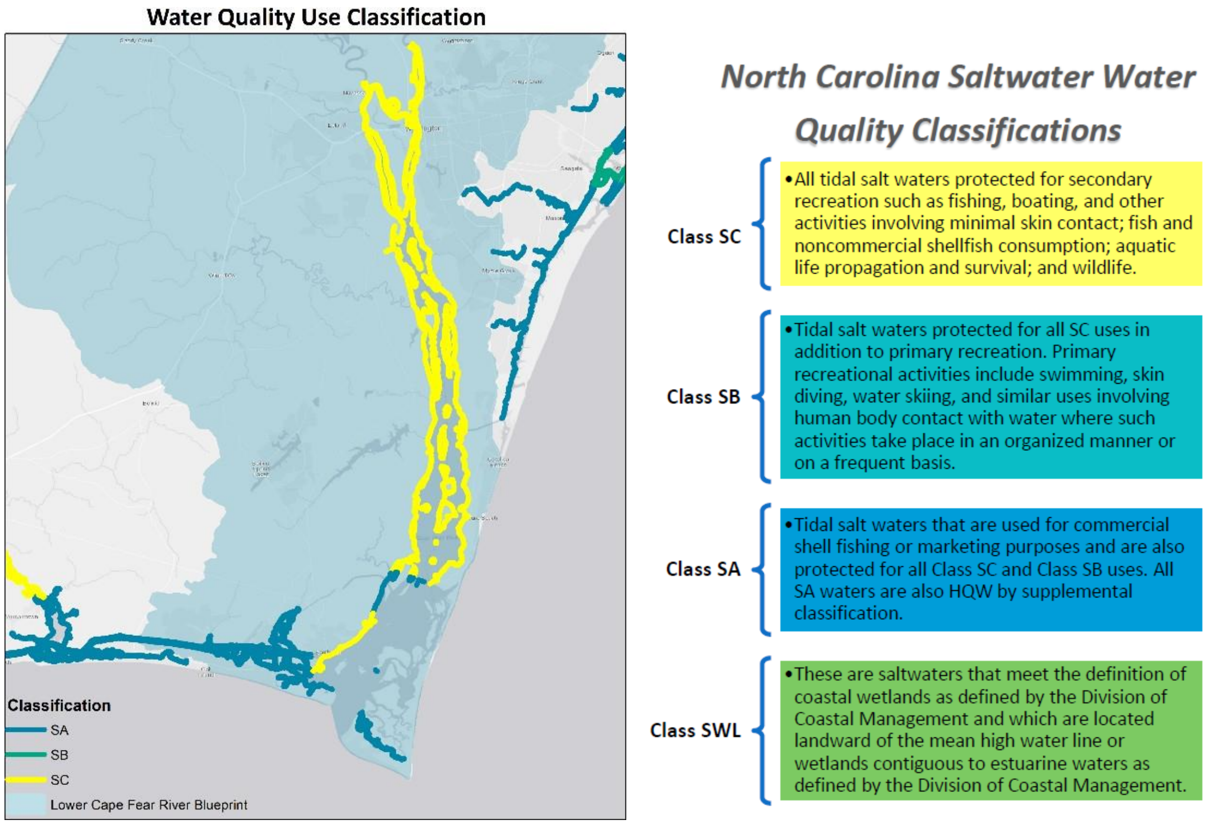


Figure 2-5. The North Carolina DEQ Water Quality Classification map shows the intended standards that waters in the Lower Cape Fear River should meet to be safe enough for their intended uses.

Water Quality Monitoring Stations

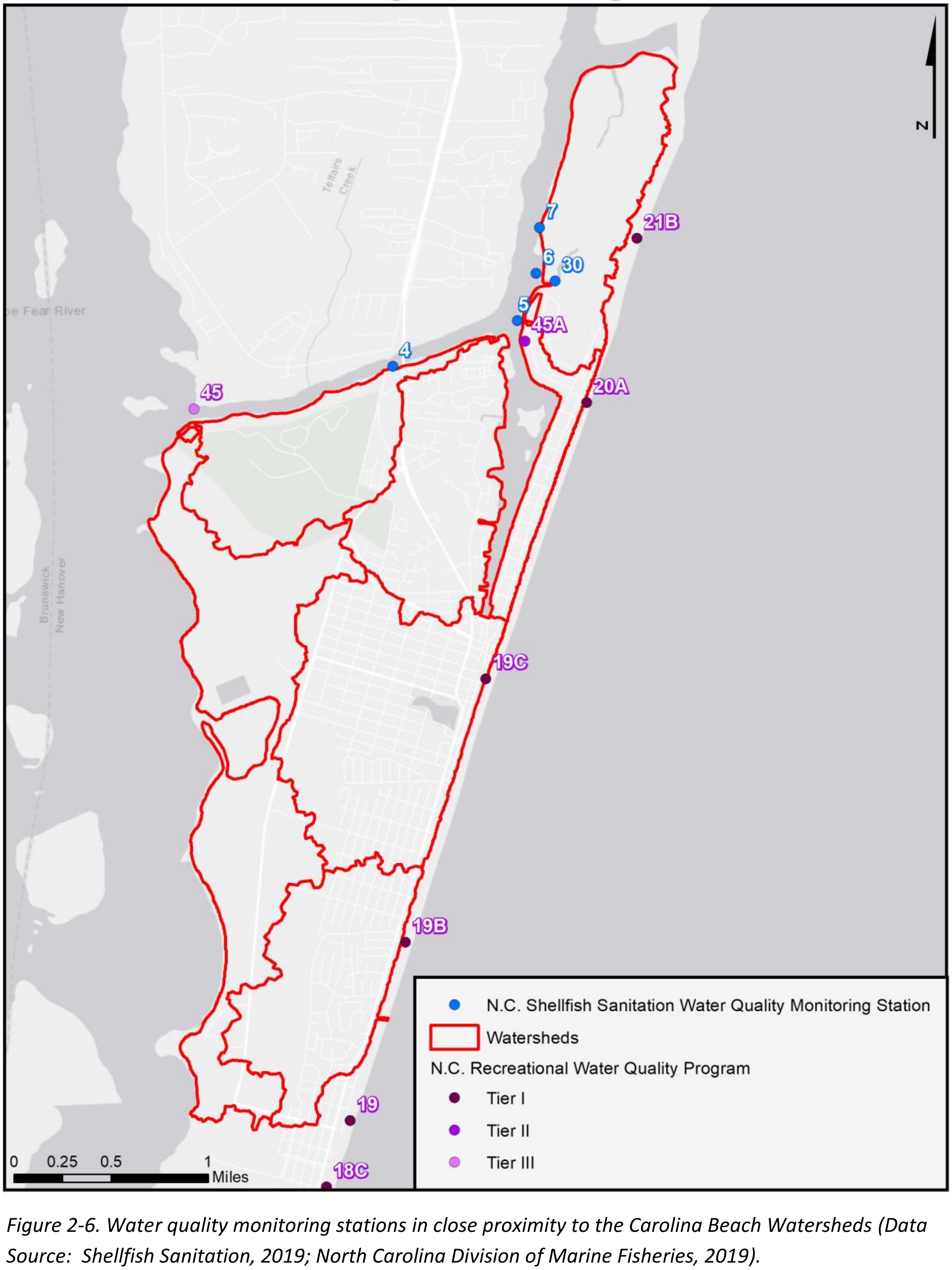


Figure 2-6. Water quality monitoring stations in close proximity to the Carolina Beach Watersheds (Data Source: Shellfish Sanitation, 2019; North Carolina Division of Marine Fisheries, 2019).

Table 2-3. Bacteriological Water Quality Standards for North Carolina Quick Guide. Refer to Appendix B for a complete guide to water quality standards (15A NCAC 18A .3400, 2004).

Bacteriological Water Quality Standards for North Carolina Quick Guide

Shellfishing

For waters to be approved as a Class SA area of harvest for direct consumption, the following criteria must be met:

(1) the shoreline survey has indicated that there are no significant sources of contamination;

(2) the area is not so contaminated with fecal coliform that consumption of the shellfish might be hazardous;

(3) the area is not so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous; and

(4) the median fecal coliform Most Probable Number (MPN) or the geometric mean MPN of water shall not exceed **14 per 100 milliliters**, and the 90^{th} percentile shall not exceed 43 per 100 milliliters (per five tube decimal dilution) in those portions of areas most probably exposed to fecal contamination during most unfavorable hydrographic conditions.

Swimming

("swimming season" April 1 – October 31)

The following standards apply to coastal North Carolina waters:

- **Tier I**
  "A swimming area used daily during the swimming season, including any public access swimming area and any other swimming area where people use the water for primary contact, including all oceanfront beaches"
  A geometric mean of at least five samples in 30 days that results in **35 enterococci per 100 ml** of water ***OR*** a single sample of **104 enterococci in a 100-ml** sample
- **Tier II**
  "A swimming area used an average of three days a week during the swimming season"
  Single sample of **276 enterococci in a 100-ml** sample
- **Tier III**
  "A swimming area used an average of four days a month during the swimming season"
  Two consecutive samples of **500 enterococci in each 100-ml** sample

In addition to bacterial limits for swimming areas for Tier I- Tier III swimming areas, state water quality narrative standards (15A NCAC 18A.3404) require posting of swimming advisories for wastewater treatment plant discharges, for storm drain or stormwater discharges actively discharging into swimming areas, and for storm drains where flood waters are being pumped into swimming areas.

> ***15A NCAC 18A .3404 SWIMMING ADVISORIES FOR POINT SOURCE DISCHARGES INTO SWIMMING AREAS***
>
> *(a) A wastewater treatment plant that discharges into swimming waters shall be posted by the Division with at least one sign until the discharge is removed.*
>
> *(b) A swimming advisory shall be issued by the Division and at least two signs shall be posted at a storm drain or storm water discharge that is actively discharging into a swimming area. Signs shall be placed to advise the public as they enter the area impacted by the drain.*
>
> *(c) A swimming advisory shall be issued by the Division and at least two signs shall be posted at a storm drain where flood waters are being pumped into a swimming area. The signs shall remain posted for at least 24 hours after the pumping of flood waters has ceased.*

Stormwater runoff results in high bacterial counts. Within the watersheds for Carolina Beach, persistently high counts have degraded water quality. Shellfish closures and swimming advisories are indicators of poor water quality from bacteria contamination. Table 2-4 is a summary of the water quality for all the watersheds, Figure 2-7 depicts the shellfish closure boundaries, and Figure 2-8 shows the status assessment and designated use of waters.

Table 2-4. Current water quality summary of Carolina Beach Watersheds (United States Environmental Protection Agency, 2016; Shellfish Sanitation, 1947; Shellfish Sanitation, 1955).

Watershed	Designated Use	Shellfish Sanitation Closure Year	Current Shellfish Status	Nearest Monitoring Station
1	SA, HQW, & SB	-	Open	B-5 Stations: • 7 • 6 • 30
2	SB	1955	Prohibited	B-5 Stations: • 5
3	Not Rated	1947	Prohibited	B-5 Stations: • 4
4	SC	1947	Prohibited	No adjacent station
5	SB	-	No shellfishing area	No adjacent station
6	SB	-	No shellfishing area	No adjacent station

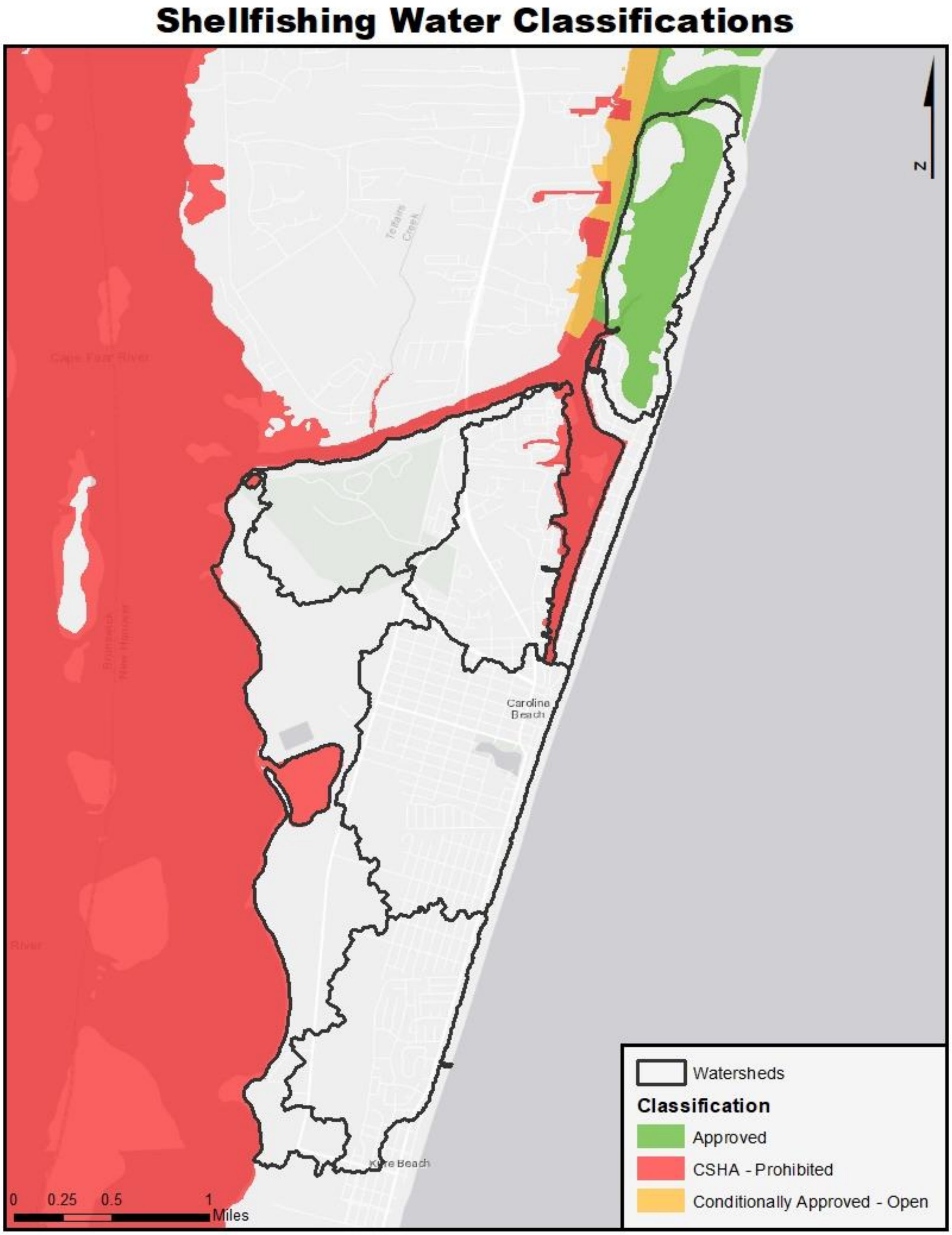


Figure 2-7. Prohibited and approved shellfishing waters (Data Source: North Carolina Department of Environmental Quality Online GIS, 2018).

The North Carolina Department of Environmental Quality classifies all coastal waters of Carolina Beach as being either class SC, SB, or SA waters, as seen in figure 2-7. The water quality standards of class SA are designed to maintain pollutant levels for safe commercial shellfishing purposes. This class also designates waters that may be used for activities involving extended body contact with water on a frequent basis. Class SA water has the supplemental classification of High Quality Water (HQW) due to excellent biological and physical/chemical characteristics. This supplemental classification is intended give extra protections to valuable freshwater and marine ecosystems. The water quality standards for class SB water allow for activities that involve extended exposure and contact to the water, such as swimming. Class SC water is the lowest classification for saltwater environments and permits for only secondary exposure to water. Secondary exposure includes activities such as boating and wading, where body contact with water is infrequent.

A large portion of the Lower Cape Fear Estuary currently is classified SC, which is the least stringent water quality classification for saltwater that the state designates. Currently, the waters between Carolina Beach State Park and Bald Head Island are classified as SC waters, although they are regularly used in primarily recreation activities such as swimming and wading. Efforts to address this issue and seek reclassification of these waters to afford higher levels of protection will be addressed in the Goals and Management Measures Section of this watershed plan.

Water Quality

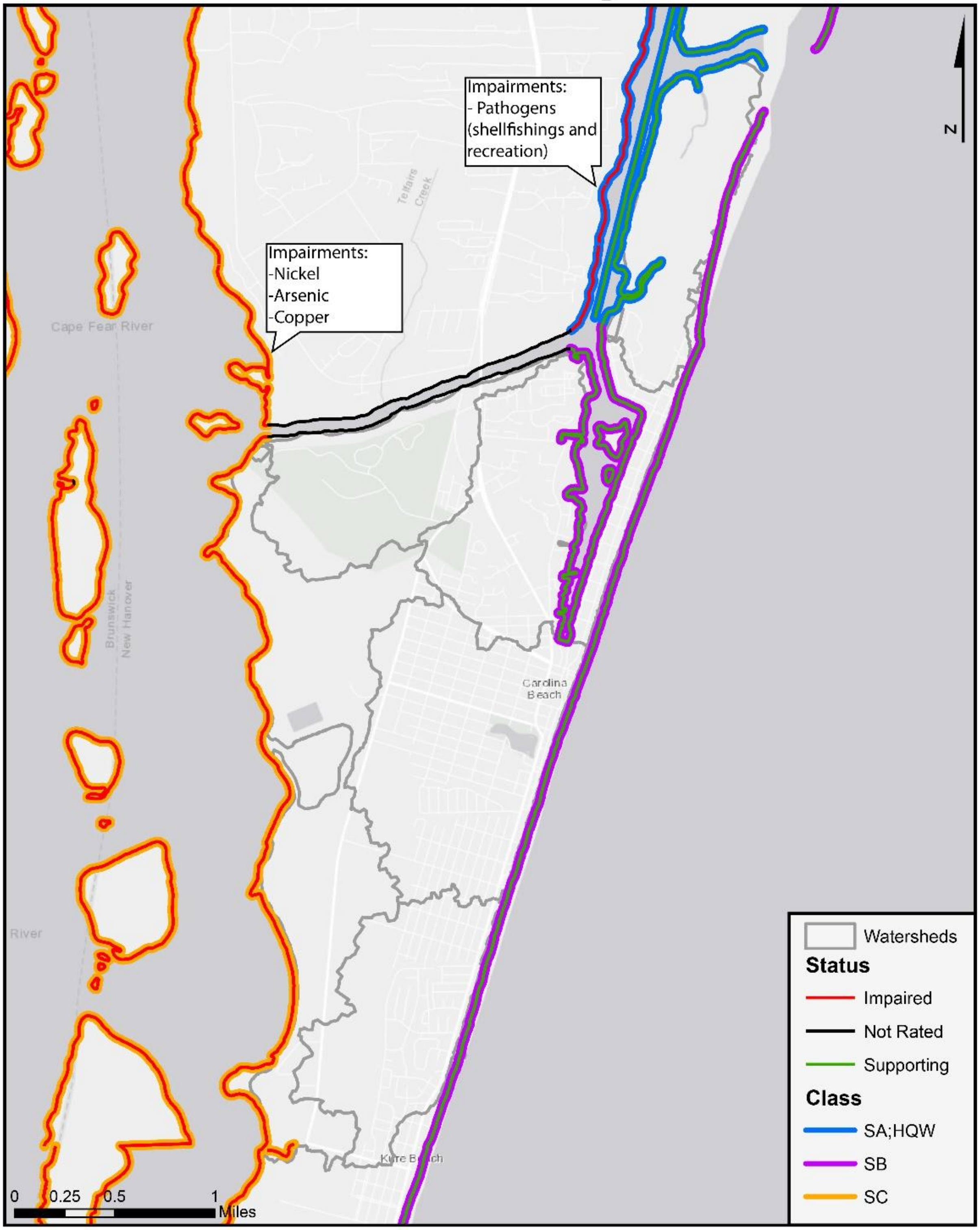


Figure 2-8. Water Classifications of Carolina Beach Watersheds and impairment status (Data Source: United States Environmental Protection Agency, 2016)

Records from the N.C. Division of Water Resources and Shellfish Sanitation Section of the N.C. Division of Marine Fisheries show that increased pathogenic loading in the creeks corresponds to water quality impairments within the watersheds. However, these impairments are not recognized on the 303(d) or 305(b) list, likely due to the low classification of the waters surrounding Carolina Beach and the dynamic hydrologic regime created by the Carolina Beach Inlet. It is the view of the North Carolina Coastal Federation that any reduction in bacterial pollution will result in waters that are safer for recreation and an environment that is relatively healthier for marine life. Partners and stakeholders agree that reduction of stormwater volume is the most beneficial and cost-effective way to eliminate bacteriologic pollutants. The following is a list of waterbodies in the region currently on the s the 2016 305(b):

Table 2-5. Waterbodies in the region currently on the 2016 305(b) list (United States Environmental Protection Agency, 2016).

Assessment Unit Number	Description	Acres	Year Placed on 305(b)	Cause
18-(71)b	From a line across the river between Lilliput Creek and Snows Cut to a line across the river from Walden Creek to the Basin	7856.70	2008	Arsenic; Copper; Nickel
18-87-31b	North of ICWW	65.10	2012	Pathogens

2.6 Impairment Sources

The primary source of surface water pollution and impairments to traditional uses being addressed through this restoration plan will be point- and non-point sources of stormwater runoff, which carries pollutants such as bacteria. The Carolina Beach watersheds also have concentrations of heavy metals (copper, nickel, arsenic) that exceed the amount allotted for their water classifications. The heavy metals are likely transported to these watersheds from industrial activities upriver.

Since 2018, 16 swimming advisories have been posted for the oceanfront areas of Carolina Beach, demonstrating violations of water quality standards for these Tier I swimming beaches (see Appendix C for monitoring data). Since Carolina Beach has no drainage outfalls or visible non-point sources of stormwater discharging onto ocean beaches within the town limits, it is likely that the sources of oceanfront water quality violations and associated advisories can be attributed to point- and non-point source pollution discharging into the estuaries and mixing with ocean waters, as well as from ocean outfall discharges within the adjacent Town of Kure Beach.

2.6.1 Nonpoint Sources

Stormwater runoff containing high levels of bacteria is the primary cause of water quality impairment in coastal Intense urbanization in the watersheds of the creeks has hardened the natural landscape, limiting its assimilative capacity to infiltrate and store rainfall instead of soaking into the ground and being taken up by vegetation, a much larger proportion of rain now quickly runs over the surface of the urban landscape and transports bacteria into the creeks.

The consequences of untreated stormwater runoff are shellfish and swimming water closures, and other impairments to ecosystem health and traditional uses of these waters. The difficulty in preventing violations of bacteria standards for coastal waters caused by stormwater runoff is compounded by the unique challenges related to coastal hydrology and bacteria pollution. These are:

1. The two bacteria used as indicators of water quality, fecal coliform and enterococcus, naturally occur across the terrestrial landscape. These bacteria are found in the feces of all warm-blooded animals, such as birds, deer, raccoons and domestic pets. Although prudent measures should be taken to reduce the sources of bacteria, these efforts alone will not result in satisfactory improvements in coastal water quality due to unnatural levels of stormwater being discharged.

2. Treating stormwater runoff to remove bacteria pollution before it flows into shellfishing and swimming waters is impractical. Although some technology exists for decreasing bacteria levels in runoff, it is not able to reduce levels to ensure water quality necessary to allow shellfish harvest and swimming, and protect ecosystem health.

3. Treated runoff can easily be re-contaminated. Due to the ubiquitous nature of bacteria within the landscape, treated runoff, once discharged back on the landscape, will simply pick up more bacteria. The result is ineffective and costly treatment.

A more practical and successful approach is to reduce the amount (volume) of stormwater entering our waterways. Since stormwater runoff can convey a number of pollutants from a variety of causes and sources, e there is no singular distinct outflow point. Typical nonpoint sources within urbanized watersheds include pets, wildlife, and drainage ditches and street drains connected to surface water outfall systems.

Within the Carolina Beach area, there are no domesticated farm animals within the watershed, making domestic cats, dogs, birds and wildlife the most likely contributors to non-point animal pollution.

There are numerous docks and boat ramps within the Carolina Beach watersheds (Figure 2-8). Issues concerning nonpoint source pollution from dockages stem from boat cleaners, litter, and fuel discharge. (Note: Marinas are defined by state regulations as having more than 10 boat slips) (see Appendix D for definition of each dockage). Dockage sites are monitored by Shellfish Sanitation, which publishes its report every three years for Area B-4 and B-5.

Non-Point Sources: Dockage

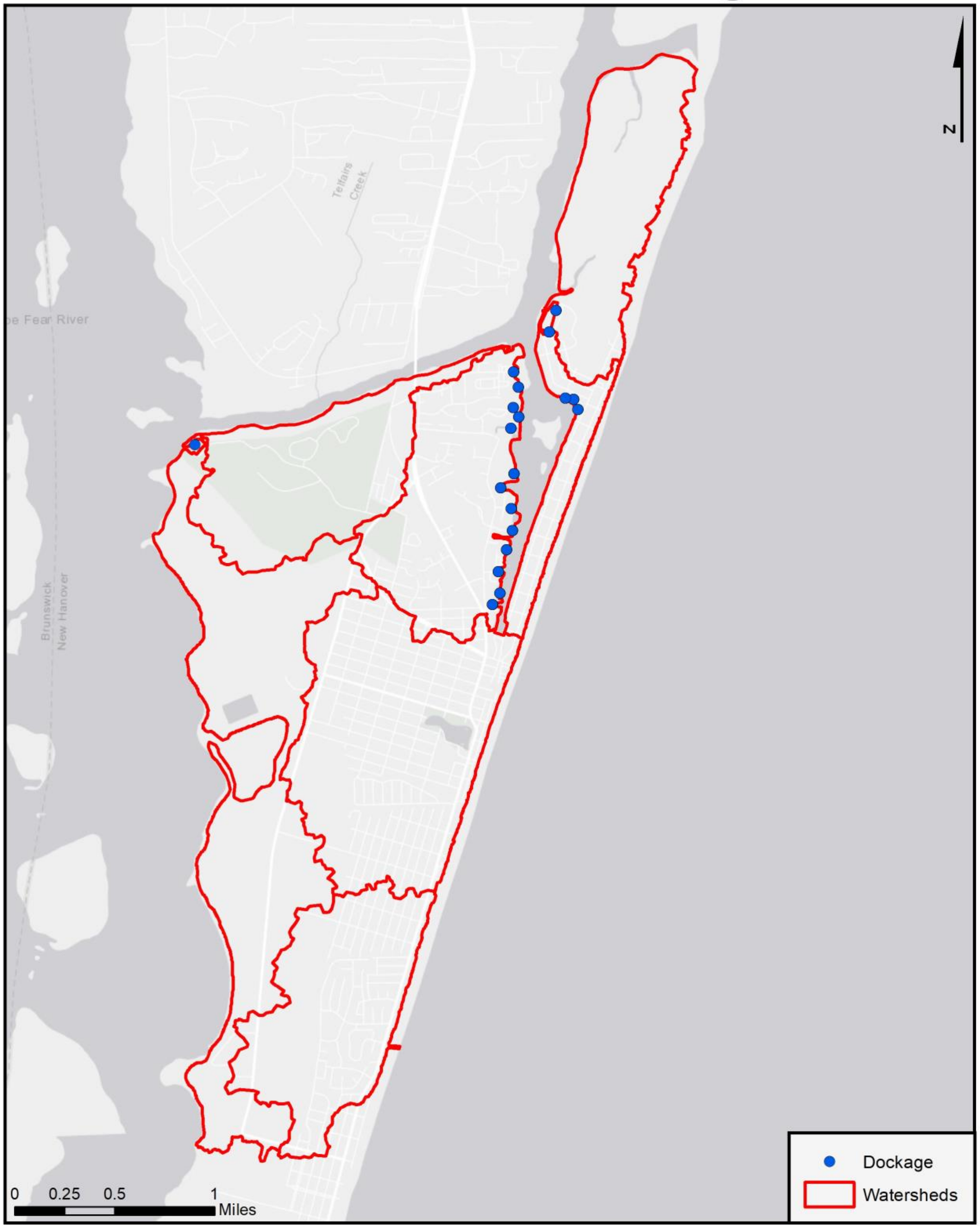


Figure 2-8. Potential non-point dockage sources. See Appendix D for definition of dock type (Data Source: Shellfish Sanitation, 2019).

As a highly developed, urbanized town, Carolina Beach has numerous engineered, connected drainage systems that enable direct conveyance of stormwater to the waterbodies of the watershed (Figure 2-9). These access points include curb and gutters, connected ditches, connected swales, and drain/pipe systems that quickly transport collected stormwater runoff off of developed lands. Monitoring of these sites is currently conducted by Shellfish Sanitation and the findings are released every three years in the reports for Area B-4 and B-5. Disconnecting the pathways for stormwater flow within these connected conveyance systems provide some of the most effective opportunities to reduce the volume of stormwater runoff reaching waterways.

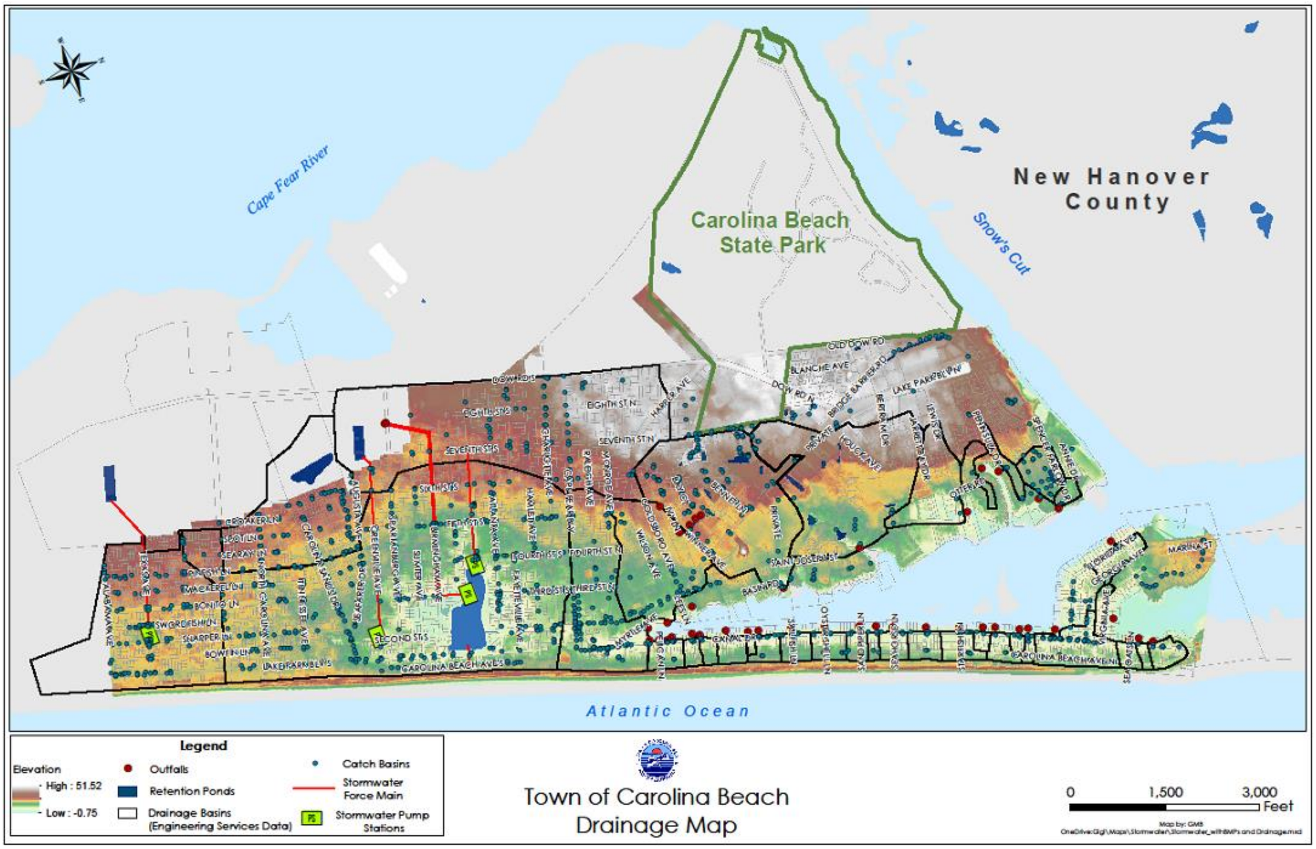


Figure 2-9. Town of Carolina Beach Drainage/Stormwater Discharge Map. (Data Source: Town of Carolina Beach).

In addition to traditional urban grid development, there are 11 established subdivisions that are potential sources of non-point source pollution (Figure 2-10). Pollutants from subdivisions have the potential to be concentrated due to the number of residences in a small area and significant hydrology alteration. Subdivisions can often be a source of concentrated loads of pollution from fertilizer nutrients, pesticides, yard debris, and bacteria from domestic pets. Subdivisions often use conventional stormwater management such as downspouts to impervious surfaces and connected conveyance systems. Monitoring is currently conducted by Shellfish Sanitation and the findings are released every three years in the reports for Area B-4 and B-5.

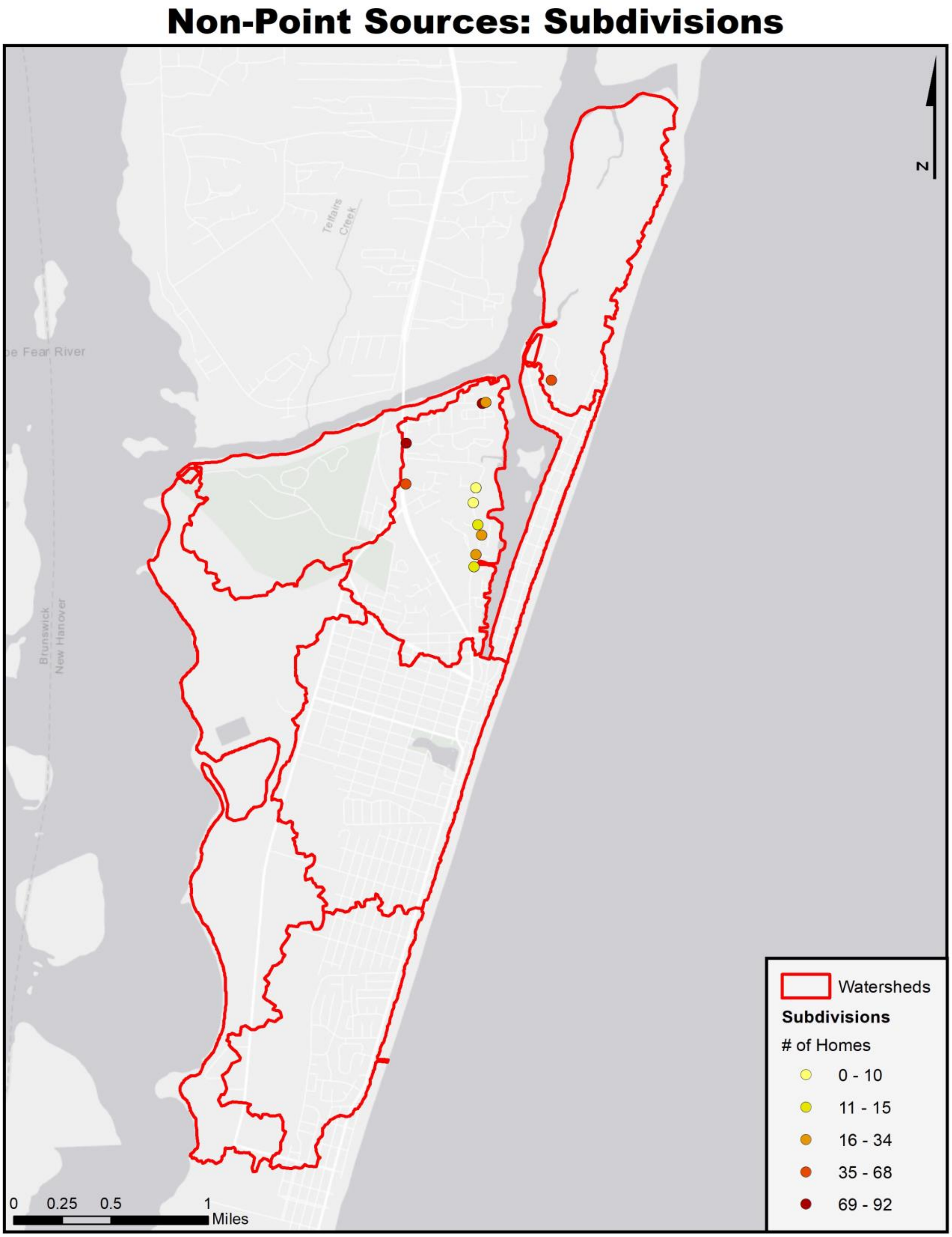


Figure 2-10. Potential non-point subdivision sources (Data Source: *Shellfish Sanitation, 2019).*

2.6.2 Point Sources

Point sources of pollution, unlike the diffuse non-point sources, are any single identifiable source of pollution from which pollutants are discharged, such as a pipe or ditch. They can pollute the water, but their effects can often be lessened or eliminated through management strategies. There are 89 state stormwater permits Figure 2-11, two National Pollutant Discharge Elimination System (NPDES) Stormwater Permits (Table 2-6), and three NPDES No Exposure Certifications in the Carolina Beach watersheds.

Carolina Lake has the potential to intermittently increase bacterial pollution within the Cape Fear River. Watershed 5 drains to Carolina Lake, and during periods of heavy rain the lake is drained to control stormwater flooding. The water is pumped to Hennicker's Ditch, which drains into the Cape Fear River.

Stormwater Permits

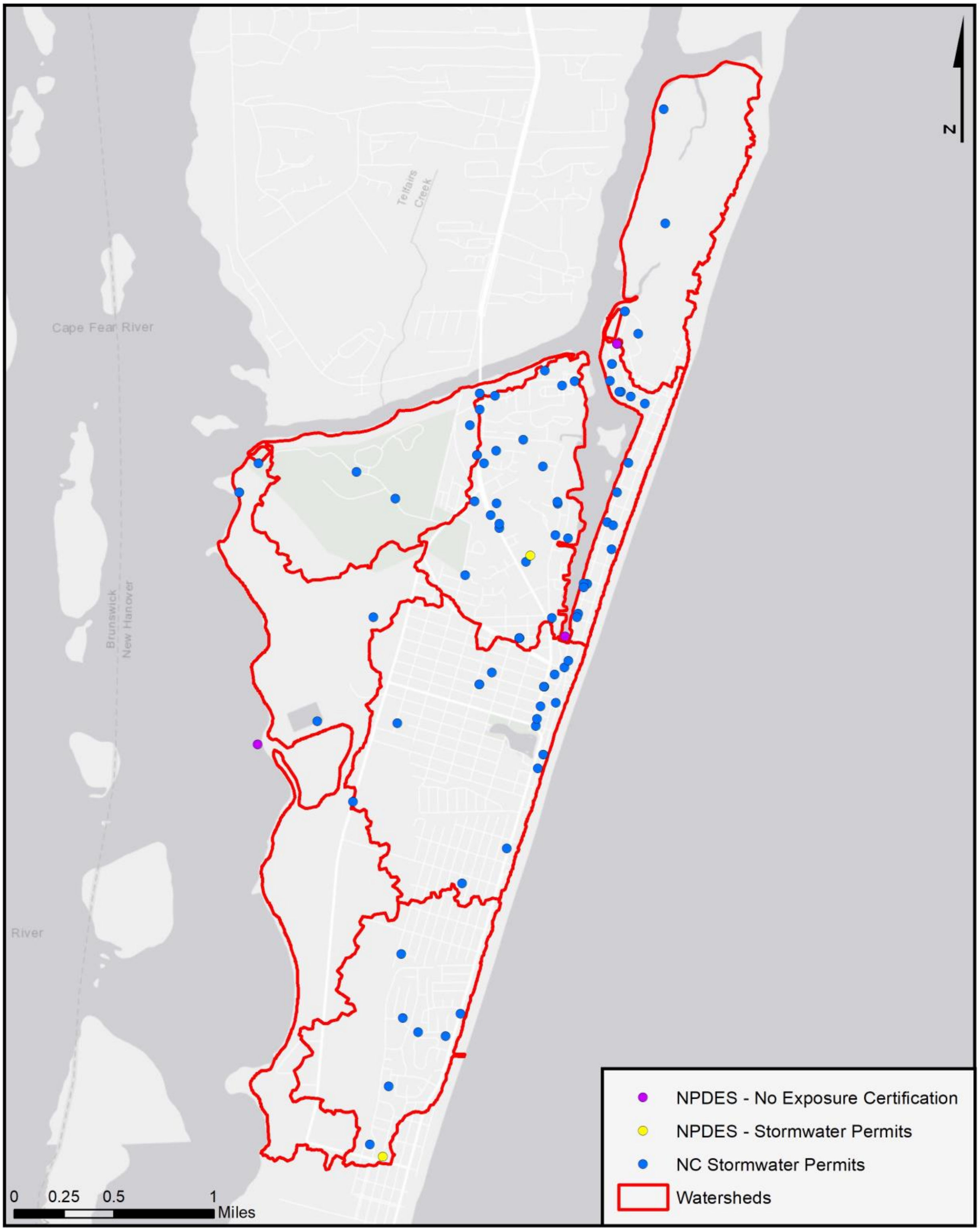


Figure 2-11. State and nationally permitted stormwater permits (Stormwater Permitting Program, 2019).

Table 2-6. NPDES sites (North Carolina Division of Water Resources, 2014).

Facility Name	Permit No.	Owner
Carolina Beach - Small MS4	NCS000394	Town of Carolina Beach
Kure Beach - Small MS4	NCS000499	Town of Kure Beach
Town of Carolina Beach Town Marina	NCGNE0891	Town of Carolina Beach
Joyner Marina, LLC	NCGNE0638	Joyner Marina LLC
Carolina Beach WWTP	NCGNE0668	Town of Carolina Beach

2.6.3 Additional Sources

There is one state designated brown field in Carolina Beach (19013-15-065), and it is located at 1317 Bridge Barrier Road, Carolina Beach, North Carolina 28428. The property is currently owned by Cape Fear Generators and is primarily used to store generators. Soil testing below a concrete pad in the wash-down area has identified soil contamination on the property.

There is one Resource Conservation and Recovery Act (RCRA) site within the Carolina Beach Watersheds, the CVS Pharmacy located at 901 Dow Road, Carolina Beach, North Carolina 28428. The facility is classified as a Large Quality Generator of hazardous waste, meaning it produces more than 1,000 kilograms of hazardous waste or 1 kilogram of acutely hazardous waste per month.

There are no known CERCLA sites or mining sites. There are multiple Underground Storage Tanks (UST) found in Carolina Beach and can be seen in Table 2-7. There have been 27 UST that have had incidents in the past thirty years within the watersheds, as seen in Table 2-8.

Table 2-7. Underground storage tanks in Carolina Beach (North Carolina Division of Waste Management, 2019).

Facility Name	Facility ID	Address	Tank Status
SCOTCHMAN 3119	00-0-0000021146	808 SOUTH LAKE BOULEVARD, CAROLINA BEACH, NC 28428	Current
SCOTCHMAN 3127	00-0-0000021379	354 CANAL DRIVE, CAROLINA BEACH, NC 28428	Current
ISLANDER KWIK MART	00-0-0000028645	111 CARL WINNER STREET, CAROLINA BEACH, NC 28428	Current
TOWN OF KURE BEACH	00-0-0000032762	701 FORT FISHER BLVD N(LIFT STAT), KURE BEACH, NC 28449	Current
TOWN OF CAROLINA BEACH - MAINTENANCE FACILITY	00-0-0000040128	404 AND 406 DOW ROAD, CAROLINA BEACH, NC 28428	Temporarily Closed

Table 2-8. Underground storage tanks incidents in Carolina Beach (North Carolina Division of Waste Management, 2019).

Incident Name	UST Number	Incident Number	Risk	Date Occurred
Scotchman #3127 - Kerosene Release	WI-8123	0	L	1/17/2019
DOW ROAD- 404 CAROLINA BEACH GENERATOR	WI-7980	43022	L	1/27/2016
TOWN OF CAROLINA BEACH GARAGE	WI-7904	32959	N/A	7/3/2013
PARK PLACE	WI-7682	32772	L	4/30/2012
CAROLINA BCH LIFT STATION UST	WI-7599	32695	L	2/10/2011
SCOTCHMAN # 127	WI-7631	32726	H	12/21/2010
CAROLINA BEACH STATE PARK	WI-7593	32690	L	4/7/2008
HERB'S BP SERVICE	WI-7165	32322	H	3/14/2006
MCINTOSH PROPERTY (MARTHA)	WI-7172	32302	L	2/3/2006
NOLAN, BETTY PROPERTY	WI-1913	22558	L	6/2/2000
CAROLINA BEACH AMOCO	WI-1698	20092	N/A	10/14/1998
SCOTCHMAN # 127	WI-1663	19728	L	3/16/1998
ISLANDER KWIK MART 11-A	WI-1673	19818	N/A	12/23/1997
HINES, CLINTON PROPERTY	WI-1814	21386	H	2/13/1997
SCOTCHMAN # 22	WI-1755	20714	L	10/4/1996
PARADISE INN	WI-1257	14150	L	5/31/1995
CITY OF WILMINGTON-NESBITT COURTS	WI-1211	12897	L	7/19/1994
MONTY'S NORTH	WI-1887	22247	L	3/10/1993
MONTY'S SOUTH	WI-1035	9675	L	1/15/1993
CAROLINA BEACH STATE PARK MARINA	WI-860	5904	L	7/23/1990
CAROLINA BEACH TOWN HALL (FORMER)	WI-7837	5796	L	5/30/1990
ISLANDER KWIK MART 11	WI-818	5614	L	5/10/1990
CAROLINA BEACH YACHT BASIN	WI-817	5602	N/A	5/7/1990
PAUL'S SUNOCO	WI-815	5570	H	5/1/1990
CAROLINA BEACH MARINA	WI-836	5690	H	2/13/1990
FAST FARE # 724	WI-800	5131	L	6/1/1989

2.6.4 Factors Affecting Water Levels

In recent years, the Town of Carolina Beach has experienced more frequent and increased flooding events, most notably evident along Canal Drive and Florida Avenue, in areas surrounding the Carolina Beach Yacht Basin. As a result, the Town commissioned a study (*Town of Carolina Beach Canal Drive Flooding and Vulnerability Study*, Aptim Coastal Planning & Engineering of North Carolina, Inc., DRAFT, February 2019, Appendix E).

Although the focus of this watershed plan is limited to better understanding the scope of and factors influencing the water quality impairments within the Town of Carolina Beach, the Aptim analysis and presentation of the forces and conditions affecting the local water levels are relevant and instructive in development of recommendations and short vs. longer-term prioritization of projects designed to preserve and restore water quality to sustain existing uses within the watershed. With permission from the Town of Carolina Beach, excerpts from this draft report are included in their entirety in this section, and provide an excellent resource for future planning efforts to address flooding issues, local climate change effects and associated changes in groundwater and sea levels and continued water quality impairments.

As identified by the Aptim 2019 report, the water levels within the study area (as well as within much of Carolina Beach) are influenced by the forces of astronomical tides, local winds, stormwater discharge from rain events, ocean storm surge, the Cape Fear River via Snow's Cut, sea level rise (and associated vertical land subsidence), and storm effects.

The following information are excerpts from the *Town of Carolina Beach Canal Drive Flooding and Vulnerability Study* (DRAFT, Aptim, 2019).

Astronomical Tides

The nearest measured water levels are those from the NOAA tide gauges located on the Cape Fear River in Wilmington, NC (Station ID 8658120) and on the Atlantic Ocean at Johnny Mercer's Pier in Wrightsville Beach, NC (Station ID 8658163), shown in Figure 3.

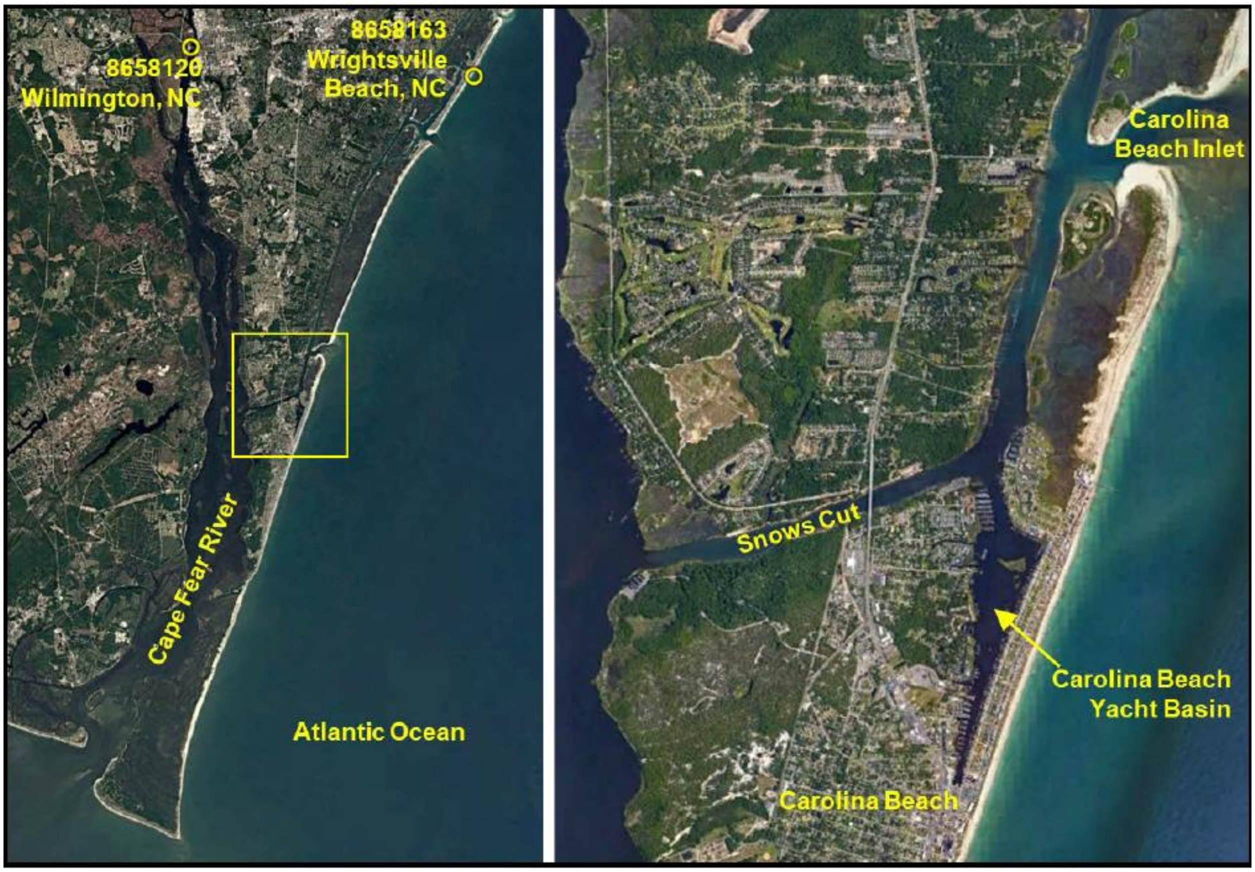


Figure 3. NOAA Tide Gauge Locations.

For purposes of this analysis, all elevations are in feet referenced to North American Vertical Datum 1988 (NAVD), unless specifically noted otherwise. Where source data is in another datum, data were converted to NAVD based on published National Oceanic and Atmospheric Administration (NOAA) tidal benchmarks. The two local tidal benchmarks used: "Gauge 8658120, Wilmington NC" and "Gauge 8658163, Wrightsville Beach NC", report NAVD as 2.60 feet above MLLW and 2.71 feet above MLLW, respectively. The tidal datum associated to NOAA's station 8658120 Wilmington, NC and station 8658163, Wrightsville Beach, NC are given in Table 1.

Table 1. Tidal Datums at 8658120 Wilmington, NC and 8658163 Wrightsville Beach, NC (NOAA).

Tide Station Datum Elevations **Units:** Feet **Epoch:** 1983-2001 **Datum:** NAVD			
Datum	**Description**	**Wilmington, NC**	**Wrightsville Beach, NC**
MHHW	Mean Higher-High Water	2.08	1.77
MHW	Mean High Water	1.83	1.42
NAVD88	North American Vertical Datum of 1988	0.00	0.00
MTL	Mean Tide Level	-0.31	-0.57
MSL	Mean Sea Level	-0.16	-0.56
DTL	Mean Diurnal Tide Level	-0.26	-0.47
MLW	Mean Low Water	-2.44	-2.56
MLLW	Mean Lower-Low Water	-2.60	-2.71

From NOAA's daily tidal predictions for 2017, the expected maximum predicted water levels for the Wilmington gauge were determined to be between approximately +1.5 to +3.0 feet NAVD (Figure 4) and approximately between +0.5 to +3.0 feet NAVD for the Wrightsville Beach gauge except for the months of January and February (Figure 5).

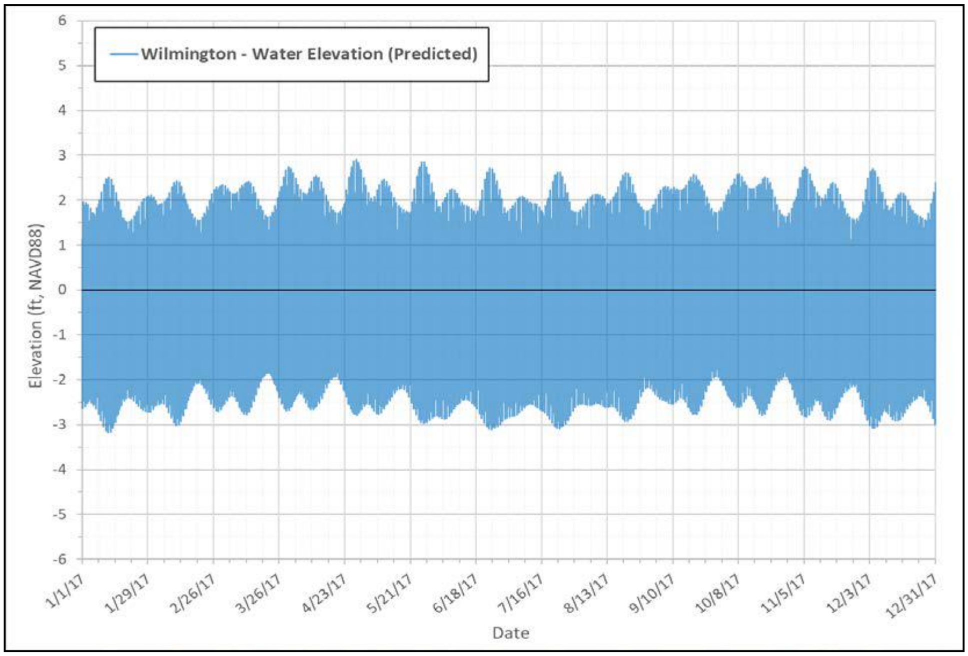


Figure 4. Wilmington, NC (Station ID 8658120) – 2017 Predicted Water Levels by NOAA.

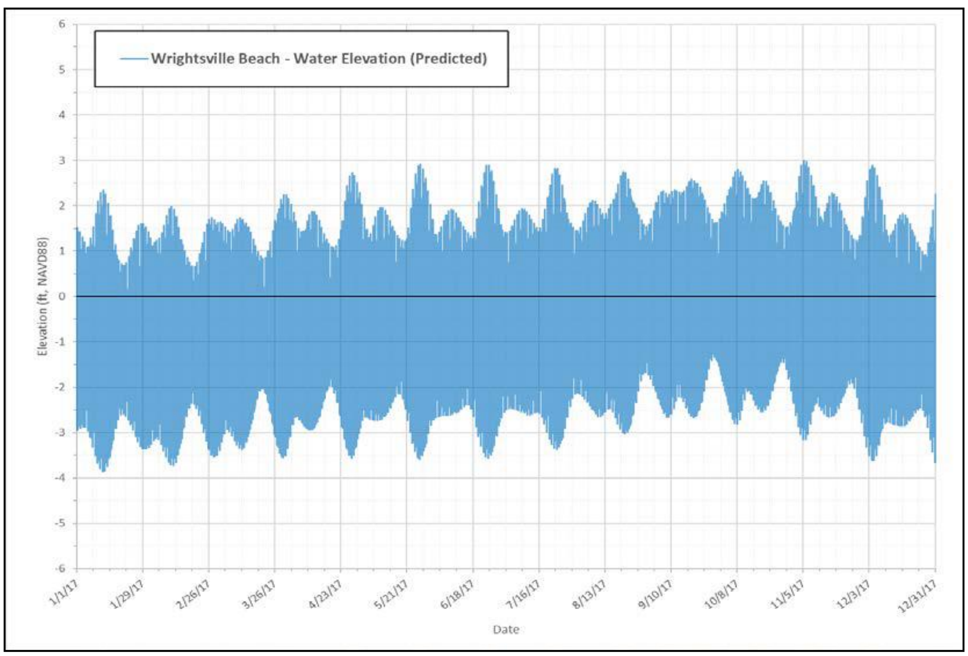


Figure 5. Wrightsville Beach, NC (Station ID 8658163) – 2017 Predicted Water Levels by NOAA.

Ocean Storm Surge

The passage of tropical systems with their associated wind fields and low central pressures can force ocean water to accumulate along the coast of the Atlantic Ocean creating an ocean storm surge. The ocean storm surge can affect the tides and flow of water through Carolina Beach inlet as well as in the Cape Fear River, via Snow's Cut, and impact the water levels in the Carolina Beach Yacht Basin. Strong northeasterly wind and wave events associated with extratropical nor'easter storms, even if distant, can also create a storm surge influencing water levels in the Carolina Beach Yacht Basin. There are also variations in the Gulfstream current and other oceanographic processes that affect the tide in the Atlantic Ocean. These processes can positively or negatively affect the tide and have been categorized for this evaluation as ocean storm surge.

The Carolina Beach Yacht Basin is connected to the Atlantic Ocean through Carolina Beach Inlet and is connected to the Cape Fear River via Snow's Cut (Figure 3). NOAA provides predicted water levels at the Wilmington Gauge (Station ID 8658120) and Wrightsville Beach Gauge (Station ID 8658163) based on astronomical tides and measured water levels. Figure 6 and Figure 7 show both predicted and measured water levels for the Wilmington and Wrightsville Beach gauges, respectively. For 2017, the deviations at the Wilmington Gauge averaged 0.29 feet with the maximum positive deviation occurring on September 12, 2017 attributable to the passing of Hurricane Jose. Likewise, the deviations at the Wrightsville Beach Gauge averaged 0.35 feet with the maximum positive deviation occurring on December 9, 2017.

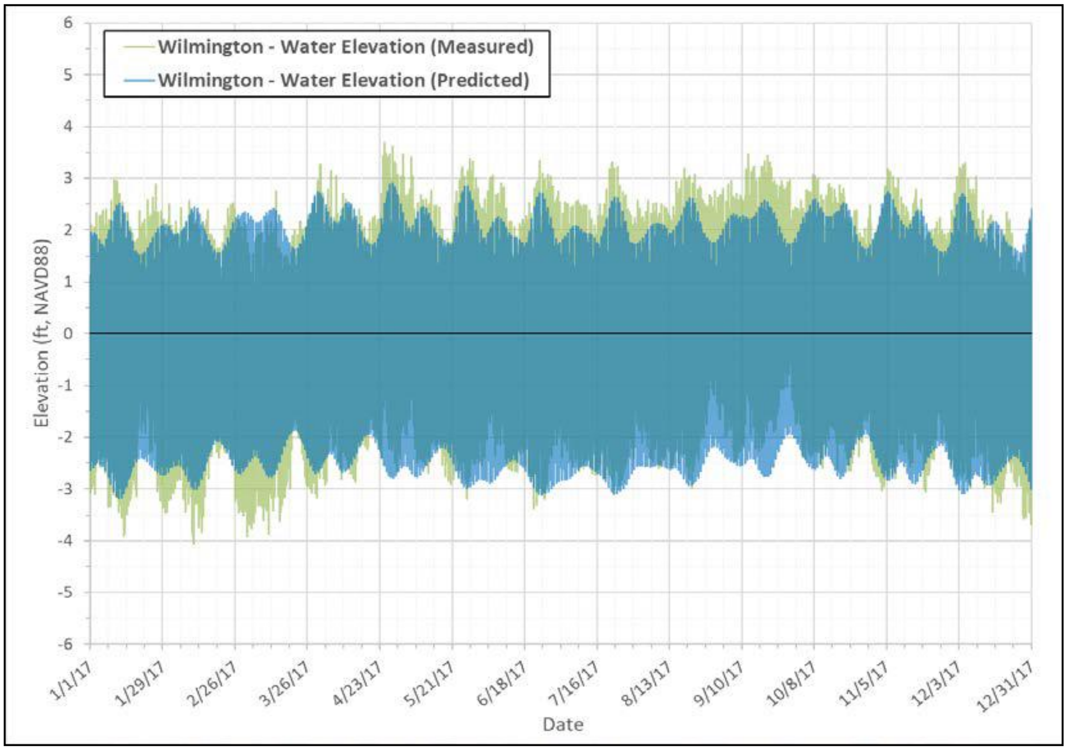


Figure 6. Wilmington, NC (Station ID 8658120) - 2017 Predicted and Measured Water Levels.

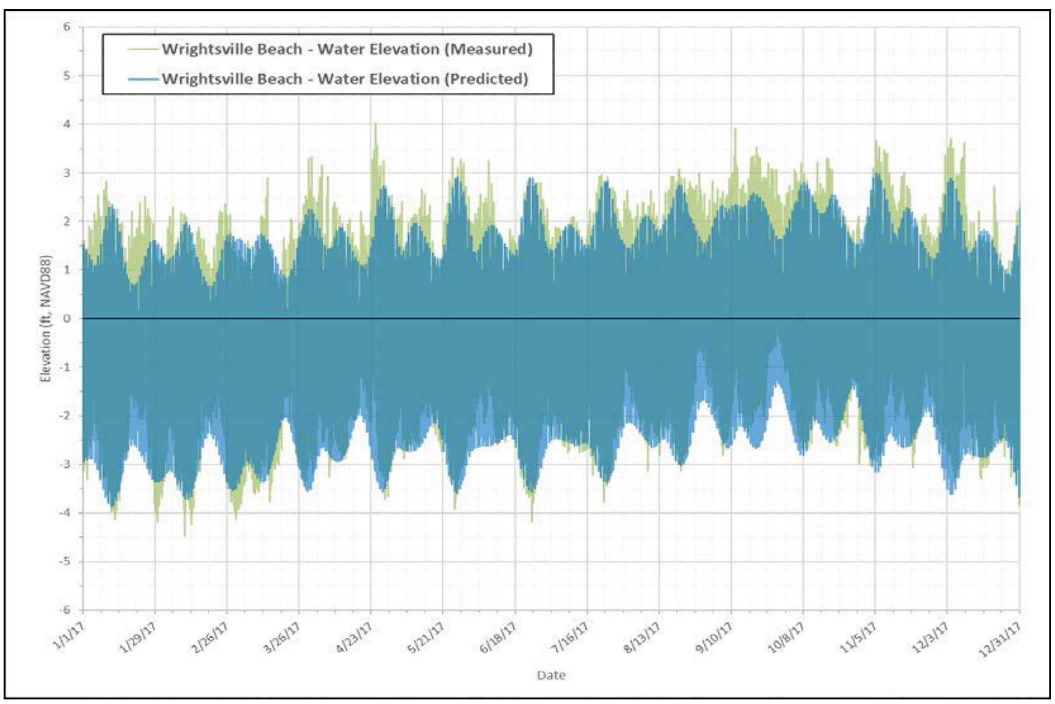


Figure 7. Wrightsville Beach, NC (Station ID 8658163) - 2017 Predicted and Measured Water Levels by NOAA.

Other Components

1.1.1.1 *Stormwater Discharge from Inland Rain*

Rain that accumulates on the surface and does not infiltrate into the ground is referred to as creating surface water. Within the study area, these surface waters are managed by the public stormwater system. Management of the stormwater is intended to provide flood protection and drainage for public and private lands. As part of this management effort, stormwater within the study site is collected at catch basins located along Canal Drive and Florida Avenue and discharged through outfall pipes to the Carolina Beach Yacht Basin.

1.1.1.2 *Local Winds*

Atmospheric conditions generate high and low pressures, as well as gradients in both air and sea temperatures. These conditions result in winds at both a regional and local scale that create friction on the water's surface. Depending on the strength, direction, and persistence of these winds, this forcing can cause localized fluctuations in water levels. In particular, northerly and northeasterly winds can force water down the Intracoastal Waterway and affect the water levels within Carolina Beach Yacht Basin.

In order to better understand the effect of wind stress on the water levels within the Carolina Beach Yacht Basin, a quantitative analysis was conducted to assess the effects as part of this study. The assessment, using an assumed average depth of 10 ft. for the entire basin and the length of the basin, determined that a wind speed of 50 mph would result in an approximate 0.3 to 0.4 ft. increase in water level within the basin. The assessment did not account for the shape of the basin that narrows toward the south end or the impacts from elevated water levels generated in the Intracoastal Waterway, which would result in an additional increase in the water level within the basin. The installation of the monitoring station within the basin will provide water level and wind data than can be analyzed to determine the impacts northerly and northeasterly winds have on the water levels within the basin.

1.1.1.3 *Sea Level Rise*

The Relative Sea Level Trend reported by NOAA for Station 8658120 Wilmington, NC for the period between 1935 and 2017 is 2.30 mm/year (+/-0.34 mm/year). Figure 8 shows the monthly mean sea level with the average seasonal cycle removed as well as the linear relative sea level trend. Relative Sea Level Trends for Station 8658163 Wrightsville Beach, NC are not reported by NOAA. Although the Wrightsville Beach Station is located in the Atlantic Ocean and the Wilmington Station is located 26 miles up the Cape Fear River, in the absence of available data for Wrightsville Beach, this analysis assumes the Relative Sea Level Trend for the Wilmington Station is representative of the Wrightsville Beach Station location. The linear trend reported by NOAA for the Wilmington Station (2.3 mm/year) results in an increase of approximately 0.2 feet from 1992 to 2018 (i.e. the midpoint of the current National Tidal Datum Epoch of 1983-2001 to present).

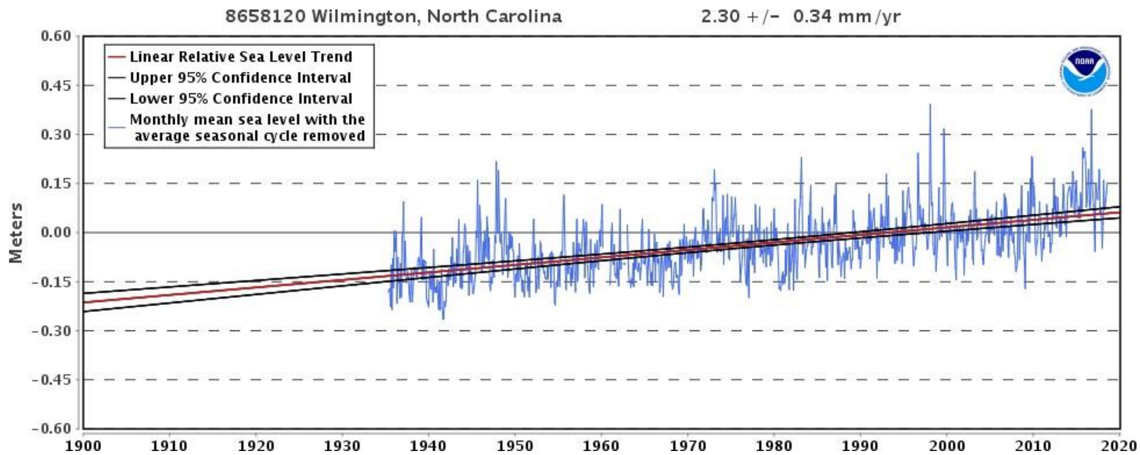


Figure 8. Relative Sea Level Trend; 8658120 Wilmington, NC (NOAA)

Projections of future sea level rise may be based on relative sea level rise derived from the most local, longest term tidal measurements. As shown by Harris (1981), the use of a long record reduces the standard error in linear regression analysis. The longest data record for North Carolina is in Wilmington (NOAA Station ID 8658120) covering a time span of 83 years (1935-2018).

The North Carolina Coastal Resources Commission (CRC) tasked the CRC Science Panel with conducting a comprehensive review of scientific literature and available data for North Carolina that addresses the full range of global, regional, and local sea level change. In 2016, the final report of the Science Panel's assessment of sea level rise in North Carolina was released, updating the initial 2010 NC Sea Level Rise Assessment report. The Science Panel chose to use scenario based global sea level rise projections provided in the most recent Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The IPCC sea level rise scenarios are referred to as Representative Concentration Pathways (RCP) that represent possible trajectories of sea level rise based on projected amounts of greenhouse gases emitted in the future. The sea level rise scenarios provided in the IPCC AR5 report are the RCP 2.6 (lowest greenhouse gas emission), RCP 4.5, RCP 6.0, and RCP 8.5 (highest greenhouse gas emission). A comparison of the published IPCC projections to the monthly mean sea level (MSL) as measured in Wilmington is shown in Figure 9.

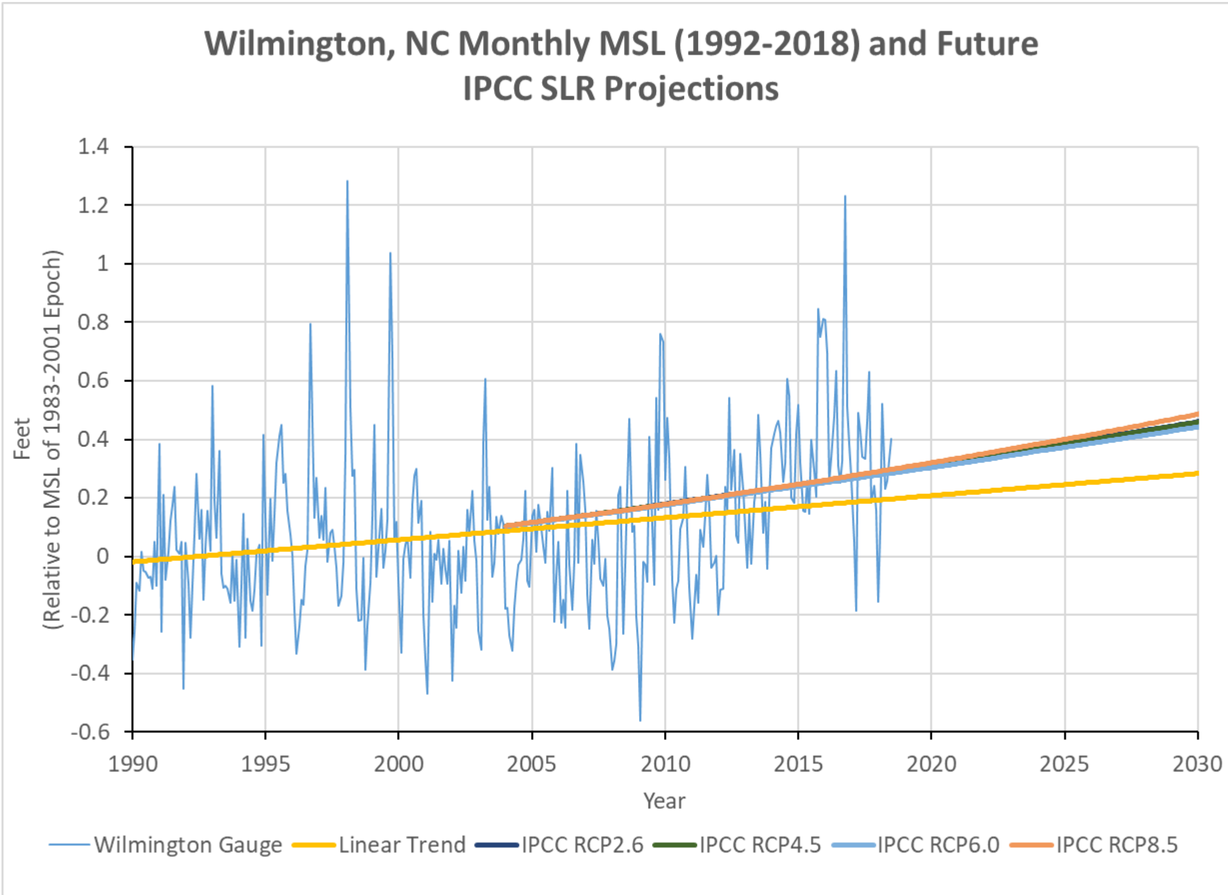


Figure 9. Sea Level Rise Projections overlain on Measured Monthly MSL at Wilmington, NC.

Based on the data comparison illustrated in Figure 9, several preliminary observations can be made:

1. A comparison between the historical linear trend (by NOAA) and the monthly mean sea level changes indicate that the sea level in Wilmington is rising at an increasing rate. Utilization of the historical linear trend does not appear to compare favorably with the measurements since approximately 2013.
2. Based on the linear trend, mean sea level has risen approximately 0.20 feet between 1992 (midpoint of the current National Tidal Datum Epoch) and 2018 in Wilmington.
3. The CRC Science Panel chose the United Nations Intergovernmental Panel on Climate Change (IPCC) AR5-RCP 2.6 (low scenario) and RCP 8.5 (high scenario) projections for use in the NC Sea Level Rise Assessment Report (2015 Update).

The 2015 NC Sea Level Rise Assessment Report focuses on the low and high greenhouse gas scenarios (RCP 2.6 and RCP 8.5) to represent the lower and upper bounds of the potential range of future sea level rise. Table 2 provides the projected mean rise of Global Sea Level in 2018 and 2048 based on a linear interpolation of the IPCC RCP 2.6 and RCP 8.5 sea level rise projections with respect to 1986-2005 at January 1st (modified from Table AII.7.7, IPCC 2013a).

Table 2. Mean Global Sea Level Rise from 2018 to 2048 as Predicted by IPCC Scenarios.

Predicted Amount of Sea Level Rise by Year	Scenario RCP 2.6 (feet)	Scenario RCP 8.5 (feet)
2018	0.24	0.24
2048	0.69	0.78
Change in SLR (2018 to 2048)	0.45	0.54

In order to relate the IPCC projections of the mean Global Sea Level Rise to Wilmington, North Carolina, the NC Sea Level Rise Assessment Report included vertical land movement (VLM) trends based tidal data from Wilmington NOAA tide station. The vertical land movement trend quantified by Zervas (2014) was used as a proxy for local effects. The vertical land movement computed a trend of subsidence at a rate of -0.39 mm/yr for Wilmington, NC (Zervas, 2014), or equivalent to -0.00128 ft./yr. This equates to an estimated vertical land movement of -0.038 ft. over a 30-year period. Table 3 provides the projected mean rise of Relative Sea Level by 2048 in Wilmington based on the IPCC RCP 2.6 and RCP 8.5 scenarios and the vertical land movement for Wilmington, NC.

Table 3. Relative Sea Level Rise by 2048 considering sea level rise predicted by IPCC Scenarios combined with projected vertical land movement for Wilmington, NC.

Relative Sea Level Rise in 30 years	Scenario RCP 2.6 + VLM (feet)	Scenario RCP 8.5 + VLM (feet)
Increase in MSL between 2018 and 2048 + VLM	0.49	0.58

<u>Storm Effects</u>

Storm surges occur within the Atlantic Ocean and propagate into the Carolina Beach Yacht Basin through tidal inlets, the Cape Fear River, and interior channels. These surges will influence local water levels and can be predicted (statistically) through analysis of historic water levels. An extreme water level analysis was conducted to determine the elevation of expected water levels for a given return period. Data used in the extreme water level analysis included local observations of historical high water marks, short-term USGS tide records measured locally during specific storms, and historical water levels at the Wilmington and Wrightsville Beach NOAA stations. A list of observed high water elevations observed within the Carolina Beach Yacht Basin between 1996 and 2018 is provided in Table 4 where the maximum event was from a local observation of +8.7 feet, NAVD that occurred on September 6, 1996 associated with the passing of Hurricane Fran. Likewise, nine of the top ten water elevation events are associated with the passage of a named tropical system and seven of the top ten water levels were observed within the study area.

Table 4. Observed High Water Elevations within the Carolina Beach Yacht Basin

Event	Water Elev. (ft. NAVD88)	Comment
H. Fran water mark (6 Sep 1996)	8.68	@ 1019 Canal Drive
H. Floyd water mark (16 Sep 1999)	8.18	@ 1019 Canal Drive
H. Bonnie water mark (26 Aug 1998)	6.58	@ 1019 Canal Drive
H. Florence (14 Sep 2018) H. Florence water mark (14 Sep 2018) H. Florence wrack line (14 Sep 2018)	5.69 5.48 5.37	USGS STN Joyner Marina @ 1019 Canal Drive @ 1001 Canal Drive
H. Matthew (8 Oct 2016) H. Matthew water mark (8 Oct 2016)	5.18 5.08	USGS STN Joyner Marina @ 1019 Canal Drive
H. Bertha water mark (July 1996)	4.98	@ 1019 Canal Drive
Lunar High Tide water mark (Sep-Oct 2013)	4.98	@ 1019 Canal Drive
Lunar High Tide water mark (Sep 2008)	4.68	@ 1019 Canal Drive
H. Irene water mark (Oct 1999)	4.63	@ 1019 Canal Drive

As shown in Table 4, elevation data were obtained by the USGS for high water levels that occurred at the Carolina Beach Yacht Basin during Hurricane Matthew and Hurricane Florence. In these two events, high water levels were measured from water level sensors deployed at Joyner Marina prior to the storms. The other high water elevations listed in Table 4 were recorded by a homeowner on the piling of his house located at 1019 Canal Drive after the storms. The water levels measured by the USGS water level sensors during Hurricane Matthew and Hurricane Florence were prioritized over the observations and used in the analysis. However, due to the close agreement between the elevations of the measured water levels by the USGS sensors and the observed high water mark elevations there is a high degree of confidence in the accuracy of the observed high water marks recorded by the homeowner following other storm and tidal events. Local high water observations were made from 1996 to 2018, while tide data associated with the Wilmington NOAA station spans from 1935 to 2018 and data from the Wrightsville Beach NOAA station spans from 2004 to 2018. A comparison between locally observed data and NOAA tide records is provided in Figure 10.

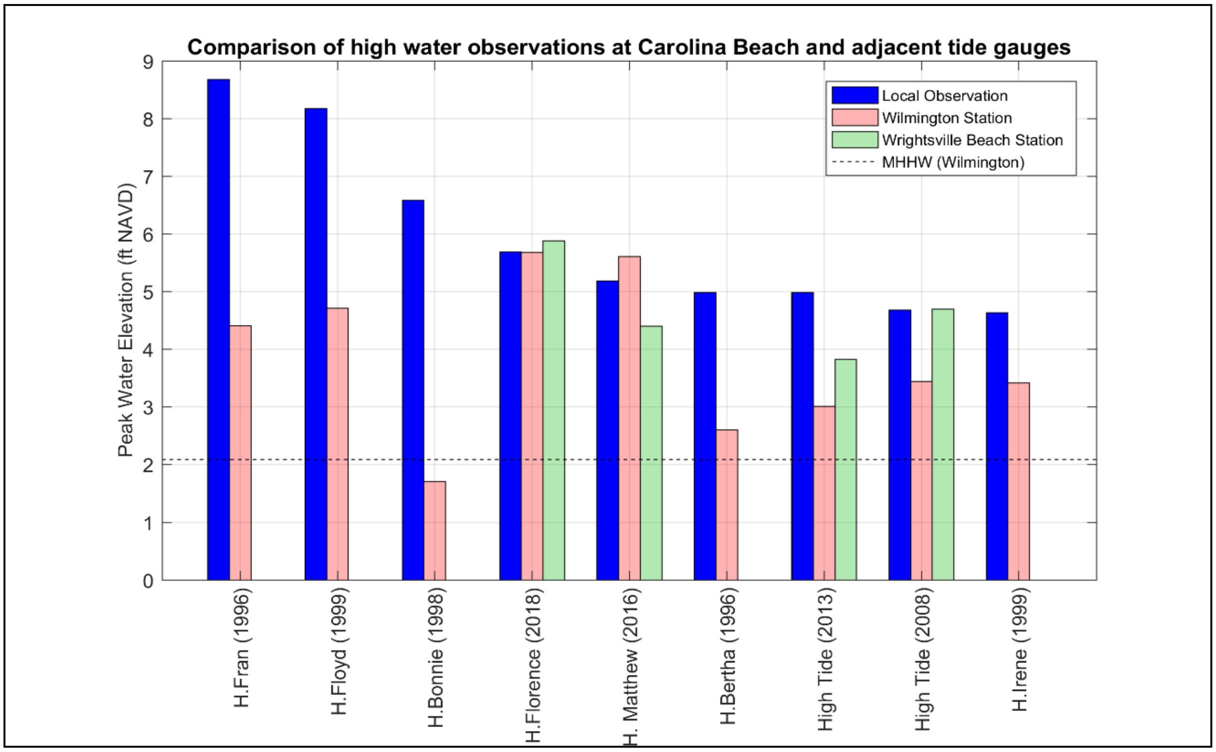


Figure 10. Comparison between local observations and tide records during extreme events.

The three events on local records with the highest recorded water levels occurred between 1996 and 1999. During this period, the Wrightsville Beach NOAA station was still not operational. The associated storm surge levels measured at the Wilmington NOAA station were considerably lower as shown in Figure 10. This discrepancy is attributed to the path of the storms and the prevailing wind speeds/directions. The three storms (Hurricanes Fran, Floyd and Bonnie) moved from the southern to the northern quadrant over or immediately east of the Cape Fear.

Western winds are not critical in terms of storm water levels within the Yacht Basin. Eastern/northeastern winds induce positive storm surges along the coast north of Cape Fear, while south of Cape Fear; surges produced by eastern/northeastern winds are expected to be smaller or even negative due to the change in shoreline orientation. Because the Cape Fear River, and therefore the Wilmington NOAA station, are connected to the coastal region immediately south of the Cape Fear, storm surges associated with eastern/northeastern wind events are less intense. The Carolina Beach Yacht Basin is situated between the eastern coast and the Cape Fear River. During eastern/northeastern wind events, the Yacht Basin is more critically affected by the coastal storm surge propagating through Carolina Beach Inlet rather than the propagation of tides from the Cape Fear River through Snow's Cut.

Divergent elevations between local observations and tidal records were also observed for the less severe events shown in Figure 10. As the local observations are considered accurate/reliable and represent the extreme water level at the study site, the local observed water level data was prioritized in the analysis. Data from the NOAA tidal stations at Wilmington and Wrightsville Beach were used to supplement these locally observed data.

Return Period Analysis

A return period analysis is a statistical analysis that utilizes historical data to determine the average recurrence interval of a particular event used for assessing risk. For this study, a recurrence interval was defined as the probability of a particular maximum water level being exceeded in any given year. The analysis was performed using a combination of locally observed historical high water marks recorded within the Carolina Beach Yacht Basin during past storm events and lunar high tides, short-term tide records measured at Joyner Marina by the USGS during specific storms, and historical water level data from the Wilmington and Wrightsville Beach NOAA tide stations as shown in Table 4. The data was used to determine the likelihood of exceedance of maximum water levels within the Carolina Beach Yacht Basin for a given return period. The return period analysis utilized available data from the 22.8-year period from 1996 to 2018.

The composite historical water level time series from 1996 to 2018 was normalized by subtracting the observed trend of MSL rise over time (2.3 mm/yr.) from the measured water levels. In doing so, the extreme water levels used in the analysis are all referenced to the same datum (NAVD88). The resulting normalized, or de-trended, water level time series is shown in Figure 11.

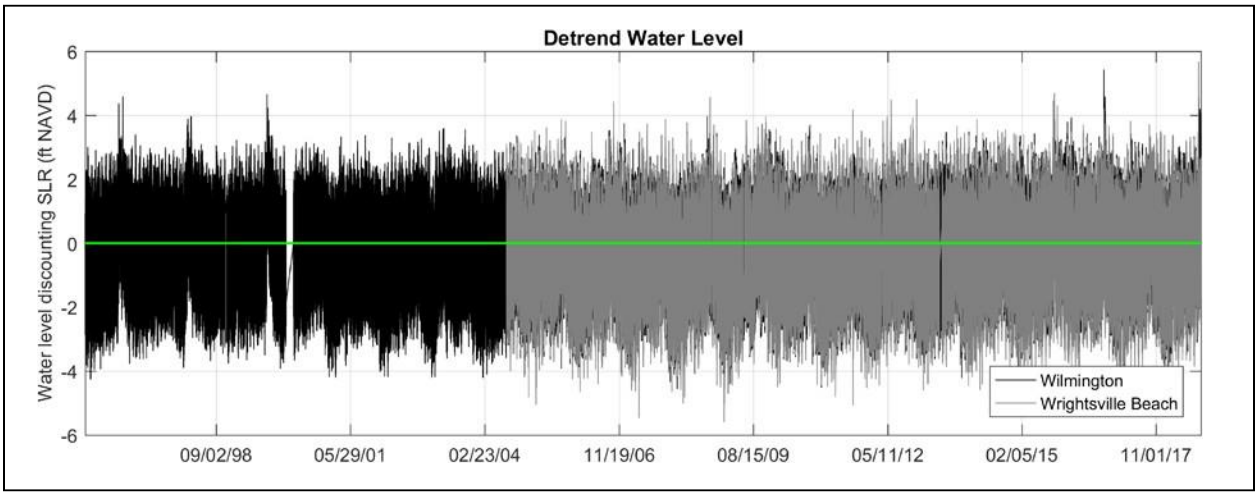


Figure 11. De-Trended Water level time series for NOAA Stations 8658120 Wilmington and 8658163 Wrightsville Beach

From the de-trended time series, a Peaks-Over-Threshold (POT) method was employed to select the individual storm events considered in the probability distribution and curve fitting. An elevation fluctuation threshold was set at +3.9 feet, which resulted in 26 events during the 22.8-year record where the de-trended water levels exceeded the threshold, providing slightly more than one event per year, on average.

To avoid double counting events, a 7-day buffer was applied before and after each peak using the following priority sequence:

1) Local Observations: first priority; peaks from tide stations occurring within 7 days of observed peaks were excluded from analysis;
2) Tide station peaks less than 7 days apart: highest peak recorded, remaining peaks removed.

The data was then fit using the Weibull distribution. The resulting curve is shown in Figure 12. Of interest is the top 10 events, which are listed in Table 5. The top events are mostly related with the passage of significant tropical and extratropical storms.

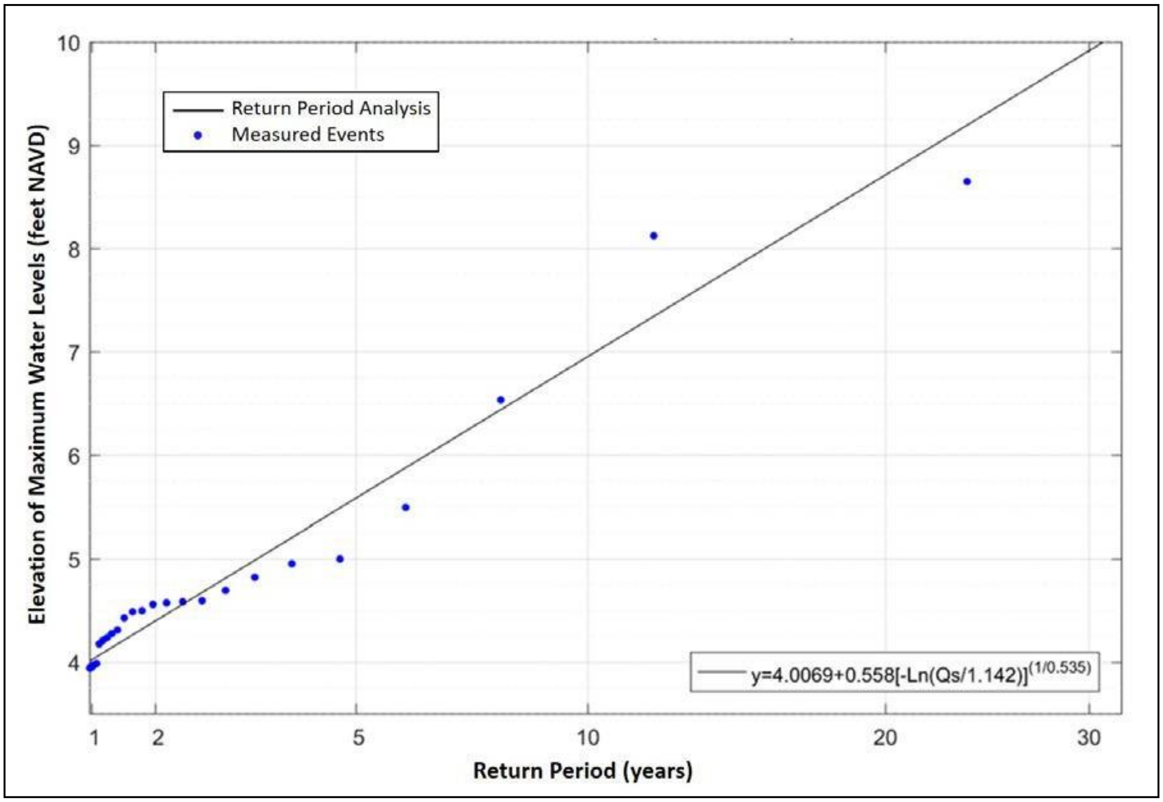


Figure 12. Maximum Water Levels (not adjusted for Sea Level Rise) for Various Return Periods.

Table 5. Top 10 Extreme High Water Events Based on the Analyzed Water Level Data.

Extreme Water Level Events				
Rank	**Date**	**Feet (NAVD)**	**Data Source**	**Event**
#1	9/6/1996	8.68	Local Observations	H. Fran
#2	9/16/1999	8.18	Local Observations	H. Floyd
#3	8/26/1998	6.58	Local Observations	H. Bonnie
#4	9/14/2018	5.69	USGS STN Joyner Marina	H. Florence
#5	10/8/2016	5.18	USGS STN Joyner Marina	H. Matthew
#6	7/12/1996	4.98	Local Observations	H. Bertha
#7	10/9/2013	4.98	Local Observations	Lunar High Tide
#8	10/4/2015	4.87	NOAA Wrightsville Beach Station	H. Joaquin
#9	10/8/1996	4.62	NOAA Wilmington Station	T.S. Josephine
#10	10/17/2016	4.77	NOAA Wilmington Station	H. Nicole

The water levels associated with a given return period are provided in Table 6. The analysis determined that a 1-year return period event (100% chance of exceedance during any given year) had a water level of approximately 4.0 feet NAVD, and a 30-year return period event (3% chance of exceedance during any given year) had a water level fluctuation above the long-term trend of approximately of 9.9 feet NAVD.

Table 6. Extreme Water Elevations – feet above NAVD (not including SLR effects)

Return period (years)	Water elevation (feet NAVD)
1	4.0
2	4.4
5	5.6
10	6.9
20	8.7
30	9.9

Due to the fact that statistical uncertainty increases as the return period exceeds the recorded length of the dataset, it is not recommended to use return period projections beyond twice the length of the measured record. In this study, there was a sufficiently long history of data (23 years) to have statistical confidence for the desired return periods.

In an effort to focus on mitigating the flooding impacts to Canal Drive and Florida Avenue that occur during high tide events the water level elevations associated with the 1-year and 2-year return period events were selected as a basis for the analysis to determine the minimum bulkhead elevation. The 1-year and 2-year return period events are above the maximum measured tide levels in 2017 for both the Wilmington (Figure 6) and the Wrightsville Beach (Figure 7) NOAA stations and are within the range of locally observed high water levels associated with lunar high tide events as shown in Table 4.

Total Water Level Projections

To determine the water levels to use in long-term planning, a total water level projection was computed by summing together the mean sea level rise (1992 to 2018), the expected sea level rise, the water level associated with the 1-year and 2-year return period events, and a "freeboard" or safety factor. The total water level projection for the Carolina Beach Yacht Basin in 2048 (30-year planning horizon) can be found by summing the following:

Design Elevation = SLR (1992-2018) + SLR (future) + Storm Effects + Structure Freeboard Where:

- **SLR (1992-2018):** The Sea Level Rise from 1992 to 2018 is equal to 0.20 feet (Section 3.1.3.3).
- **SLR (future):** The expected sea level rise for 30 years based on the IPCC RCP projections + Vertical Land Movement (Table 3).
- **Storm Effects:** The expected water level above the average daily maximum associated with return period events in any given year (Table 6).
- **Structural Freeboard:** An additional vertical distance that represents a safety factor, which can be defined by the Town. It is recommended that a minimum of 0.5 feet be utilized.

The planning elevations in Table 7 represent a range of projected water levels based on the results of the analysis that combine the mean sea level rise (1992 to 2018), the expected sea level rise, expected water levels to occur during a storm event having a 1-year or 2-year return period within the next 30 years and a structural freeboard factor.

Table 7. Summary of Design Planning Water Elevation Projections

	Low Range (1-year Return Period)	Mid-Range (1-year Return Period)	Upper Range (2-year Return Period)
SLR 1992-2018 (ft.)	0.20	0.20	0.20
IPCC RCP 2.6 (ft.)	0.49	0.49	-
IPCC RCP 8.5 (ft.)	-	-	0.58
Storm Effects (ft. NAVD)	4.0	4.0	4.4
Structure Freeboard (ft.)	0.0	0.5	0.5
2048 Design Elev. (ft. NAVD)	**4.7**	**5.2**	**5.7**

Therefore, for a 30-year planning horizon, it is recommended that the Town prepare for a minimum design water level elevation of at least 4.7 ft., NAVD (1-year return period event, RCP 2.6 projection, and no structural freeboard). Using the results of this study, the calculation was also completed for a 1-year return period event, RCP 2.6 projection, with the minimum structural freeboard (Mid-Range) and a 2-year return period event, RCP 8.5 projection, with the minimum structural freeboard (High Range) and resulted in water levels of 5.2 ft. and 5.7 ft. NAVD, respectively.

3 Runoff Volume Reduction

Rather than focusing on reducing sources of pollutants from stormwater runoff, *the proven management techniques used in this plan focus on reducing the overall volume of stormwater runoff to limit the conveyance from the land into coastal waters.* Low-impact development (LID) and stormwater reduction techniques can achieve this goal by replicating the natural hydrology and increasing infiltration of water into soils. LID practices are a form of land planning and engineering that primarily focus on mimicking natural hydrology of the area to limit stormwater runoff. For already developed locations stormwater reduction techniques can reduce the amount of stormwater entering waterways. The result of implementing stormwater control practices is that less bacteria and pollutants are transported off the land and into water systems. The primary issue to be addressed through the stormwater runoff volume reduction methodology is the reduction of fecal coliform contamination caused by urban development within the watershed (Table 3-1).

Table 3-1. Identifying and linking concerns, causes and indicators.

Issue	Source of Issue	Quantify Issue Indicators
Water quality is impaired and not meeting its Designated Use standard of Class SA	Non-point source bacteria transported by stormwater runoff	• Fecal coliform cannot exceed GM of 14/100 ml
Instances of localized flooding	Volume of stormwater runoff due to impervious surfaces	• Volume of water

3.1 Stormwater Volume Reduction Calculation Methodology

The process of calculating stormwater runoff volume reduction goals has been standardized utilizing instructions developed by the North Carolina Coastal Federation, a non-profit organization dedicated to preserving and protecting North Carolina's coast, and Withers & Ravenel, a civil and environmental engineering firm. This methodology is described in a Watershed Restoration Planning Guidebook that can be found at www.nccoast.org.

The year 1993 was selected as the baseline year due to there being excellent aerial images available that provide high enough resolution to conduct a land use classification with good accuracy. It was also the earliest year that aerial imagery that was georeferenced was readily available that covered the entire area. Since Carolina Beach was largely developed before the baseline year and has had shellfishing closures since the 1940s, a hypothetical scenario of 100% of wooded land use was added as a demonstration of the changes in hydrography between pre-development conditions and current development conditions. It is important to keep in mind that the estimates for reducing the volume of runoff is not expected to be precisely accurate, but rather provide a ballpark goal for the amount of runoff that needs to be eliminated to see improvements in water quality to a designated goal. Further review and evaluation of water quality as management measures are implemented will provide the opportunity to further refine and adjust volume reduction targets as the plan is carried out. Utilizing this 1993 aerial imagery for the baseline year, land characterization was conducted by delineating parcel information, development (wooded, open land, impervious), and soil characteristics (HSG) for each land use scenario. The delineated land use parcels were then analyzed to estimate the average percent impervious, wooded, and open land coverage. Summations were calculated of overall percent coverage based on land use and soil. From this information, the runoff curve number is calculated then runoff depth is calculated for the 1-year, 24-hour depth of precipitation using formulas developed by the United States Department of Agriculture Natural Resource Conservation Service (USDA NRCS) in the *TR-55 Manual*. A runoff curve number (commonly referred to as CN) is a numeric parameter derived from combining the effects of soil, watershed characteristics, and land use.

The following curve numbers were utilized:

Land Use Classification	HSG			
	A	B	C	D
Impervious	98 CN	98 CN	98 CN	98 CN
Open Space	39 CN	61 CN	74 CN	80 CN
Woods	30 CN	55 CN	70 CN	77 CN

The following designations were utilized to categorize land use:

Land Use Classification	Designation
Impervious	Areas with distinctive impervious coverage from paved parking lots, roofs, driveways, curbs, etc.
Open Space	Grassy areas where there is 75% or more grassy space such as from lawns, parks, golf courses, cemeteries, fields, pastures, etc.
Woods	Forested areas with thorough coverage, these areas are often protected from grazing, and forest litter and brush adequately cover the soil.

The resulting value is then multiplied by the area of the watershed, which will give the total estimated stormwater runoff volume anticipated in response to the prescribed depth of rainfall over a 24-hour period. The volume difference between the baseline year and the analyzed year is calculated to determine the estimated volume of stormwater runoff that needs to be reduced to replicate pre-impairment conditions.

NOAA precipitation frequency models state that a 1-year, 24-hour storm results of **4.06 inches of precipitation** and the results for a **2-year, 24-hour storm is 4.92 inches** (Table 3-2). The 1-year, 24-hour storm and 2-year, 24-hour storm estimations are used because it has been established as the maximum storm parameter possible to protect shellfishing waters (Class SA) in North Carolina by DEQ. The 2-year, 24-hour storm event depth of precipitation will also be necessary as part of developing hydrographs of the data.

Table 3-2. NOAA precipitation frequency table for Carolina Beach Watersheds (National Oceanic and Atmospheric Administration, 2017).

PRECIPITATION FREQUENCY ESTIMATES (Time/years) IN INCHES										
Duration	**1**	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min:	0.542	0.646	0.752	0.836	0.943	1.02	1.11	1.19	1.3	1.39
10-min:	0.866	1.03	1.2	1.34	1.5	1.63	1.76	1.89	2.06	2.19
15-min:	1.08	1.3	1.52	1.69	1.9	2.07	2.22	2.38	2.59	2.75
30-min:	1.49	1.79	2.16	2.45	2.82	3.11	3.41	3.71	4.12	4.46
60-min:	1.85	2.25	2.77	3.19	3.76	4.21	4.69	5.2	5.91	6.5
2-hr:	2.2	2.69	3.41	4.01	4.86	5.58	6.36	7.22	8.47	9.55
3-hr:	2.34	2.86	3.64	4.32	5.31	6.17	7.11	8.16	9.74	11.1
6-hr:	2.95	3.61	4.61	5.47	6.74	7.86	9.1	10.5	12.6	14.4
12-hr:	3.46	4.24	5.44	6.5	8.06	9.46	11	12.8	15.5	17.9
24-hr:	4.06	4.92	6.38	7.65	9.6	11.3	13.3	15.6	19.1	22.2
2-day:	4.67	5.65	7.25	8.64	10.7	12.6	14.7	17.1	20.7	23.9
3-day:	4.9	5.92	7.55	8.95	11.1	12.9	14.9	17.2	20.8	24.1
4-day:	5.13	6.2	7.85	9.26	11.4	13.2	15.2	17.4	20.9	24.2
7-day:	5.81	7	8.8	10.3	12.5	14.4	16.4	18.6	21.8	24.5

3.2 Runoff Volume Reduction Calculations

The volume reduction results represent base numbers of volumetric changes between the years based on land use changes (Table 3-3). These idealized volumetric reduction goals do not take into consideration more complex nuances, such as changes in stormwater regulation or minor or major stormwater reduction and retrofit projects. This subtly is addressed through the goals and objectives discussed in the following section, where an inventory of stormwater reduction measures throughout the watersheds should be taken and volumetric credit could be calculated during planning/implementation and accounted for towards meeting the volume reduction goals. These general reduction volumetric goals represent an over-arching and consistent pattern throughout the watersheds of land use changes resulting in an increase in stormwater runoff and an increase in the number of closures.

Based on the modeling results and land use conditions, the final numeric total stormwater runoff reduction volume goal for Carolina Beach is 11,121,962 gallons. This is the target goal that management and restoration plans seek to achieve (Table 3-4). For comparison, if the town sought to reduce stormwater runoff to the level of mimicking the hydrology of the watersheds being 100% wooded, the associated volume reduction goal would be 26,084,894 gallons.

Table 3-3. Land use change from 1993 to 2016.

Soil Type	Land Use	1993 Total Area	2016 Total Area	Difference
A	Open	50	121	+71
A	Impervious	760	725	-35
A	Woods	328	292	-36
B	Open	0.70	0.51	-0.19
B	Impervious	27	28	+1
B	Woods	8	7	-1
C	Open	-	-	-
C	Impervious	-	-	-
C	Woods	-	-	-
D	Open	197	373	+176
D	Impervious	986	765	-221
D	Woods	385	392	+7

Table 3-4. Volume reduction goals for Carolina Beach

Carolina Beach Watersheds			
Year	**Condition Peak Flow (cubic feet per second)**	**Reduction Goals**	
		Runoff Volume (ac-ft)	**Volume Change from Baseline Conditions (ac-ft)**
1993	2,029.05	192.83	--
2016	2,527.25	226.97	+ 34.14
Total Acres		2741.47	
Runoff Reduction Goal		34.14 acre-feet	
Reduction Goal		11,121,962 GAL per 1-yr, 24-hr storm	
Runoff Volume per Acre		4,436 gal/ac	

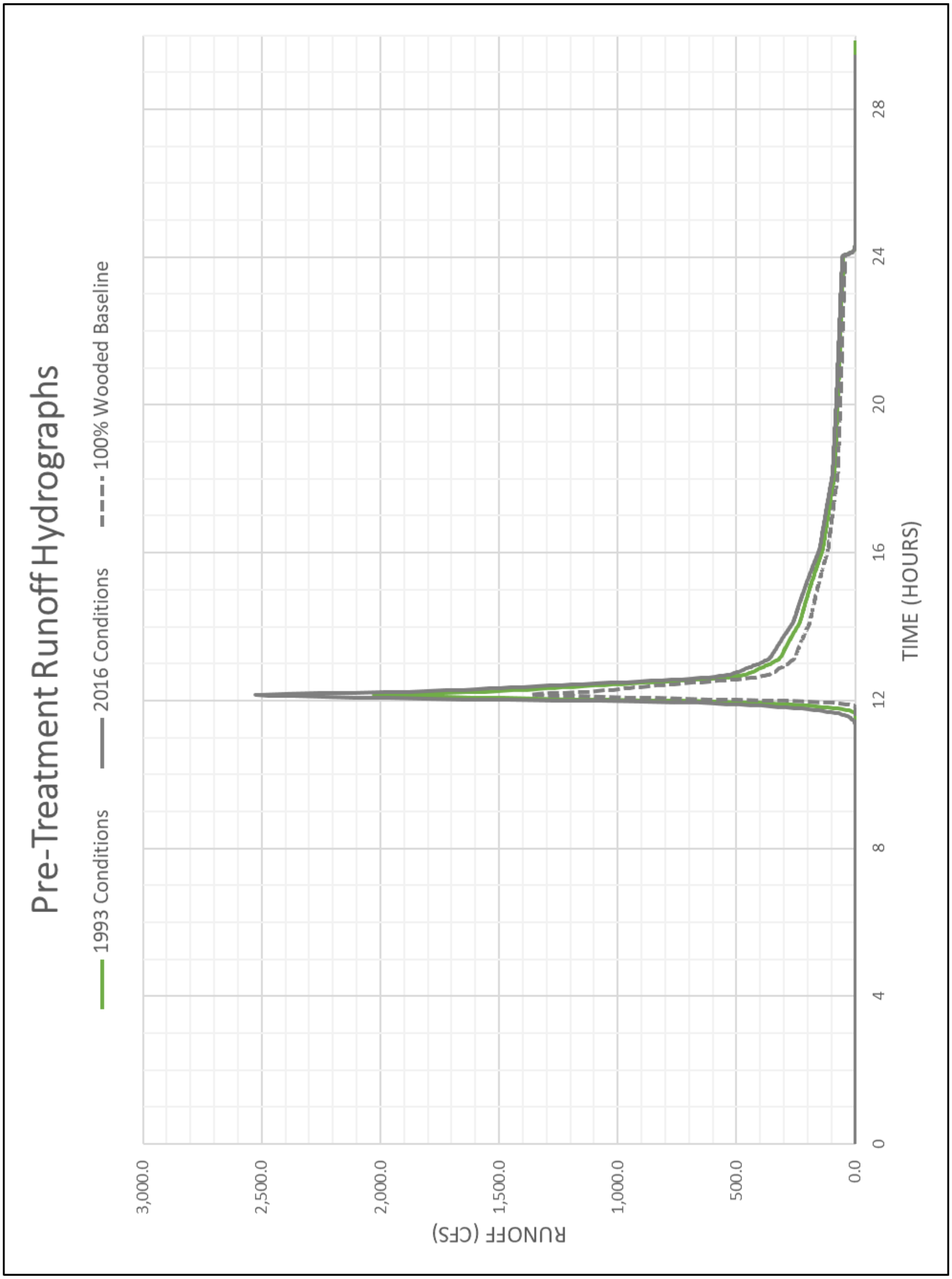


Figure 3-1. Hydrographs of the Carolina Beach Watersheds

4 Goals and Management Measures

The Carolina Beach Watershed partners seek to utilize various stormwater reduction techniques to reduce the volume of stormwater runoff reaching coastal waters. The target volume reduction goal is 11,121,962 gallons or 34.13 acre-feet during a 1-year, 24-hour event to reach 1993 water quality conditions. Volume reduction will be achieved by:

(1) Tallying the volume that is currently being collected by existing stormwater retrofit (current projects are not included in the reduction estimate);
(2) Installing new targeted stormwater reduction projects in the watersheds;
(3) Engaging the community in plan implementation.

4.1 Goals, Objectives and Management Measures

The goal of this plan will be accomplished by combining cost-effective, high-yield strategies such as active groundwater management strategies as well as lot level and street-wide retrofit projects that reduce the impact of impervious surface by mimicking natural hydrology to reduce flooding, protect water quality, and provide the community with clean, usable waters. Over time, reductions in the volume of stormwater runoff will be achieved through implementation of this plan and will result in measurable water quality improvements. This restoration plan uses the innovative approach of reducing runoff volumes within the region's watersheds to reduce existing water quality impairments and restore water quality. As with other plans that incorporate this volume reduction philosophy, this plan emphasizes five restoration objectives to accomplish its goals (Table 4-1).

Table 4-1. The primary goal of the watershed management plan and the objectives.

Primary Goal ***Improve water quality in Carolina Beach watersheds and reduce permanent shellfish closures***	
OBJECTIVES	
1	New development, existing and redevelopment does not create additional water quality impairments.
2	Stormwater reduction techniques are applied on public properties.
3	The volume of stormwater runoff is reduced from existing private land uses.
4	Conduct periodic monitoring and review to ensure the goals and objectives of the plan are being met.
5	The community is educated about stormwater pollution and volume reduction needs and engaged in accomplishing the plan objectives.

4.1.1 Objective 1

This objective aims to ensure that new development and redevelopment do not produce additional water quality impairments to the watershed. Actions to achieve this objective include evaluations and potential modifications of existing local and state codes, ordinances and rules, to ensure adequate protection of water quality and existing uses for new development and redevelopment.

Objective 1. New development, existing, and redevelopment does not create additional water quality impairments.

Action #	Specific Action
1-1	The Town of Carolina Beach staff and Council will review existing town codes and ordinances to determine impediments to low impact stormwater designs for new development and redevelopment. The findings will be presented to the Town with any suggested amendments and discussion of any potential incentive plans.
1-2	The Town will determine the need for amendments to the current, locally adopted stormwater management program to supplement gaps in the state's stormwater program and the Town's needs to prevent further impairments from new and redevelopment projects. Some regulatory gaps identified thus far include: • Impairments resulting from existing development and redevelopment • Smaller projects not covered under the State's Stormwater Program • Oversight of installation and maintenance of State permitted systems
1-3	The North Carolina Coastal Federation will partner with the Town of Carolina Beach and Carolina Beach State Park to seek reclassification of the Cape Fear River Surface Waters between Carolina Beach State Park and Bald Head Island from Class SC waters to Class SB waters, to provide a higher level of protection for waters and their existing uses.

Appendix F includes an outline of potential stormwater incentive strategies that municipalities may utilize to encourage LID implementation, including model ordinance and codes worksheets.

4.1.2 Objective 2

The volume of stormwater runoff being transported over land to waterways needs to be reduced to restore water quality. The goal is to reduce the volume of stormwater conveyed to levels that occurred prior to the baseline year of 1993. By focusing one of the objectives on efforts at public lands and conveyance systems, the Town can demonstrate commitment to improving watershed health to the community.

Objective 2. Stormwater reduction techniques are applied on public properties.	
Action #	**Specific Action**
2-1	Identify feasibility of potential stormwater reduction measures at town streets, buildings, public beach accesses, parking lots, drainage systems, and other public properties. Prioritize retrofits at public buildings and properties that can serve as demonstration sites of stormwater retrofits.
2-2	Utilize town rights-of-ways to maximize stormwater reduction measures.
2-3	Evaluate existing stormwater systems on public properties for potential volume reduction enhancements, and if feasible, retrofit them to achieve volume reduction.
2-4	Secure funds for retrofits at public properties.
2-5	Incorporate, where practical, *Green Street Designs* (Appendix G) or similar low-impact design strategies into future capital improvements of the town.
2-6	Pursue strategy with state agencies to incorporate retrofits to state properties. Pursue strategies with N.C. Department of Transportation (DOT) to incorporate retrofits into the Carolina Beach highway/ roadway drainage system and that any new road upgrades or maintenance plans include plans for reducing runoff. Pursue additional strategies within Snows Cut Park and Boat Ramp/Parking lot, and Carolina Beach State Park to incorporate retrofits/restoration projects into annual parks planning to reduce polluted runoff and protect existing uses within the park.

4.1.3 Objective 3

This objective is intended to address existing stormwater runoff from private land use by identifying and promoting cost effective strategies private residences and businesses can incorporate.

Objective 3. The volume of stormwater runoff is reduced from existing private land uses.	
Action #	**Specific Action**
3-1	Identify retrofit sites with private partners, prioritizing sites by potential for volume reduction cost-benefit; such as sites identified as exceptional because of the physical and natural characteristics, accessibility, cost, public outreach opportunity, and current land uses.
3-2	Work with governmental agencies and NGOs to secure grants to provide funding to install lot-level, low-cost retrofits that disconnect impervious surfaces and enhance stormwater infiltration.
3-3	Seek funding for stormwater retrofit projects that have been identified.
3-4	Provide landowners incentives to disconnect impervious surfaces or minimize stormwater runoff from their property.
3-5	Explore opportunities for partnerships and technical assistance with N.C. Soil and Water Conservation's Community Conservation Assistance Program (CCAP).

4.1.4 Objective 4

Accomplishing the actions in this plan requires monitoring of performance of the plan and projects that are implemented. Progress made in achieving water quality improvements will be measured. This plan will be updated as necessary based upon the results of this monitoring.

Objective 4. Conduct periodic monitoring and review to ensure the goal and objectives of the plan are being met.	
Action #	**Specific Action**
4-1	Monitor ongoing water quality monitoring by NC Division of Shellfish Sanitation, NC Division of Marine Fisheries, as well as 3-year Shellfish Sanitation Sanitary Report data, and current/future 303 (d) and 303 (b) listings of impaired waters (U. S. Environmental Protection Agency.
4-2	Review the plan every three years to evaluate findings from water quality data and the status of implementation. Conduct scheduled assessment of the plan and progress made to date with the project team.
4-3	Maintain a simple inventory of retrofits and monitor performance of stormwater reduction retrofits that have been installed within the watersheds.
4-4	Document the volume of stormwater reduced by each retrofit by utilizing the *Runoff Reduction Calculator Tool* or *Watershed EZ*, or similar volume reduction calculation tools.
4-5	Coordinate with academic partners, such as UNCW, Cape Fear Community College, NCSU and others to conduct periodic monitoring of water quality and supporting research efforts.
4-6	Explore opportunities to utilize community members to conduct citizen science-based monitoring of stormwater reduction retrofits and inventory installed retrofits.

4.1.5 Objective 5

Community education will be a necessary component to achieving the primary goal of this plan. Education of all members of the community including residents, property owners, developers and others can help ensure understanding of the issues and need for action.

Objective 5. The community is educated about stormwater pollution and volume reduction needs and engaged in accomplishing the plan objectives.	
Action #	Specific Action
5-1	Collaborate with partners to educate and engage property owners, businesses, and K-12 students and their families on stormwater management. For example, facilitate the circulation of *Smart Yards*, a stormwater retrofit education guide for homeowners created by the North Carolina Coastal Federation via Town websites, inclusion in water bills, etc.
5-2	Facilitate technical training opportunities for planners, engineers, developers, landscapers and local government staff on techniques to reduce volume of stormwater within the town.
5-3	Partner with existing water quality outreach professionals, including: North Carolina Coastal Federation, Carolina Beach State Park, NC Department of Environmental Quality, New Hanover County Stormwater Program, N.C. Soil and Water Conservation's Community Conservation Assistance Program (CCAP), UNCW, etc. on stormwater education initiatives.
5-4	Include education signage at existing and new retrofits, with an emphasis on the importance of stormwater management for coastal water quality, and an emphasis on highlighting the Town's commitment to reducing polluted stormwater runoff.

4.1.6 Management Strategies

Reducing the volume of runoff by approximately 11,121,962 gallons from a 1-year, 24-hour storm event will require management strategies that enhance the ability of the landscape to infiltrate stormwater. The non-regulatory “natured based” management strategies within this section seek to identify potential retrofit opportunities based on the information compiled during the development of this restoration plan. The number one priority is to find ways to make the landscape infiltrate as much stormwater as practical.

Conventional Stormwater Control Measures (SCM) listed in the Table 4-2 are ranked based upon their effectiveness in lowering fecal coliform bacteria in impaired coastal waters. Approximate construction and annual costs of these measures are listed as well.

Table 4-2. Conventional SCM Performance for Bacteria Reduction on HSG Type ‘A’ Soil [a]

Practice	Removal of Bacteria	% Annual RO Eliminated (ETI) [d]	Approximate Annual Cost Per-Acre Treated ($/Ac/Yr)
Rainwater Harvesting [c]	Good - Excellent	<100%	
Bioretention w/IWS [b]	Excellent	85%	$700 - $870
Silva Cell	Excellent	85%	
Infiltration	Excellent	84%	$330 - $450
Permeable Pavement, Infiltrating [b]	Excellent	84%	
Green Roof	Good	60%	
Disconnected Impervious Surface	Good	58%	
Level Spreader-Filter Strip	Poor	54%	$500 - $1,150
Wet Grass Swale	Poor	36%	$360 - $420
Stormwater Wetland	Good	34%	$225 - $350
Dry Grass Swale	Poor	22%	$360 - $420
Wet Pond	Fair	21%	$460 - $560
Sand Filter, Open	Good	9%	$2,500 - $2,600
Dry Pond	Poor	8%	$460 - $560

[a] Values for practices designed per DEMLR Minimum Design Criteria (15A NCAC 2H .1000) unless stated otherwise.

[b] Design variants available w/performance estimated by Hyper Tool.

[c] All designs are custom w/performance estimated by Rainwater Harvesting Tool.

[d] DEMLR Stormwater Control Measure Credit Document and as calculated by DWR SNAP Tool v 4.1.

In addition to these individual on-site SCM measures, the Town is also pursuing active management of groundwater levels in low-lying public areas and neighborhoods with seasonally high groundwater tables. It has developed an active pumping system that will lower water levels in Carolina Beach Lake to benefit the residential area of town that experiences chronic flooding. The system is designed to draw down the water level prior to significant rainfall events, and to direct to and treat that pumped water within the town's existing retention ponds located within the MOTSU territory, away from residential properties.

Specific project selection to install SCMs will be based on field assessments that include site feasibility, site specific soils, proximity of project to impaired waters and project costs. Figure 4-1 shows the location of 56 potential sites where SCMs can be used. These sites have been evaluated based upon the soil types where they are located, the type of retrofit they will require and/or accommodate, factors affecting the efficacy and engineering potential for a successful project, stormwater volumetric reduction potential, and their proximity to shellfish growing waters.

Table 4-3 provides an individual brief list of these sites. Table 4-4 provides a more detailed listing of highest priority project sites, along with a brief description of the potential SCM and other relevant factors.

Table 4-3-List of potential SCMs for Town of Carolina Beach

Site No.	Potential Retrofit/Project
1	Living Shoreline
2	Alabama Beach Access Parking Lot - Pervious Pavement, Modified Landscape Areas
3	Alabama East Beach Access Parking Lot - Pervious Pavement, Infiltration
4	Ocean Blvd Beach Access Parking Lot - Pervious Pavement, Infiltration
5	Shell Lot - Infiltration Basin
6	Hamlet Beach Access Parking Lot - Infiltration Basin, Pervious Pavement
7	Bank of America - Potential Site
8	TOCB Infiltration Basin
9	TOCB Town Hall - Cisterns, Pervious Pavements
10	Community Center - Rain Barrels
11	Cape Fear Street Scape
12	S 3rd to Lake Drive - Wetland Conservation / Land Acquisition
13	CB Lake Parking Lot - Pervious Pavement
14	CB Lake - Rain Barrels, Pervious Pavement
15	Sandpiper to Sand Dollar - Dune Infiltration
16	Street End Parking - Infiltration Basin
17	Street End Parking - Infiltration Basin
18	Street End Parking - Infiltration Basin
19	Street End Parking - Infiltration Basin
20	Street End Parking - Infiltration Basin
21	Methodist Church - Pervious Pavement / Rain Garden
22	Potential Demonstration Site - Rain Garden
23	Potential Demonstration Site - Rain Garden / Barrel
24	Dow Rd - Street Sides Swales
25	Good Hops - Potential Re-route of stormwater
26	Potential Infiltration / Swale from Ocean Heights
27	Intersection of Bridge Barrier / Old Dow Rd streetside swales
28	State Park / Living Shoreline ?
29	1500 Bridge Barrier/ State Park swales, infiltration
30	8th St- Pervious Pavement
31	Mike Chappel & Clarendon - Pervious Pavement
32	Mike Chappel Park Concession & Soccer Field- vegetated swales, rain gardens
33	Parking swales, pervious strips, signs
34	Rain garden, pervious pavement for demo
35	Rain garden, demo sign
36	Rain garden, demo sign
37	Rain barrel, cistern, demo signs
38	Rain garden, pervious pavement, signs
39	Rain barrel
40	Plant, elevation in swale
41	Plant, elevation in swale
42	Parking swale
43	More elevation in swales
44	Curb cuts, swales, trees
45	Rain garden, demo signs

46	Cistern
47	Gutters to swale
48	Rain barrel, garden, demo signs
49	Swales, berms guiding away from river
50	Rain barrel, swale
51	Reduce pavement, median, native plants
52	Bumper/berms/infiltration basin
53	Existing Boat ramp, living shoreline, riparian buffer
54	Bumper, infiltration swales
55	CBSP Tidal Creek/Marsh Restoration
56	CBSP Oyster Reef/ Living shoreline restoration

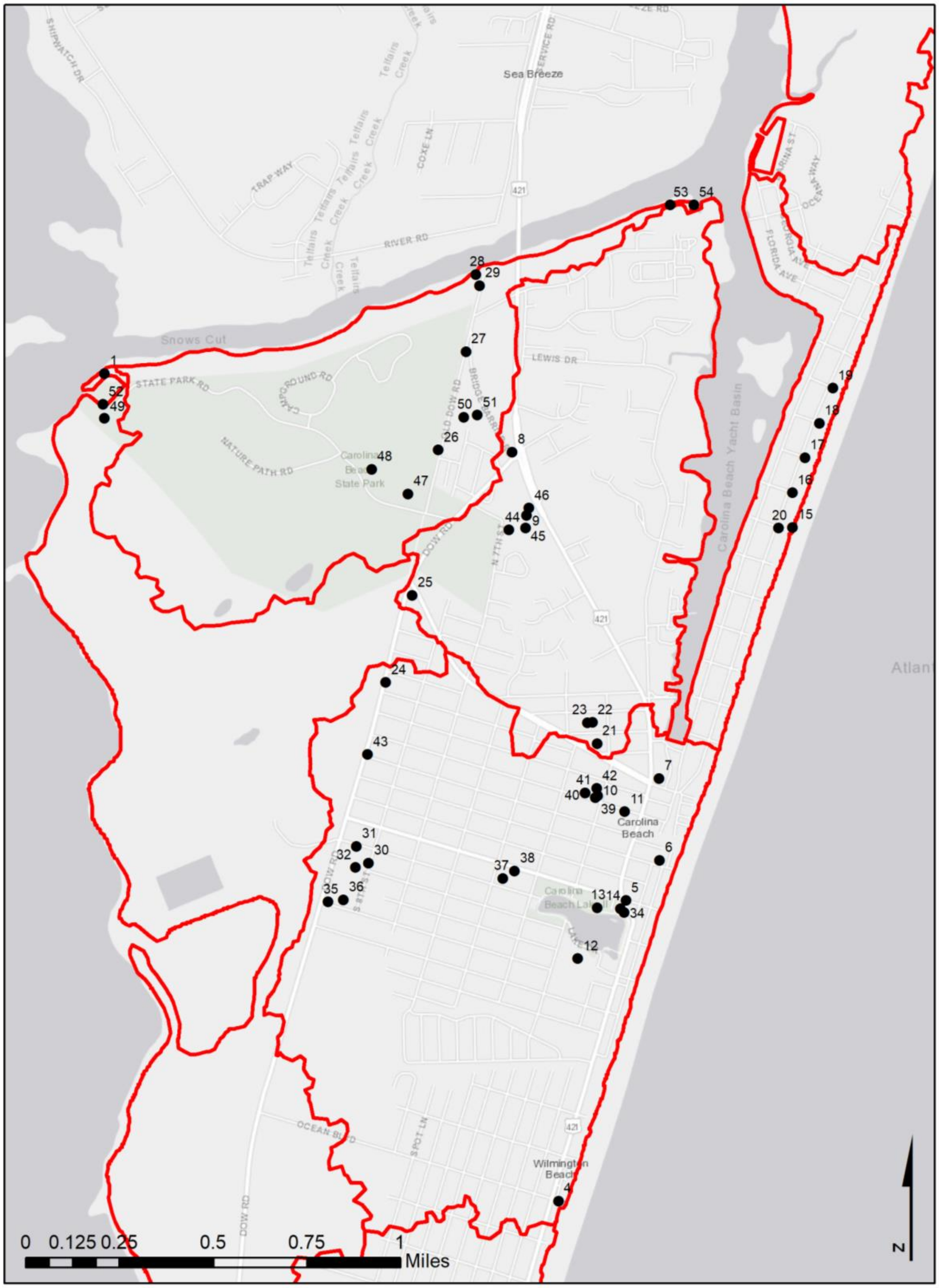


Figure 4-1. Map of Potential SCMs for the Town of Carolina Beach.

Table 4-4. Listing and description of high priority stormwater management projects/sites that can be installed in the Town of Carolina Beach to reduce runoff volumes from specific properties. These sites contribute large amounts of stormwater runoff in their current condition, and represent high potential to significantly reduce the volume of runoff and improve water quality.

Site No.	Description
15-20	**Sites 15-20 Infiltration Basins on Carolina Beach Avenue North:** The Town will be budgeting for the 2020/2021 year to resurface the length of Carolina Beach Avenue-North, which is currently in need of repair. To allow for the future installation of stormwater infiltration systems on the beach side street ends at these locations, catch basins could be installed during the paving process. Pipes can be stubbed out of the basins to the east, which would allow for connection of the infiltration systems, as funding is appropriated. Installation of engineered infiltration systems in this area would provide a significant reduction of runoff that currently sheet flows to the stormwater outfall basins on Cana Drive, which will reduce polluted stormwater runoff and could potentially reduce flooding issues within this corridor. **Sites 26-27 Old Dow Road:** Road side swales along Old Dow Road would allow for containment and infiltration of stormwater runoff from Old Dow and Snow's Cut Path, which both represent a substantial amount of impervious coverage and associated stormwater runoff. As an added high priority measure, the infiltration swales associated with the Ocean Heights area (to be installed in 2020) could be connected to this swale to allow for increased stormwater containment and infiltration. **Sites 24-26 Dow Road**: As a potential partnership between the Town of Carolina Beach and NCDOT, road- side swale areas along Dow Road would allow for treatment of stormwater from the impervious asphalt of this section of road as well as providing relief of current drainage and flooding issues from detrimental runoff onto the properties to the east. **Sites 13-14 Lake Park:** Upon completion of the CB Lake dredge project and the potential implementation of the Lake Park Masterplan, stormwater infiltration could be improved through construction of pervious pavement in place of traditional asphalt in the areas that surround the catch basins that feed into the Lake. This would improve the water quality by reduction of existing runoff and allow for a widely received source of public education for park patrons. **Site 12 Land Acquisition South of Lake:** Wetland areas south of the lake are decreasing through growth and development. Land acquisition, in combination with properties previously donated to the Town would allow the possibility of a wetland park in this location. Preserving wetlands in this area is important for protecting water quality, reducing flooding through water storage, maintain critical habitats, and providing a highly visible public space and educational area to educate visitors on the many values of wetlands in our coastal environment.
53-54	**Sites 53-54 Snows Cut/WRC Boat Ramp and Parking Lot:** In partnership with the NC Division of Wildlife Resources, this existing boat ramp and impervious parking lots provide a high priority opportunity to install SCMs, potentially including pervious pavement, vegetated swales/rain gardens and infiltration

	basins. These measures would significantly reduce polluted stormwater runoff from this site, which is located in close proximity to remaining open shellfish waters in Watershed 1 to the northeast of Snows Cut.
27,28 29,51	**Sites 27, 29, 51 Bridge Barrier Road/Snows Cut State Park Land:** In partnership between the Town of CB, Carolina Beach State Park, and the US Army Corps of Engineers, several priority opportunities exist to reduce polluted stormwater runoff along Bridge Barrier Road between its intersection with Old Dow Rd. and the terminus at Snows Cut. These could include streetside swales, bio retention areas, a living shoreline project and increase native plantings.
1,49, 52	**Sites 1, 49, 52 Carolina Beach State Park (CBSP) Marina:** In partnership with CBSP, opportunities exist to reduce polluted stormwater runoff currently generated from the state park marina and adjacent parking lot. High priority measures could include vegetated swales and berms, an infiltration basin, and a living shoreline project. **Sites 31, 32 Mike Chappel Park/Clarendon:** This park area includes various opportunities to capture and infiltrate stormwater runoff and provide educational through demonstration and signage in a heavily visited park. Potential measures include pervious pavement, rain gardens, streetside swales, and cisterns. **Sites 55-56 Carolina Beach State Park (CBSP):** In partnership with Carolina Beach State Park and the North Carolina Coastal Federation, restoration of 13 acres of tidal marsh and the implementation of up to 5 acres of oyster reef and living shorelines has been planned, for ecological restoration and water quality protection. Funding has been requested for this project, proposed for implementation in 2021-2023.

5 Technical and Financial Assistance and Management Costs

In accordance with the EPA minimum measures guidelines, the Town expects to implement the plan in short term (<3 years) mid-term (years 4-6) and long-term (years 7-10). Using past experience, municipalities generally require about three years to identify, plan, fund, design, permit and then build a suite of SCMs that can infiltrate somewhere between 300,000 gallons and 1 million gallons of runoff from a one-year, 24-hour storm. The Town projects that the total cost of these measures for each three-year period will run between $300,000 to $2 million, depending on site conditions, complexity of design and other factors that influence final cost figures. The Town could incorporate costs for these measures into short and long-term infrastructure planning and maintenance budgets, and can also actively seek outside financial support to help pay for these measures. Most outside grants require, at a minimum, it must be prepared to cover matching cost requirements for these funds. These matching requirements can be as high as 50 percent of project costs. As the Town becomes more proficient in installing these measures, it will seek to do as much of the work itself using its own town public works and administrative employees, which can also be used to leverage more outside grant funding. The costs of this in-house labor and equipment are included in the cost estimates outlined above to implement this plan.

Presently, technical needs for all projects include the need for engineering services, skilled construction expertise for technically difficult projects, surveying needs, and assistance with securing grants and loans. Town officials have engaged in continuing education to learn more about stormwater management, including design, operation and maintenance requirements. Additional technical needs include the development of project partnerships with state agencies, local organizations, or academia professionals who can provide expertise. The Maintenance Schedule column of Table 5-1 should be taken into consideration as part of the technical considerations of the plan as maintenance requires forethought to ensure funding and technical skills are available for the duration of the life cycle of the projects. Table 5-1 should be taken into consideration when determining maintenance costs of each project. Other various project-based needs include receiving advanced knowledge of groundwater conditions. The Town will continue to rely on Shellfish Sanitation and the UNC Institute of Marine Sciences for water quality and fisheries data and studies it will need to determine if the plan is successful.

Table 5-1. Approximate cost per unit of various stormwater retrofit techniques.

Stormwater Retrofit Technique	Approximate Cost per Unit[3]	Maintenance Cost[3]
Amend Soil	\$15-\$60 per cubic yard	\$.02 per cubic yard
Curb Cuts	\$5-\$25 per ft^2	\$.30-\$.60 per ft^2
Bioswale (for parking lot or roadside)	\$6-\$24 per ft^2	\$.06-\$.21 per ft^2
Native Plants	\$.02-\$.15 per ft^2	\$.03-\$.08 per ft^2
Permeable pavement	\$5-\$12 per ft^2	\$.01-\$.22 per ft^2
Planter Boxes	\$.55-\$24 per ft^2	\$.04-\$1 per ft^2
Rain garden	\$5-16 per ft^2	\$.30-\$.60 per ft^2
Rainwater harvesting	\$200/rain barrel \$1,000/1400-gal cistern \$10,000/10,000-gal cistern	\$0 \$0 \$0
Reroute downspout	\$9/downspout	\$0
Tree Box Filter	\$70-\$600 per ft^2	\$3-\$14 per ft^2
Trees	\$100-400 each	\$20 each
Vegetated Filter Strips	\$.03-\$3.33	\$.07 per ft^2

Note: Estimations from Green Values National Stormwater Management Calculator[3] based on national averages.

[3] Cost average approximation derived from:
Green Values Stormwater Calculator. (2016). Center for Neighborhood Technology. Retrieved from http://greenvalues.cnt.org/national/cost_detail.php

6 Education and Outreach

6.1 Public Understanding

The targeted audience of education and outreach for the community, which include residents of the watershed, business owners and K-12 students. Partnerships with public schools are an effective means of engaging the community and implementing education and outreach objectives. The area has a mixture of renters and homeowners residing within its boundaries. Residents, whether renting or homeowners, can be encouraged to understand how their homes and properties contribute to the water quantity and quality of the watersheds. This information can potentially be disseminated to residents through the following techniques, further research and collaboration with environmental educators should be considered before beginning an outreach project:

- Distribution of the *Smart Yards* informational booklet developed by the North Carolina Coastal Federation. The *Smart Yards* booklet can be mailed directly to all residents or can be made available at public buildings like the Town Hall, linked to Town websites, included as information sheet in public utility bills and/or other mail/email communications.
- Presentations on residential solutions at public town meetings on a regular basis and through utilization of social media outreach opportunities.
- Encourage residents to attend or participate in project demonstrations and installation at public buildings to learn how to install retrofits.
- Install educational signs about stormwater runoff at public areas.
- Outreach to subdivision homeowner's associations to encourage stormwater and water quality education and disconnecting impervious surfaces.

6.1.1 Businesses, Developers, and Commercial Land Owners

There are many businesses and commercial landowners within the area. Commercial areas account for some of the largest continuous, non-disconnected areas of impervious surfaces. Businesses could be encouraged to participate in retrofits at public and commercial properties. Education and outreach to businesses, developers, real estate agents, landscapers, and commercial landowners can focus on the disconnection of impervious surfaces, capital improvements, and LID techniques for new development. Various methods could be used to educate the business community; examples include:

- Encourage businesses to host *Smart Yards* or other stormwater information for distribution to the community.
- Meet with businesses to encourage participation and discuss potential retrofits that align with their capital improvement plans.
- Conduct meeting for businesses and commercial land owners to educate them on stormwater issues and to promote LID techniques.

- Encourage businesses, developers, and others to attend *Low Impact Development for Water Quality Protection Workshop*, hosted by NC Coastal Reserve, or similar workshops that educate attendees on stormwater management solutions.
- Invite businesses to participate or sponsor events, such as stormwater retrofit installations, to encourage community involvement and cooperation.
- Encourage those who are interested in retrofits that increase green space and permeable surfaces. Retrofits can vary from small-scale solutions like planting shade trees, installing box planters or installing rain gardens to large-scale solutions like converting retention ponds into constructed wetlands.
- Encourage businesses with large parking lots to remove curbed medians and replace them with rain gardens, swales, or permeable pavement.
- Encourage businesses to install signs of their retrofit accomplishments. Create a recognition award for those who install retrofits.

6.1.2 K-12 Students

Water quality education for students is not only beneficial for the long-term integrity of the watershed but for North Carolina. Education and outreach to students can focus on stormwater, water quality, and non-structural retrofit lessons that students can relay to their families or strategies they can implement at their homes. Students can be encouraged to understand their role within the watersheds. Collaboration with environmental educators should be considered before beginning an outreach plan:

- Development of age appropriate lessons associated with demonstration sites in the watershed.
- Encourage class participation in the installation of rain gardens, downspout disconnection, and other retrofit techniques as service projects or field trips.
- Present an article in the school’s newsletter for parents to encourage family discussion.

7 Implementation Schedule

Carolina Beach will work with partners to implement the goals, objectives, actions and management strategies identified in this watershed restoration plan.

Based on the Plan’s stated Goals and Objectives, 7.1 provides an overview of the associated implementation actions and timelines that will be pursued from Year 1 through Year 10 for the Pl.

Table 7-1. Overview of General Implementation Schedule.

Actions	Timeframe
1-1 The Town of Carolina Beach staff and Council will review existing town codes and ordinances to determine impediments to low impact stormwater designs for new development and redevelopment during year one. *The findings will be presented to the Town with any suggested amendments and discussion of any potential incentive plans.*	Year 1-2
1-2 The Town will determine the need for amendments to the existing locally adopted stormwater management program to supplement gaps in the state's stormwater program and the Town's needs.	Year 1 - 2
2-1 Identify feasibility of potential stormwater reduction measures at town streets, buildings, public beach accesses, parking lots, drainage systems, and other public properties. Prioritize retrofits at public buildings and properties that can serve as demonstration sites of stormwater retrofits. *This will begin with planning around highest priority SCMs identified within Table 4-4. These will be targeted for phase I funding. Remaining projects will be reviewed annually for annual grant applications for implementation. See milestones section for detailed timeline.*	Year 1, Annually
2-2 Utilize town right-of-ways to maximize stormwater reduction measures. *This is a priority of the town and builds on a commitment to reduce roadside runoff. Secure funding Year 1, implement phase 1 project year 2, monitor and promote year 3, secure additional funding year 3 until feasible ROWs in town are retrofitted throughout the duration of the planning period.*	Monthly, Annually
2-3 Evaluate existing stormwater systems on public properties for potential volume reduction enhancements, and if feasible, retrofit them to achieve volume reduction. *This evaluation will be discussed at project team meetings with specific plans for enhancements determined.*	Year 1, Annually as Part of Prioritization of Retrofits
2-4 Secure funds for retrofits at public properties. *Annually apply for funding to install retrofits from sources such as NCDEQ (319) and CWMTF and CCAP programs.*	Annually
2-5 Incorporate, where practical, *Green Street Designs* or similar low-impact design strategies into future capital improvements of the town. *This will be matched with annual Capital Improvement Planning and utilized when feasible.*	Year 1, annually
2-6 Pursue strategy with state agencies to incorporate retrofits at state properties. Pursue strategies with N.C. Department of Transportation (DOT) to incorporate retrofits into any new road upgrades or maintenance plans include plans for reducing runoff. *The Town will build the existing relationship with N.C. DOT to identify and pursue funding and support for retrofits in the linear system.*	Year 1, annually

3-1 Identify retrofit sites with private/public partners, beginning planning around the highest priority sites identified in Table 4-4. *Other potential projects will be reviewed annually for grant applications for implementation.*	Year 1, Annually
3-2 Work with governmental agencies, university partners, community partners, and NGOs to secure grants to provide funding to install lot-level, low-cost retrofits that disconnect impervious surfaces and enhance stormwater infiltration. *Grant applications will be identified annually. Bringing in project partners will help strengthen application interest.*	Year 1, Annually
3-3 Seek funding for stormwater retrofit projects that have been identified. *Annually identify funding to install retrofits from sources such as NCDEQ (319), CCAP and CWMTF.*	Annually
3-4 Provide landowners incentives to disconnect impervious surfaces or minimize stormwater runoff from their property. *This will begin with education and outreach during the first quarter of plan implementation. Project partners will help identify the potential for incentives to disconnect during second and third quarter.*	Year 1, annually
3-5 Explore opportunities with N.C. Soil and Water Conservation's Community Conservation Assistance Program (CCAP). *The project team will match up potential private landowner or public site retrofit projects with this annual cost share program to attempt to fund small scale retrofits.*	Year 1, annually
4-1 Monitor Shellfish Sanitation Sanitary Report data as reports are produced. *The Town will review the Shellfish Sanitation Reports as they are produced every 3 years.*	Year 3, 6, 10
4-2 Review the plan every three years to evaluate findings from water quality data and the status of implementation. Conduct scheduled assessment of the plan and progress made to date with the project team. *This will take place at project team level and include town council and members of the public. This will occur every 3 years beginning in 2022.*	Year 3, 6, 10
4-3 Maintain a simple inventory of retrofits and monitor performance of stormwater reduction retrofits that have been installed within the watersheds. *The Town will keep an ongoing inventory of retrofits as they are installed.*	Year 2, 4, 6, 8, 10
4-4 Document the volume of stormwater reduced by each retrofit by utilizing the *Runoff Reduction Calculator Tool* or *Watershed EZ*, or similar volume reduction calculation tools. *Documentation will be prepared utilizing tools and outreach on the reduction will take place immediately following the implementation of individual projects by the Town and other project partners*	Year 2, 4, 6, 8, 10
4-5 Coordinate with academic partners, such as UNC-W, CFCC, to conduct periodic monitoring of water quality. *The Town will actively coordinate with academic partners to identify opportunities monitoring.*	Year 2, 4, 6, 8, 10

4-6 Explore opportunities to utilize community members to conduct citizen science-based monitoring of stormwater reduction retrofits and inventory already installed retrofits. *The project team will identify the potential for citizen – science monitoring as part of the grant application process that will occur about every 1-2 years.*	Year 2, 4, 6, 8, 10,
5-1 Collaborate with partners to educate and engage property owners, businesses, and K-12 students and their families on stormwater management. For example, facilitating the circulation of Smart Yard, a stormwater retrofit education guide for homeowners by N.C. Coastal Federation. *An annual community education and engagement strategy will be developed and implemented via the Town and community partners. This strategy will be developed year one of Plan implementation discussed annually.*	Year 1, annually
5-2 Facilitate technical training opportunities for planners, engineers, developers, landscapers and local government staff on techniques to reduce volume of stormwater within the town. *The Town will work with project team to determine annual opportunities for trainings then work plan events approximately every two years.*	Year 2, 4, 6, 8, 10
5-3 Work with existing water quality outreach professionals, including: North Carolina Coastal Federation, UNC – W, New Hanover County, CFCC, etc. on stormwater education initiatives. *The Town will build on existing collaborations with academia and NGOs in New Hanover County to identify, develop and offer education initiatives in the Town and County.*	Year 2, 4, 6, 8,
5-4 Include education signage at select retrofits and place emphasis on highlighting the town's commitment to reducing stormwater. *The Town will work with the Coastal Federation to develop signs utilizing outreach funding that is secures as part of retrofit implementation funding.*	Year 2, 4, 6, 8, 10

Implementation of SCMs

Site specific stormwater retrofit selection will be based on additional field assessments that include determination of site feasibility, site specific soils, proximity of project to impaired waters, engineering considerations, and project costs. Implementation of each strategy will involve the following steps and timeline.

First 6 months– year one - *review site for feasibility, rank priority based on soils, impaired waters, infiltration potential, general engineering considerations, projected costs, approving partners and level of difficulty (see Section 5)*

Year one – *Apply for funding for prioritized sites in accordance with RFP schedule.*

Years one- two – *Funding secured, begin outreach and design phase of project*

Years two - three – *Construct, monitor, engage community and promote success*

Years four-ten- *Repeat management strategy funding and implementation steps*

8 Interim Milestones

Milestones are measurable accomplishments utilized to track positive changes and success of the plan. It is recommended that milestones are evaluated during the annual plan review to assess the status of the Plan milestones, and determine the cause and the appropriate steps that can be taken to address any shortcomings or unforeseen circumstances. The milestones for restoring water quality through volume reduction of surface runoff are:

8.1 Short-Term (< 3 years)

- Reduce at least 600,000 gallons of stormwater runoff that occurs during a one-year, 24-hour storm event through the implementation of stormwater reduction techniques that have already been identified and prioritized by the Town (Objective 2 and 3).
- Review development ordinances and revise as needed to ensure that new development and redevelopment does not create additional water quality impairments (Objective 1; Actions 1-1 to 1-3).
- Identify potential new stormwater reduction measures that can be installed during years 4 to 6 years of the plan will reduce stormwater runoff by another 400,000 gallons for the design storm (Action 2-1).
- Ensure, when/where practical, *Green Street Designs* or similar low-impact design strategies are regularly incorporated into future capital improvements (Action 2-5).
- Review ongoing water quality monitoring reports/data, 303 (d) and 305(b) reports, and Shellfish Sanitation triannual report and evaluating the plan for any needed changes. (Actions 4-1 and 4-2).
- Develop a simplified inventory of retrofits that have already been installed (Action 4-3).
- Create and maintain an educated and engaged community (Goal 5).

8.2 Mid-Term (4 to 6 years)

- Reduce at least 400,000 gallons of stormwater runoff that occurs during a one-year, 24-hour storm event through the implementation of stormwater reduction techniques (Objectives 2 and 3).
- Identify potential new stormwater reduction measures that can be installed during years 7 to 10 years of the plan will reduce stormwater runoff by another 350,000 gallons for the design storm (Action 2-1).
- Ensure ongoing actions, such as Action 5-2, continue to be supported (Objective 5).
- Review Shellfish Sanitation triannual report and evaluate the plan for any needed changes (Actions 4-1 and 4-2).

8.3 LONG-TERM (7 TO 10 YEARS)

- Reduce at least 350,000 gallons of stormwater runoff that occurs during a one-year, 24-hour storm event through the implementation of stormwater reduction techniques (Objectives 2 and 3).
- Identify potential new stormwater reduction measures that can be installed during long term years of the plan to reduce stormwater runoff by another 300,000 gallons for the design storm (Action 2-1).
- Review Shellfish Sanitation triannual reports and evaluating the plan at year 25 and year 30 (Actions 4-1 and 4-2).
- Accomplish all actionable Actions in Objectives 1-5.

9 Progress Criteria

To ensure that the plan is meeting the needs of the watershed and community, the management plan should be evaluated every three years when Shellfish Sanitation issues its new Sanitary Survey for the Town. The Town will track progress on plan implementation by maintaining an inventory of SCMs it installs, a cumulative total of reductions in stormwater runoff achieved by the projects it installs, and by reviewing the status of shellfish closures (acres of permanently closed waters, and number of days each year temporary closures of waters occur. In addition, the town will maintain a log of its emergency pumping operations to keep records on gallons pumped, costs of pumping, and days that pumping results in automatic closures of shellfish waters.

Table 9-1. Evaluation of the Town of Carolina Beach Watershed Management Plan.

Evaluation	Indicator
Calculate the approximate volume reduced by stormwater retrofits that are installed	Utilize *Watershed EZ*, *Runoff Reduction Calculator*, or similar tool to determine a volumetric total of projects installed.
Mid-course evaluation	Conduct full assessment of plan with suggestions on ways to enhance or redirect the plan
Publicize successes	Update community on successes to increase commitment, motivation, and morale. Publish report on watershed health. Recognize past, current and future projects for the year.

Ultimately, the success of this plan will be determined by whether impairments of shellfish waters are reduced, and whether recreational water quality is maintained at healthy levels. This will be determined by the Sanitary Survey that is completed by Shellfish Sanitation every three years, and the extent of permanent and temporary shellfish harvest closures that are required. It is projected that it will take approximately 20 years to fully reduce the volume of runoff by approximately 2.5 million gallons. These reductions in the volume of stormwater runoff will occur incrementally with SCM projects that will each take about three years to plan, design, fund and construct. The Town will work in three year increments, and has set volume reduction goals for each of these three-year time periods.

As the volume of stormwater is reduced, the Town expects to see two outcomes in terms of impaired water quality. The extent of permanent closures in shellfish waters surrounded Carolina Beach will begin to shrink. It is expected that the rate of reduction of impairment will roughly correlate with the percent of the 2.5-million-gallon reduction goal that is achieved. In addition, the number of temporary closures should go down as the number of days that the Town is forced to pump stormwater due to emergency conditions is reduced.

10 Monitoring

Shellfish Sanitation and Recreational Water Quality sections of the Division of Marine Fisheries (DMF) is responsible for monitoring the bacteria levels in coastal waters and has the authority to close waters to shellfishing and issue swimming advisories when bacterial levels are unacceptable. Every three years Shellfish Sanitation staff ground truth the entire shoreline of shellfish growing areas to document current and potential pollution sources. The data collected by Shellfish Sanitation is publicly available and is a source of historical and present-day information regarding water quality of an area. These up-to-date surveys and monitoring station data will be the primary source of information. Monitoring will be conducted by using the indicators listed in Section 5.

Table 10-1. The primary water quality indicators and how to measure the indicators (Shellfish Sanitation, 2016).

Primary Indicators

Reduce stormwater runoff volume to restore water quality

	Indicator	Measured by	Collected by	Collection Cycle
1	Fecal Coliform	Comparing numerical historical data and modern measurements of fecal coliform for changes in impairment frequencies and quantity of bacteria per sample.	Shellfish Sanitation	Yearly; reports released every 3 years.
2	Stormwater Runoff Volume	Applying stormwater reduction techniques and determining how much stormwater is reduced by the techniques; these measures should attempt to reduce current stormwater runoff volume to the levels of the baseline year.	Partners	Upon completion of projects.

Table 10-2 provides a list of existing water monitoring stations in the area of Carolina Beach, identified through N.C. Shellfish Sanitation.

Table 10-2. Water quality monitoring stations (Shellfish Sanitation, 2019).

Waterbody	Station Name	Station No	Organization
Snows Cut	Old Bridge	4	N.C. Shellfish Sanitation
Snows Cut	Marker #161	5	N.C. Shellfish Sanitation
Intracoastal Waterway	Marker #159	6	N.C. Shellfish Sanitation
Intracoastal Waterway	Marker #157	7	N.C. Shellfish Sanitation
Myrtle Grove Sound	400 Yards East of Marker #159	30	N.C. Shellfish Sanitation

Water Quality Monitoring Stations

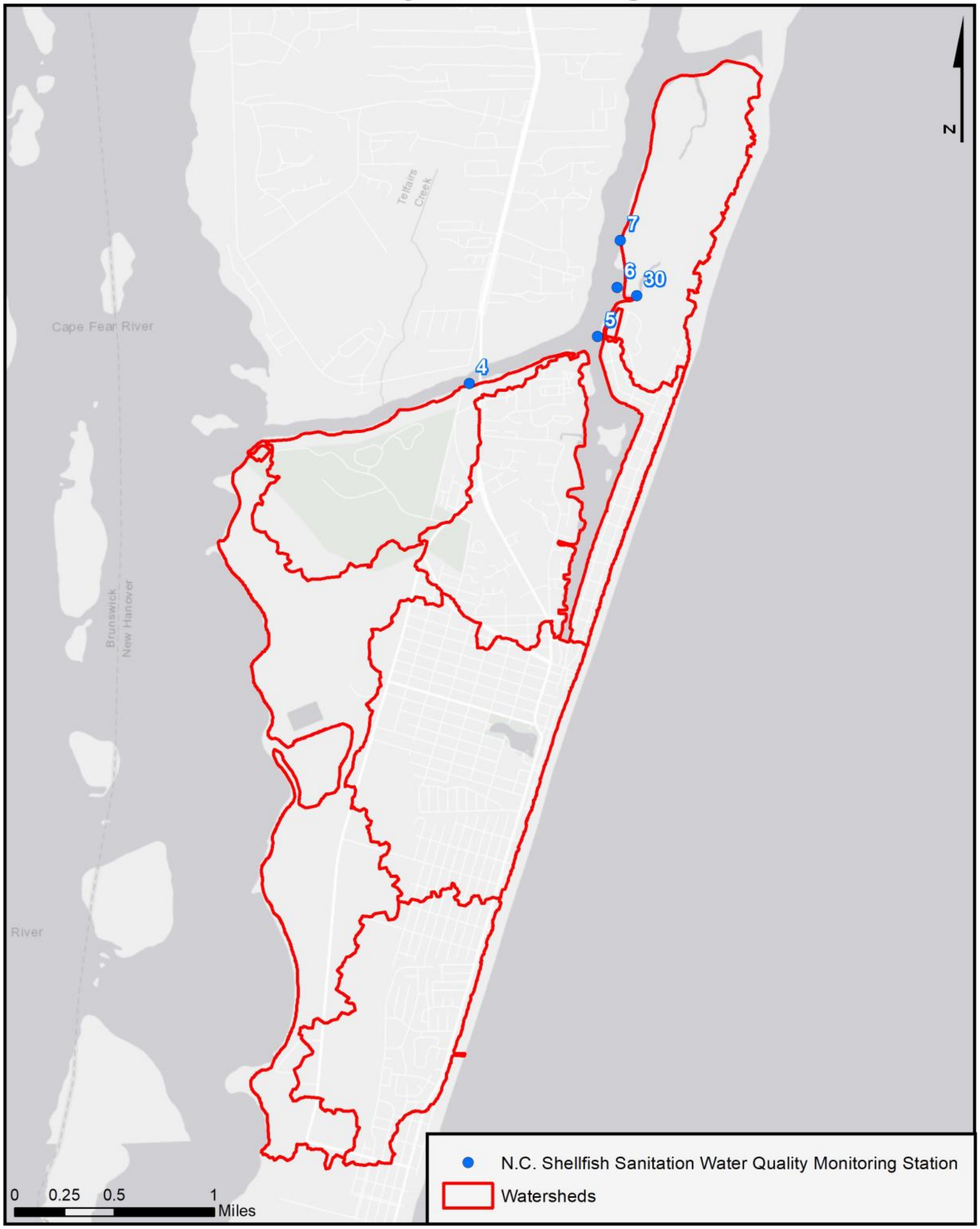


Figure 10-1. Location of monitoring stations within the area as registered through Shellfish Sanitation's system (Data Source: Shellfish Sanitation, 2019).

Within the Carolina Beach watersheds, Table 10-3 presents data for shellfish monitoring stations exceeding fecal coliform levels of Class SA (GM >14/100 ml). Specifically, fecal coliform group not to exceed a median MF of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions- (See Appendix B). The data indicates significant variability in frequency over the course of the last two decades. Understanding how often water quality stations have exceeded a single sample reading of 14/100 ml aid in the development of milestones and assist in the monitoring of progress.

Table 10-3. Frequency of shellfish sanitation stations exceeding 14/100 ml of fecal coliform (Shellfish Sanitation, 1999; Shellfish Sanitation, 2002; Shellfish Sanitation, 2006; Shellfish Sanitation, 2010; Shellfish Sanitation, 2013; Shellfish Sanitation, 2016).

Survey Report Cycle	1993-1999	1997-2002	2001-2006	2005-2009	2008-2013	2011-2016
Station No.	Percent of samples station exceeded 14/100 ml out of 30 samples					
B-5 #4	37%	20%	13%	13%	17%	20%
B-5 #5	60%	47%	30%	17%	17%	30%
B-5 #6	23%	27%	3%	10%	20%	23%
B-5 #7	23%	17%	10%	17%	13%	20%
B-5 #30	17%	10%	20%	13%	13%	30%
>50% of samples exceed SA standard		25-49% of samples exceed SA standards		10-24% of samples exceed SA standards		<10% of samples exceed SA standards

Note: These numbers represent a single sample in which 14/100ml was exceeded.

Within the Carolina Beach watersheds, Table 10-4 presents data from shellfish monitoring stations exceeding fecal coliform levels above 43/100 ml (MF count; Appendix B). This is part of Class SA standards for water quality in which fecal coliform group not to exceed a median MF of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions. The data indicates lower exceedances and less variability in frequency over the course of the last two decades, but an overall increase in exceedances during the 2011-2016 monitoring timeframe over all previous sampling timeframes except for4 1993-1999. Understanding how often water quality stations have exceeded a single sample reading of 43 /100 ml aid in the development of milestones and assist in the monitoring of progress.

Table 10-4. Frequency of shellfish sanitation stations exceeding 43/100 ml of fecal coliform (Shellfish Sanitation, 1999; Shellfish Sanitation, 2002; Shellfish Sanitation, 2006; Shellfish Sanitation, 2010; Shellfish Sanitation, 2013; Shellfish Sanitation, 2016).

Survey Report Cycle	1993-1999	1997-2002	2001-2006	2005-2009	2008-2013	2011-2016
Station No.	Percent of samples station exceeded 43/100 ml out of 30 samples					
B-5 #4	10%	3%	3%	7%	3%	7%
B-5 #5	17%	7%	3%	3%	3%	13%
B-5 #6	10%	3%	0%	3%	3%	7%
B-5 #7	7%	3%	3%	0%	0%	7%
B-5 #30	3%	0%	3%	3%	0%	10%
>50% of samples exceed 43/100 ml		25-49% of samples exceed 43/100 ml		10-24% of samples exceed 43/100 ml		<10% of samples exceed 43/100 ml

Note: These numbers represent a single sample in which 43/100ml was exceeded.

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Acronyms and Definitions

303(d) List	A list of waterbodies in each state that are too polluted or degraded to meet water quality standards. States are required to update their lists every two years.
319 Grant	A grant program, named after Section 319 of the Clean Water Act, funded by EPA and administered by NC DEQ to study and find solutions to impaired water.
APPROVED AREA	An area determined suitable for the harvest of shellfish for direct market purposes.
BIORETENTION AREAS	Also, known as rain gardens, these provide onsite retention of stormwater using vegetated depressions engineered to collect, store, and infiltrate runoff.
BMP	Best Management Practice of stormwater management; also, commonly referred to as *Stormwater Control Measure (SCM)* or *Stormwater Infiltration Practice (SIP)*.
CAFO	Confined Animal Feeding Operation
CATCHMENT	A geographic unit within a sub watershed made up of a singular river, stream, or branch that contributes to a larger watershed.
CFU	Colony Forming Unit, used to measure fecal coliform bacteria concentrations.
CONDITIONALLY APPROVED CLOSED	This management strategy by North Carolina Shellfish Sanitation, refers to shellfish-growing waters that are closed to harvest because of high bacteria concentrations but can be opened temporarily, usually during periods of drought, when bacteria levels are low enough to make the shellfish safe to eat.
CONDITIONALLY APPROVED OPEN	This management strategy by North Carolina Shellfish Sanitation, refers to shellfish growing areas that are open to harvest but are temporarily closed after periods of moderate or heavy rain.
CWA	Clean Water Act
DCM	North Carolina Division of Coastal Management
DEGRADED WATERS	General description of surface waters that have elevated pollution levels, could include high bacteria levels, pathogens, sediment, low dissolved oxygen, and/or high nutrient levels. This is not a legal description of impairment (see impaired waters definition).
DEQ	North Carolina Department of Environmental Quality
DESIGNATED USE	A Clean Water Act term referring to the use, such as swimming, shellfish harvesting or aquatic life support, that a waterbody has been designated with by the state. The waterbody may not actually be able to support its designated use.
DOT	Department of Transportation
EPA	Environmental Protection Agency
EXISTING USE	A Clean Water Act term referring to all current uses and any use the waterbody has supported since November 28, 1975.
FDA	U.S. Food and Drug Administration
FECAL COLIFORM	These bacteria are found in the intestines of warm-blooded animals. They are not normally harmful to humans, but if found in a waterbody they could indicate the presence of harmful bacteria. Because they are easy to detect in the environment, these bacteria have been used for decades to determine the suitability of shellfish-growing waters.
FLOW	The volume of water, often measured in cubic feet per second (cfs), flowing in a stream or through a stormwater conveyance system.

GIS	Geographic Information Systems
GROWING WATERS	Waters that support or could support shellfish life.
HUC	Hydrologic Unit Code
HYDROGRAPH	A graph showing changes in the discharge of a surface water river, stream or creek over a period of time.
HYDROLOGIC CYCLE	The cycle by which water evaporates from oceans and other bodies of water, accumulates as water vapor in clouds, and returns to the oceans and other bodies of water as precipitation or groundwater. Also, known as the water cycle.
HYDROLOGY	The science dealing with the waters of the earth, their distribution on the surface and underground, and the cycle involving evaporation, precipitation, flow to the seas, etc.
IMPAIRED WATERS	This Clean Water Act term refers to waters that no longer meet their designated uses. That would include conditionally approved and conditionally closed waters and any water where swimming advisories are being issued. These waters have been listed as impaired on the state's 303(d) list for EPA.
IMPERVIOUS COVER	A hard surface area, such as a parking lot or rooftop, that prevents or retards water from entering the soil, thus causing water to run off the surface in greater quantities and at an increased rate of flow.
INTERTIDAL	Area of land that is submerged during high tide and exposed at low tide.
LAND USE	The management and modification of natural environment or wilderness into built environment such as settlements and semi-natural habitats such as arable fields, pastures, and managed woods.
LID	Low Impact Development refers to management strategies that attempt to mimic conditions to reduce the flow of stormwater. To be successful, they should be integrated into all phases of urban planning and design from the individual residential lot level to the entire watershed.
LULC	Land use/land cover
MAXIMUM EXTENT PRACTICABLE	This term appears in many state and federal pollution regulations. It generally refers to pollution controls that are technologically available and capable of being done after taking into consideration cost and logistics.
MS4	Municipal separate storm sewer systems
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
Nonpoint Source (NPS)	Nonpoint Source, diffused sources of pollution, where there is no singular distinct outflow point.
NRCS	Natural Resources Conservation Service
NSSP	National Shellfish Sanitation Program
Point Source	A singular, identifiable discharge source of pollution.
RETROFITTING	Structural stormwater management measures for preexisting development designed to help reduce the effect of impervious areas, minimize channel erosion, reduce pollutant loads, promote conditions for improve aquatic habitat, and correct past efforts that no longer represent the best science or technology.
ROW	Right of Way

RUNOFF CURVE	A runoff curve number is a numeric parameter derived from combining the effects of soil, watershed characteristics, and land use.
SA	This is a state salt water classification intended for shellfish harvesting. These are waters that should also support aquatic life, both primary and secondary recreation (activities with frequent or prolonged skin contact), and shellfishing for market purposes. It is one of the highest water classifications in the state.
SB	This is a state salt water classification intended for swimming.
SC	This is a state salt water classification intended for fish propagation and incidental swimming. The waters are safe for swimming but have a higher risk of pollution and human illness than SB waters.
SCM	Stormwater Control Measure, also more commonly known as a Best Management Practice (BMP) of stormwater management; also, commonly referred to as *Stormwater Infiltration Practice (SIP)*
Shellfish	"Shellfish" as referenced in this document means molluscan shellfish, oysters and clams.
SHELLFISH SANITATION	Shellfish Sanitation and Recreational Water Quality Section, N.C. Division of Marine Fisheries, N.C. DEQ.
SIP	Stormwater Infiltration Practice, also more commonly known as a Best Management Practice (BMP) of stormwater management; also, commonly referred to as *Stormwater Control Measure (SCM)*.
STORMWATER	Water from rain that flows over the land surface, picking up pollutants that are on the ground.
SUBWATERSHED	A geographic unit within a watershed made up of individual minor rivers, streams, or branches that contribute to a larger watershed.
TMDL	Total maximum daily load, the maximum amount of a pollutant that can be found in a waterbody and still meet federal Clean Water Act standards.
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WATERSHED	All areas that drain to a waterbody, whether that be a lake, mouth of a river, or ocean.
WQS	Water quality standards
WWTP	Wastewater Treatment Plant

Appendix A: Soils

Appendix B: Regulatory Water Quality Standards

When implementing projects consideration should be given to Coastal Area Management Act (CAMA). Some projects may require CAMA permits, consideration of the should be given when developing a timeline for project completion.

Congress enacted the federal Clean Water Act (CWA) (33 U.S.C. §1251 et seq. (1972)) to establish regulations on water quality standards for waters with a purpose of protecting surface waters for drinking, fishing and recreation. The EPA set water quality standards for many contaminants in surface waters as well as established pollution control programs. The CWA establishes use designations that mandate that waters maintain their designated usage. In North Carolina, the Department of Environmental Quality Division of Water Resources is responsible for delegating water quality designations. When waters do not meet this, they are listed on the 303(d) lists.

North Carolina first adopted formal coastal stormwater management rules in 1988. These rules proved inadequate to stop the continued spread of bacteria pollution in coastal waterways. The failure of these rules was recognized in 2008 by the N.C. Environmental Management Commission when more robust rules were adopted. The new rules increased the amount of stormwater that must be controlled in all 20 coastal counties, especially within one-half mile of Class SA waters (North Carolina's Surface Water Classification designation for commercial shellfishing waters and one of the highest designations given). By using Class SA waters as a standard, a management plan can focus on achieving the highest water quality that is regularly monitored.

WATER QUALITY STANDARDS

Further information regarding 303(d) List and its reporting categories[4]:

> *"The term "303(d) list" or "list" is short for a state's list of impaired and threatened waters (e.g. stream/river segments, lakes). States are required to submit their list for EPA approval every two years. For each water on the list, the state identifies the pollutant causing the impairment, when known. In addition, the state assigns a priority for development of Total Maximum Daily Loads (TMDL) based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors (40 C.F.R. §130.7(b)(4)).*
>
> *In general, once a water body has been added to a state's list of impaired waters it stays there until the state develops a TMDL and EPA approves it. EPA reporting guidance provides a way to keep track of a state's water bodies, from listing as impaired to meeting water quality standards. This tracking system contains a running account of all the state's water bodies and categorizes each based on the attainment status. For example, once a TMDL is developed, a water body is no longer on the 303(d) list, but it is still tracked until the water is fully restored."*

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[4] Environmental Protection Agency. Retrieved from https://www.epa.gov/tmdl/program-overview-303d-listing

Table 1. EPA 303(d) List Integrated Report Categories

Category/Subcategory	Description
Category 1	**Meets tested standards for clean waters.** All designated uses are supported, no use is threatened.
Category 2	**Waters of concern.** Available data and/or information indicate that some, but not all, designated uses are supported.
Category 3	**Insufficient data.** There is insufficient available data and/or information to make a use support determination.
Category 4	**Polluted waters that do not require a TMDL.** Available data and/or information indicate that at least one designated use is not being supported or is threatened, but a TMDL is not needed.
Category 4a	**Has a TMDL.** A State developed TMDL has been approved by EPA or a TMDL has been established by EPA for any segment-pollutant combination.
Category 4b	**Has a pollution control program.** Other required control measures are expected to result in the attainment of an applicable water quality standard in a reasonable period of time.
Category 4c	**Is impaired by a non-pollutant.** The non-attainment of any applicable water quality standard for the segment is the result of pollution and is not caused by a pollutant.
Category 5	**Polluted waters that require a `.** Available data and/or information indicate that at least one designated use is not being supported or is threatened, and a TMDL is needed.

DWR PRIMARY SURFACE WATER CLASSIFICATIONS

All surface waters in North Carolina are assigned a primary classification by the N.C. Division of Water Resources (DWR). All waters must at least meet the standards for Class C (fishable / swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water (Water Supply Classes I through V). To find the classification of a water body you can either use the BIMS database or contact Adriene Weaver of the Classifications & Standards/Rules Review Branch. To view the regulatory differences between the currently implemented classifications for freshwaters, click here for the freshwater classifications table. To view the regulatory differences between the currently implemented classifications for tidal salt waters, click here for the tidal saltwater classifications table.

Table 2. North Carolina surface water classifications. Full descriptions available on DEQ Website.

Primary Use Classifications	
SA	Commercial Shellfishing
SB	Primary Recreation in tidal salt water
SC	Aquatic Life, Secondary Recreation, and Fishing in tidal salt water
SWL	Coastal wetlands

Supplemental Use Classifications	
HQW	High Quality Waters
ORW	Outstanding Resource Waters
NSW	Nutrient Sensitive Waters
CA	Critical Area
UWL	Unique Wetland
+, @, #, *	Special Designations (variable based on river basin)

Class C

Waters protected for uses such as secondary recreation, fishing, wildlife, fish consumption, aquatic life including propagation, survival and maintenance of biological integrity, and agriculture. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner.

Class B

Waters protected for all Class C uses in addition to primary recreation. Primary recreational activities include swimming, skin diving, water skiing, and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis.

Water Supply I (WS-I)

Waters protected for all Class C uses plus waters used as sources of water supply for drinking, culinary, or food processing purposes for those users desiring maximum protection for their water supplies. WS-I waters are those within natural and undeveloped watersheds in public ownership. All WS-I waters are HQW by supplemental classification. More information: Water Supply Watershed Protection Program Homepage

Water Supply II (WS-II)

Waters used as sources of water supply for drinking, culinary, or food processing purposes where a WS-I classification is not feasible. These waters are also protected for Class C uses. WS-II waters are generally in predominantly undeveloped watersheds. All WS-II waters are HQW by supplemental classification. More information: Water Supply Watershed Protection Program Homepage

Water Supply III (WS-III)

Waters used as sources of water supply for drinking, culinary, or food processing purposes where a more protective WS-I or II classification is not feasible. These waters are also protected for Class C uses. WS-III waters are generally in low to moderately developed watersheds. More information: Water Supply Watershed Protection Program Homepage

Water Supply IV (WS-IV)

Waters used as sources of water supply for drinking, culinary, or food processing purposes where a WS-I, II or III classification is not feasible. These waters are also protected for Class C uses. WS-IV waters are generally in moderately to highly developed watersheds or Protected Areas. More information: Water Supply Watershed Protection Program Homepage

Water Supply V (WS-V)

Waters protected as water supplies which are generally upstream and draining to Class WS-IV waters or waters used by industry to supply their employees with drinking water or as waters formerly used as water supply. These waters are also protected for Class C uses. More information: Water Supply Watershed Protection Program Homepage

Class WL

Freshwater Wetlands are a subset of all wetlands, which in turn are waters that support vegetation that is adapted to life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. These waters are protected for storm and flood water storage, aquatic life, wildlife, hydrologic functions, filtration and shoreline protection.

Class SC

All tidal salt waters protected for secondary recreation such as fishing, boating, and other activities involving minimal skin contact; aquatic life propagation and survival; and wildlife.

Class SB

Tidal salt waters protected for all SC uses in addition to primary recreation. Primary recreational activities include swimming, skin diving, water skiing, and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis.

Class SA

Tidal salt waters that are used for commercial shellfishing or marketing purposes and are also protected for all Class SC and Class SB uses. All SA waters are also HQW by supplemental classification.

Class SWL

These are salt waters that meet the definition of coastal wetlands as defined by the Division of Coastal Management and which are located landward of the mean high water line or wetlands contiguous to estuarine waters as defined by the Division of Coastal Management.

DWR SUPPLEMENTAL CLASSIFICATIONS

Supplemental classifications are sometimes added by DWR to the primary classifications to provide additional protection to waters with special uses or values.

Future Water Supply (FWS)

Supplemental classification for waters intended as a future source of drinking, culinary, or food processing purposes. FWS would be applied to one of the primary water supply classifications (WS-I, WS-II, WS-III, or WS-IV). Currently no water bodies in the state carry this designation.

High Quality Waters (HQW)

Supplemental classification intended to protect waters which are rated excellent based on biological and physical/chemical characteristics through Division monitoring or special studies, primary nursery areas designated by the Marine Fisheries Commission, and other functional nursery areas designated by the Marine Fisheries Commission.

The following waters are HQW by definition:

- WS-I,
- WS-II,
- SA (commercial shellfishing),
- ORW,

Primary nursery areas (PNA) or other functional nursery areas designated by the Marine Fisheries Commission, or Waters for which DWR has received a petition for reclassification to either WS-I or WS-II.

Outstanding Resource Waters (ORW)
All outstanding resource waters are a subset of High Quality Waters. This supplemental classification is intended to protect unique and special waters having excellent water quality and being of exceptional state or national ecological or recreational significance. To qualify, waters must be rated Excellent by DWR and have one of the following outstanding resource values:

- Outstanding fish habitat and fisheries,
- Unusually high level of water-based recreation or potential for such kind of recreation,
- Some special designation such as North Carolina Natural and Scenic River or National Wildlife Refuge,
- Important component of state or national park or forest, or
- Special ecological or scientific significance (rare or endangered species habitat, research or educational areas).

For more details, refer to the Biological Assessment Branch homepage.

Nutrient Sensitive Waters (NSW)
Supplemental classification intended for waters needing additional nutrient management due to being subject to excessive growth of microscopic or macroscopic vegetation.

Swamp Waters (Sw)
Supplemental classification intended to recognize those waters which have low velocities and other natural characteristics which are different from adjacent streams.

Trout Waters (Tr)
Supplemental classification intended to protect freshwaters which have conditions which shall sustain and allow for trout propagation and survival of stocked trout on a year-round basis. This classification is not the same as the NC Wildlife Resources Commission's Designated Public Mountain Trout Waters designation.

Unique Wetland (UWL)
Supplemental classification for wetlands of exceptional state or national ecological significance. These wetlands may include wetlands that have been documented to the satisfaction of the Environmental Management Commission as habitat essential for the conservation of state or federally listed threatened or endangered species.

Table 3. North Carolina water quality classification and standards.

Classification	Description
Class SA	Tidal salt waters that are used for commercial shellfishing or marketing purposes and are also protected for all Class SC and Class SB uses. All SA waters are also HQW by supplemental classification. The following water quality standards apply to surface waters that are used for shellfishing for market purposes and are classified SA. Water quality standards applicable to Class SC waters as described in Rule .0220 of this Section also apply to Class SA waters. (1) Best Usage of Waters. Shellfishing for market purposes and any other usage specified by the "SB" or "SC" classification; (2) Conditions Related to Best Usage. Waters shall meet the current sanitary and bacteriological standards as adopted by the Commission for Health Services and shall be suitable for shellfish culture; any source of water pollution which precludes any of these

	uses, including their functioning as PNAs, on either a short-term or a long-term basis shall be considered to be violating a water quality standard; (3) Quality Standards applicable to Class SA Waters: a. Floating solids; settleable solids; sludge deposits: none attributable to sewage, industrial wastes or other wastes; b. Sewage: none; c. Industrial wastes, or other wastes: none which are not effectively treated to the satisfaction of the Commission in accordance with the requirements of the Division of Health Services; d. **Organisms of coliform group: fecal coliform group not to exceed a median MF of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions.**
Class SB	Tidal salt waters protected for all SC uses in addition to primary recreation. Primary recreational activities include swimming, skin diving, water skiing, and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis. The following water quality standards apply to surface waters that are used for primary recreation, including frequent or organized swimming, and are classified SB. Water quality standards applicable to Class SC waters are described in Rule .0220 of this Section also apply to SB waters. 1. Best Usage of Waters. Primary recreation and any other usage specified by the "SC" classification; 2. Conditions Related to Best Usage. The waters shall meet accepted sanitary standards of water quality for outdoor bathing places as specified in Item of this Rule and will be of sufficient size and depth for primary recreation purposes; any source of water pollution which precludes any of these uses, including their functioning as PNAs, on either a short-term or a long-term basis shall be considered to be violating a water quality standard; 3. Quality Standards applicable to Class SB waters: a. Floating solids; settleable solids; sludge deposits: none attributable to sewage, industrial wastes or other wastes; b. Sewage; industrial wastes; or other wastes: none which are not effectively treated to the satisfaction of the Commission; in determining the degree of treatment required for such waters discharged into waters which are to be used for bathing, the Commission shall take into consideration quantity and quality of the sewage and other wastes involved and the proximity of such discharges to the waters in this class; discharges in the immediate vicinity of bathing areas may not be allowed if the Director determines that the waste cannot be treated to ensure the protection of primary recreation; c. **Organisms of coliform group: fecal coliforms not to exceed a geometric mean of 200/100 ml (MF count) based on at least five consecutive samples examined during any 30-day period and not to exceed 400/100 ml in more than 20 percent of the samples examined during such period.**

Class SC	All tidal salt waters protected for secondary recreation such as fishing, boating, and other activities involving minimal skin contact; aquatic life propagation and survival; and wildlife. The water quality standards for all tidal salt waters are the basic standards applicable to Class SC waters. Additional and more stringent standards applicable to other specific tidal salt water classifications are specified in Rules .0221 and .0222 of this Section. 1. Best Usage of Waters. Aquatic life propagation and maintenance of biological integrity (including fishing, fish and functioning PNAs), wildlife, secondary recreation, and any other usage except primary recreation or shellfishing for market purposes. 2. Conditions Related to Best Usage. The waters shall be suitable for aquatic life propagation and maintenance of biological integrity, wildlife, and secondary recreation; Any source of water pollution which precludes any of these uses, including their functioning as PNAs, on either a short-term or a long-term basis shall be considered to be violating a water quality standard. 3. Quality standards applicable to all tidal salt waters: a. Chlorophyll a (corrected): not greater than 40 ug/l in sounds, estuaries, and other waters subject to growths of macroscopic or microscopic vegetation; the Commission or its designee may prohibit or limit any discharge of waste into surface waters if, in the opinion of the Director, the surface waters experience or the discharge would result in growths of microscopic or macroscopic vegetation such that the standards established pursuant to this Rule would be violated or the intended best usage of the waters would be impaired; b. Dissolved oxygen: not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayment, or estuarine bottom waters may have lower values if caused by natural conditions; c. Floating solids; settleable solids; sludge deposits: only such amounts attributable to sewage, industrial wastes or other wastes, as shall not make the waters unsafe or unsuitable for aquatic life and wildlife, or impair the waters for any designated uses; d. Gases, total dissolved: not greater than 110 percent of saturation; **e. Organisms of coliform group: fecal coliforms not to exceed geometric mean of 200/100 ml (MF count) based upon at least five consecutive samples examined during any 30 day period; not to exceed 400/100 ml in more than 20 percent of the samples examined during such period**; violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution; all coliform concentrations are to be analyzed using the MF technique unless high turbidity or other adverse conditions necessitate the tube dilution method; in case of controversy over results the MPN 5-tube dilution method shall be used as the reference method; f. Oils; deleterious substances; colored or other wastes: only such amounts as shall not render the waters injurious to public health, secondary recreation or to aquatic life and wildlife or adversely affect the palatability of fish, aesthetic quality or impair the waters for any designated uses; for the purpose of implementing this Rule, oils, deleterious substances, colored or other wastes shall include but not be limited to substances that cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines pursuant to 40 CFR 110.4(a)-(b);

g. pH: shall be normal for the waters in the area, which generally shall range between 6.8 and 8.5 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;
h. Phenolic compounds: only such levels as shall not result in fish-flesh tainting or impairment of other best usage;
i. Radioactive substances: (i) Combined radium-226 and radium-228: The maximum average annual activity level (based on at least four samples, collected quarterly) for combined radium-226, and radium-228 shall not exceed five picoCuries per liter; (ii) Alpha Emitters. The average annual gross alpha particle activity (including radium-226, but excluding radon and uranium) shall not exceed 15 picoCuries per liter; (iii) Beta Emitters. The maximum average annual activity level (based on at least four samples, collected quarterly) for strontium-90 shall not exceed eight picoCuries per liter; nor shall the average annual gross beta particle activity (excluding potassium-40 and other naturally occurring radio-nuclides) exceed 50 picoCuries per liter; nor shall the maximum average annual activity level for tritium exceed 20,000 picoCuries per liter;
j. Salinity: changes in salinity due to hydrological modifications shall not result in removal of the functions of a PNA; projects that are determined by the Director to result in modifications of salinity such that functions of a PNA are impaired will be required to employ water management practices to mitigate salinity impacts;
k. Temperature: shall not be increased above the natural water temperature by more than 0.8 degrees C (1.44 degrees F) during the months of June, July, and August nor more than 2.2 degrees C (3.96 degrees F) during other months and in no cases to exceed 32 degrees C (89.6 degrees F) due to the discharge of heated liquids;
l. Turbidity: the turbidity in the receiving water shall not exceed 25 NTU; if turbidity exceeds this level due to natural background conditions, the existing turbidity level shall not be increased. Compliance with this turbidity standard can be met when land management activities employ Best Management Practices (BMPs) [as defined by Rule .0202(6) of this Section] recommended by the Designated Nonpoint Source Agency (as defined by Rule .0202 of this Section). BMPs must be in full compliance with all specifications governing the proper design, installation, operation and maintenance of such BMPs;
m. Toxic substances: numerical water quality standards (maximum permissible levels) to protect aquatic life applicable to all tidal saltwaters: (i) Arsenic, total recoverable: 50 ug/l; (ii) Cadmium: 5.0 ug/l; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators. (iii) Chromium, total: 20 ug/l; (iv) Cyanide: 1.0 ug/l; (v) Mercury: 0.025 ug/l; (vi) Lead, total recoverable: 25 ug/l; collection of

data on sources, transport and fate of lead shall be required as part of the toxicity reduction evaluation for dischargers that are out of compliance with whole effluent toxicity testing requirements and the concentration of lead in the effluent is concomitantly determined to exceed an instream level of 3.1 ug/l from the discharge; (vii) Nickel: 8.3 ug/l; attainment of these water quality standards in surface waters shall be based on measurement of total recoverable metals concentrations unless appropriate studies have been conducted to translate total recoverable metals to a toxic form. Studies used to determine the toxic form or translators must be designed according to the "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators. (viii) Pesticides: (A) Aldrin: 0.003 ug/l; (B) Chlordane: 0.004 ug/l; (C) DDT: 0.001 ug/l; (D) Demeton: 0.1 ug/l; (E) Dieldrin: 0.002 ug/l; (F) Endosulfan: 0.009 ug/l; (G) Endrin: 0.002 ug/l; (H) Guthion: 0.01 ug/l; (I) Heptachlor: 0.004 ug/l; (J) Lindane: 0.004 ug/l; (K) Methoxychlor: 0.03 ug/l; (L) Mirex: 0.001 ug/l; (M) Parathion: 0.178 ug/l; (N) Toxaphene: 0.0002 ug/l. (ix) Polycholorinated biphenyls: 0.001 ug/l; (x) Selenium: 71 ug/l; (xi) Trialkyltin compounds: 0.002 ug/l expressed as tributyltin.

4. Action Levels for Toxic Substances: if the Action Levels for any of the substances listed in this Subparagraph (which are generally not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream characteristics or associated waste characteristics) are determined by the waste load allocation to be exceeded in a receiving water by a discharge under the specified low flow criterion for toxic substances (Rule .0206 in this Section), the discharger shall be required to monitor the chemical or biological effects of the discharge; efforts shall be made by all dischargers to reduce or eliminate these substances from their effluents. Those substances for which Action Levels are listed in this Subparagraph may be limited as appropriate in the NPDES permit if sufficient information (to be determined for metals by measurements of that portion of the dissolved instream concentration of the Action Level parameter attributable to a specific NPDES permitted discharge) exists to indicate that any of those substances may be a causative factor resulting in toxicity of the effluent. NPDES permit limits may be based on translation of the toxic form to total recoverable metals. Studies used to determine the toxic form or translators must be designed according to: "Water Quality Standards Handbook Second Edition" published by the Environmental Protection Agency (EPA 823-B-94-005a) or "The Metals Translator: Guidance For Calculating a Total Recoverable Permit Limit From a Dissolved Criterion" published by the Environmental Protection Agency (EPA 823-B-96-007) which are hereby incorporated by reference including any subsequent amendments. The Director shall consider conformance to EPA guidance as well as the presence of environmental conditions that limit the applicability of translators in approving the use of metal translators. (a) Copper: 3 ug/l; (b) Silver: 0.1 ug/l; (c) Zinc: 86 ug/l.

Shellfish Sanitation Classifications

Table 4. Classifications used by Shellfish Sanitation for shellfish harvesting waters.

North Carolina Shellfish Sanitation Growing Area Classifications	
Approved	These areas are always open to shellfish harvesting and close only after rare heavy rainfall events such as hurricanes. The median fecal coliform Most Probable Number (MPN) or geometric mean MPN of water shall not exceed 14 per 100 milliliters, and the estimated 90th percentile shall not exceed an MPN of 43 per 100 mL for a five-tube decimal dilution test.
Conditionally Approved-Open Shellfish Areas	Sanitary Survey indicates an area can meet approved area criteria for a reasonable period of time, and the pollutant event is known and predictable and can be managed with a plan. These areas are open to harvest much of the year, but are immediately closed after certain sized rainfall events.
Conditionally Approved-Closed Shellfish Areas	Sanitary Survey indicates an area can meet approved area criteria during dry periods of time, and the pollutant event is known and predictable and can be managed with a plan. This growing area classification allows harvest when fecal coliform bacteria levels are lower than the state standard in areas that otherwise might be closed to harvesting. These areas are regularly monitored to determine if temporary openings are possible.
Prohibited Shellfish Harvest Areas	Sanitary Survey is not routinely conducted because previous sampling data did not meet criteria for Approval or Conditional Approved. Area may also be closed as a matter of regulation due to the presence of point source discharges or high concentrations of boats with heads.

Recreational Water Quality Standards

Tier	Description
Tier I	"Tier I swimming area" means a swimming area used daily during the swimming season, including any public access swimming area and any other swimming area where people use the water for primary contact, including all oceanfront beaches. 1. The enterococcus level in a Tier I swimming area shall not exceed either: a. A geometric mean of 35 enterococci per 100 milliliter of water, that includes a minimum of at least five samples collected within 30 days; or b. A single sample of 104 enterococci per 100 milliliters of water. Tier I Swimming areas: (1) A swimming advisory shall be issued by the Division when samples of water from a swimming area exceeds a geometric mean of 35 enterococci per 100 milliliters during the swimming season. (2) A swimming alert shall be issued by the Division when a single sample of water from a swimming area exceeds 104 enterococci per 100 milliliters and does not exceed 500 enterococci per 100 milliliters during the swimming season. (3) A swimming advisory shall be issued by the Division when a sample of water from a swimming area exceeds a single sample of 500 enterococci per 100 milliliters during the swimming season.

	(4) A swimming advisory shall be issued by the Division when at least two of three concurrent water samples collected at a swimming area exceeds 104 enterococci per 100 milliliters during the swimming season. A Tier I swimming area advisory shall be rescinded when two consecutive weekly water samples and the geometric mean meet the bacteriological limits in Rule 18A .3402(a) of this Section. A swimming alert shall be rescinded within 24 hours of compliance with Rule 18A .3402(a)(2) of this Section.
Tier II	"Tier II swimming area" means a swimming area used an average of three days a week during the swimming season. The enterococcus level in a Tier II swimming area shall not exceed a single sample of 276 enterococci per 100 milliliters of water. Tier II swimming areas: (1) A swimming alert shall be issued by the Division when a single sample of water from a swimming area exceeds 276 enterococci per 100 milliliters and does not exceed 500 enterococci per 100 milliliters during the swimming season. (2) A swimming advisory shall be issued by the Division when a single sample of water from a swimming area exceeds 500 enterococci per 100 milliliters during the swimming season. A Tier II or Tier III swimming area advisory or alert shall be rescinded after water samples meet the bacteriological standard in Rule 18A .3402(b) or (c) of this Section.
Tier III	"Tier III swimming area" means a swimming area used an average of four days a month during the swimming season. Tier III swimming area with a water sample result of 500 enterococci per 100 milliliters or higher on the first sample shall be resampled the following day. If the laboratory results of the second sample exceed 500 enterococci per 100 milliliters a swimming advisory shall be issued by the Division. A Tier II or Tier III swimming area advisory or alert shall be rescinded after water samples meet the bacteriological standard in Rule 18A .3402(b) or (c) of this Section.
Swimming Season	April 1 through October 31 of each year. The enterococcus level in a Tier III swimming area shall not exceed two consecutive samples of 500 enterococci per 100 milliliters of water.
Winter Season	November 1 through March 31 of each year.

Appendix C: NC DEQ Water Quality Monitoring Data for Tier I Beaches

Appendix D: Dockage in Carolina Beach

Appendix E: Town of Carolina Beach Canal Drive Flooding and Vulnerability Study, Aptim Coastal Planning & Engineering of North Carolina, Inc., DRAFT, February 2019

Appendix F: Potential Stormwater Incentive Strategies

The following is an outline of potential stormwater incentive strategies that municipalities could consider to encourage early LID implementation.

Begin by reviewing the town's codes and ordinances utilizing the following worksheet:

https://www.scdhec.gov/HomeandEnvironment/docs/ModelOrdinances/CodesandOrdinancesWorksheet.pdf

Incentive Categories

The EPA has identified five basic incentive categories that can be utilized to encourage the reduction of stormwater[5]:

Incentive Type	Description
Stormwater Fee Discount	Require a stormwater fee that is based on impervious surface area. If property owners reduce need for service by reducing impervious area and the volume of runoff discharged from the property, the municipality reduces the fee.
Development Incentives	Offered to developers during the process of applying for development permits. Examples include: zoning upgrades, expedited permitting, reduced stormwater requirements and increases in floor area ratios
Grants	Provide direct funding to property owners and/or community groups for implementing a range of green infrastructure projects and practices.

[5] *Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanism*. 2009. US Environmental Protection Agency, EPA-833-F-09-001. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/gi_munichandbook_incentives_0.pdf

Rebates & Installation Financing	Provide funding, tax credits or reimbursements to property owners who install specific practices. Often focused on practices needed in certain areas or neighborhoods
Awards & Recognition Incentive	Provide marketing opportunities and public outreach for exemplary projects. May include monetary awards. Emphasize LID projects on website, at Council meetings and in utility mailers.

Basic Strategies

The following is a compiled list of basic strategies and descriptions (summarized or quoted directly from Slo County[6] and EPA[7]; see Reference):

Strategy	Description
Adjustments to the Required Parking	Reducing parking is both a LID technique for reducing impervious surfaces as well to encourage more projects.
Dedicated Review Team	Create a LID review team that is familiar with and dedicated to LID projects.
Density bonuses	Allow greater residential densities with the implementation of LID techniques.
Disconnect of rooftop runoff credit	A credit is given when rooftop runoff is disconnected and then direction to a vegetated area where it can either infiltrate into the soil or filter over it. The credit is typically obtained by grading the site to promote overland filtering or by providing bioretention areas on single family residential lots.
Disconnection of Non-Rooftop Runoff Credit (aka Impervious Area Disconnection Credit)	This credit may be granted when impervious areas are disconnected from the stormwater control system via overland flow filtration/ infiltration (i.e., pervious) zones. These pervious areas are incorporated into the site design to receive runoff small impervious areas (e.g., driveways, small parking lots, etc.). This can be achieved by grading the site to promote overland vegetative filtering or by providing infiltration or "rain garden" areas.
Environmentally Sensitive Large Lot Neighborhood Credit (aka	This credit is targeted toward large lot residential developments that implement several Better Site Design practices to reduce stormwater discharges from the development. This credit may be granted when a group of environmental site design techniques are applied to low and very low-density residential development (e.g., 1 dwelling unit per 2 acres

[6] Slo County. n.d. *List of Potential Municipal LID Incentive Programs.* Retrieved from http://www.slocounty.ca.gov/Assets/PW/stormwater/Potential+LID+Incentives.pdf

[7] *Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanism*. 2009. US Environmental Protection Agency, EPA-833-F-09-001. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/gi_munichandbook_incentives_0.pdf

Environmentally Sensitive Development Credit)	[du/ac] or lower). The credit can eliminate the need for structural stormwater controls to treat water quality volume requirements. The project must have a total impervious cover (including streets) of less than 15% of the total area. utilize grass channels to convey runoff versus curb and gutter, etc.
Exemptions from local stormwater permitting	Allow redevelopment projects from being exempt from local stormwater permitting requirements if they can: • reduce the total impervious cover by 40% from existing conditions • Where site conditions prevent reduction in stormwater practices, implement controls for at least 40% of the site's impervious area, or Where a combination of impervious area reduction and implementation of stormwater practices is used for redevelopment projects, the combination of impervious area reduction and area controlled by stormwater management practices is equal to or exceeds 40%.
Fast track of review process	Provide priority status to LID projects with decreased time between receipt and review.
Green Roof Bonus	Add one square foot of additional floor area for each square foot of green roof, if green roof covers at least 50% of roof area and at least 30% of the garden contains plants.
LID Point system	Require a certain number of LID points and provide points when using approved LID IMP practices.
Managed Conservation Area Credit	A credit may be granted when areas of managed open space, typically reserved for passive recreation or agricultural practices, are conserved on a site. Under this credit, a designer would be able to subtract conservation areas from total site area when computing water quality volume requirements.
Modify building and inspection codes to include LID	Municipal entities that enforce building and inspection standards can also modify these standards in ways that acknowledge LID. In this subsection, we list sources of information on modifying building and inspection codes to make them more LID friendly. The list includes sources specific to Oregon and the Pacific Northwest, as well as from outside the region. http://www.econw.com/media/ap_files/ECONorthwest_Publication_LID-Clackamas-County-Case-Study_2009.pdf
Natural Area Conservation Credit	Credit may be granted when undisturbed, natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics. Under this credit, a designer would be able to subtract conservation areas from total site area when computing water quality volume requirements.
Property tax reduction	Reduce or waive property taxes on a LID project for a given number of years.
Reduction of municipal submittal fees	Projects that infiltrate 100 percent of stormwater receive up to 50% reduction in the stormwater utility fee

Steam and Vegetated Buffer Credit (aka Stream Buffer Credit or Sheet flow to Buffer Credit)	This credit may be granted when stormwater runoff is effectively treated by a stream buffer or other vegetated buffer. Effective treatment constitutes treating runoff as overland sheet flow through an appropriately vegetated and forested buffer. Under the proposed credit, a designer would be able to subtract areas draining via overland flow to the buffer from total site area when computing water quality volume requirements.
Tree canopy credit	Reduce stormwater treatment volume requirements as a ratio of the number of acceptably sized trees planted on the project
Vegetated Channel Credit (aka Grass Channel Credit (in lieu of Curb and Gutter)	This credit may be granted when vegetated (grass) channels are used for water quality treatment. Site designers will be able to subtract the areas draining to a grass channel and the channel area itself from total site area when computing water quality volume requirements.
Education Strategy	• Municipal sponsored public workshops on how to build rain gardens and emphasizing the increase in property value and curb appeal of LID landscaping • Municipal sponsored public workshops on how to make your own rain barrels • Municipal public education and outreach on how to conserve water and save money using rain barrels, rainwater harvesting water tanks, cisterns, and rain chains • Municipal sponsored contests with giveaways using rain barrels, rain harvesting water tanks, cisterns, and rain chains • Municipal sponsored gardening workshops promoting the value of rainwater harvesting, rain gardens, etc.
Business Outreach	Communication about grant opportunities, partnerships, awards, competitions, and regulations via email, newsletter, website, etc. directed directly at business owners and commercial land owners to encourage participation and encourage a vested interest in the community

Examples of LID-friendly Regulatory Language

"Several cities and counties list LID-friendly stormwater ordinances on their web sites. A recent Google search of "LID regulation" found the following LID ordinances:

- City of Sammamish, Washington: Ordinance 02008-236 Low Impact Development Regulations. An ordinance of the City of Sammamish, Washington, amending the City of Sammamish Municipal Code to create a Low Impact Development Chapter, and amending certain other Chapters of the City of Sammamish Municipal code to ensure consistency with the Low Impact Development Chapter. http://www.ci.sammamish.wa.us/Ordinances.aspx?ID=107 (accessed January 5, 2009).
- Fauquier County, Virginia: A zoning ordinance text amendment to Sections 5-006.5, 12-610 and 15-300 related to utilization of Low Impact Development techniques with site development. http://www.fauquiercounty.gov/government/departments/BOS/past agendas/02-14-08/lid_ord.htm (accessed January 5, 2009).

- Township of Lower Makefield, Pennsylvania: Ordinance No. 364. An ordinance of the Township of Lower Makefield, Bucks County, Pennsylvania, amending the Lower Makefield Township Codified Zoning Ordinance of 1996, as amended, to provide for Low Impact Development Standards. http://www.lmt.org/LID%20- %20ZONING%20v%206%20_4_.pdf (accessed January 5, 2009)."[8]
- Vermont utilizes a suite of stormwater regulations http://acrpc.org/files/2012/04/LID_For_VT_Towns.pdf

Discussion of challenges faced by developers and how municipalities can maximize the effectiveness of stormwater programs:

http://www.econw.com/media/ap_files/ECONorthwest_Publication_LID-Clackamas-County-Case-Study_2009.pdf

List of Cost savings from installed LID stormwater controls:

http://www.econw.com/media/ap_files/ECONorthwest_Publication_LID-Clackamas-County-Case-Study_2009.pdf

http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/guidance/factsheets/Documents/Incorporating%20ESD%20into%20Municipal%20SW%20Programs.pdf

https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/IncorporatingLID.pdf

Reference

Slo County. n.d. *List of Potential Municipal LID Incentive Programs.* Retrieved from http://www.slocounty.ca.gov/Assets/PW/stormwater/Potential+LID+Incentives.pdf

Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanism. 2009. US Environmental Protection Agency, EPA-833-F-09-001. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/gi_munichandbook_incentives_0.pdf

Doll, A., and G. Lindsey. 1999. Credits Bring Economic Incentives for Onsite Stormwater Management. Watershed and Wet Weather Technical Bulletin, January 1999, Water Environment Federation. http://stormwaterfinance.urbancenter.iupui.edu/PDFs/LindseyDoll.pdf

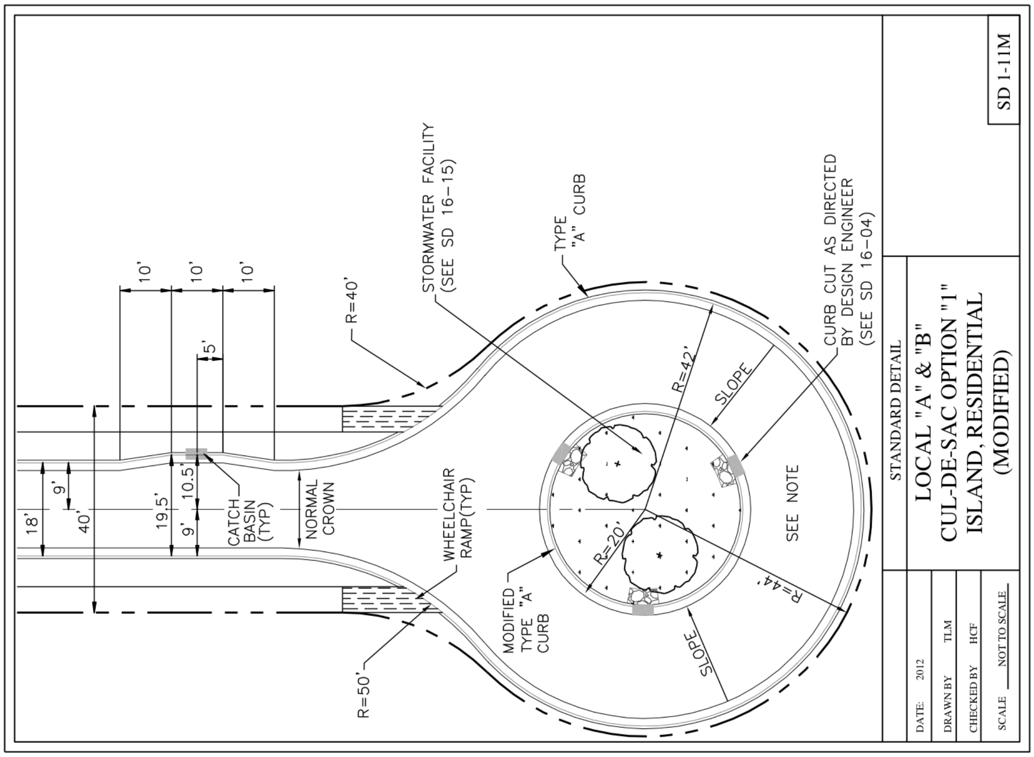
ECONorthwest. 2009. Low Impact Development at the local level: Developer's experiences and city and county support. Retrieved from http://www.econw.com/media/ap_files/ECONorthwest_Publication_LID-Clackamas-County-Case-Study_2009.pdf

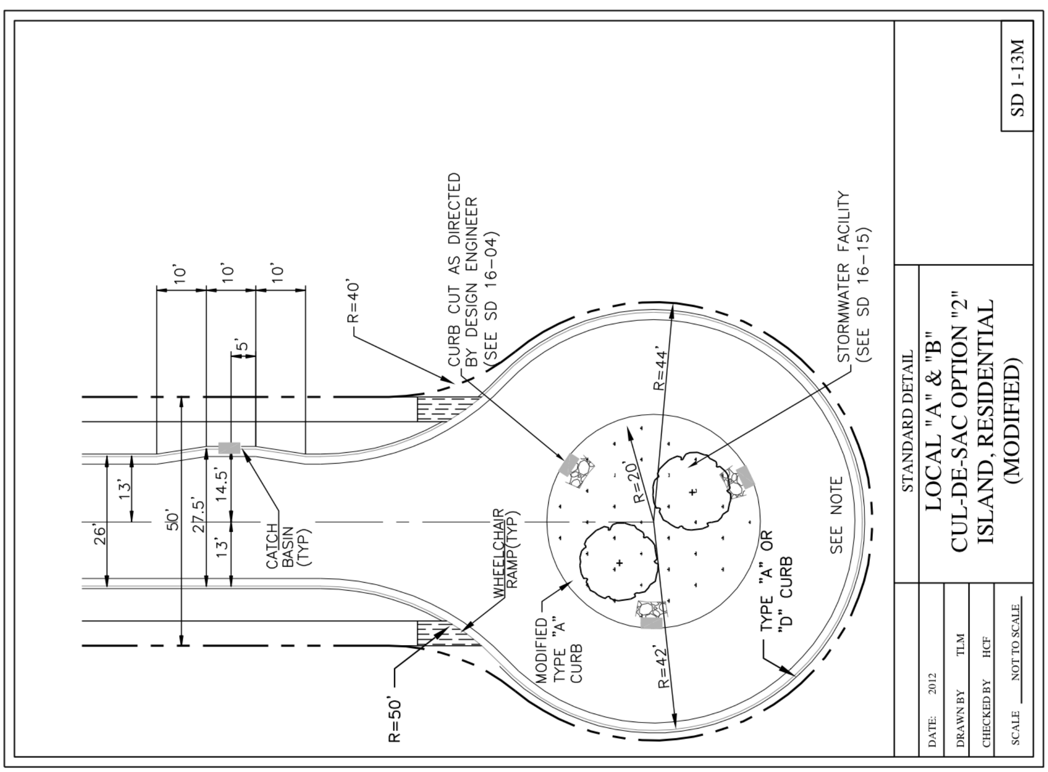
[8] ECONorthwest. 2009. Low Impact Development at the local level: Developer's experiences and city and county support. Retrieved from http://www.econw.com/media/ap_files/ECONorthwest_Publication_LID-Clackamas-County-Case-Study_2009.pdf

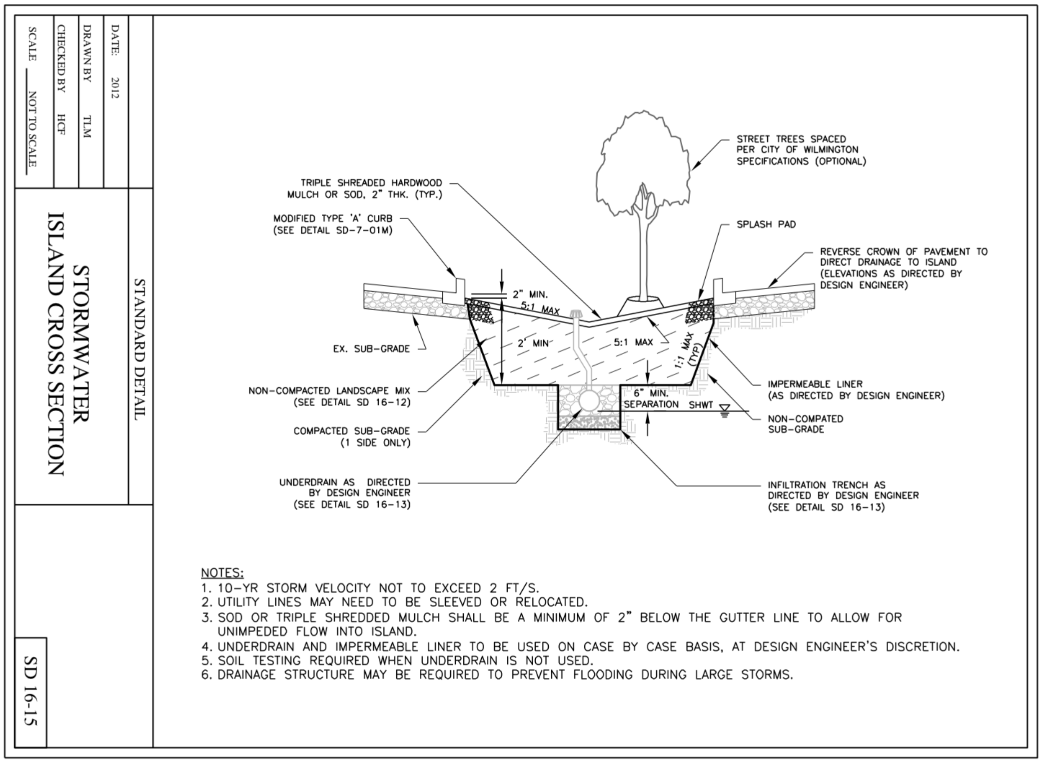
Appendix G: *Green Street* Stormwater Management Devices

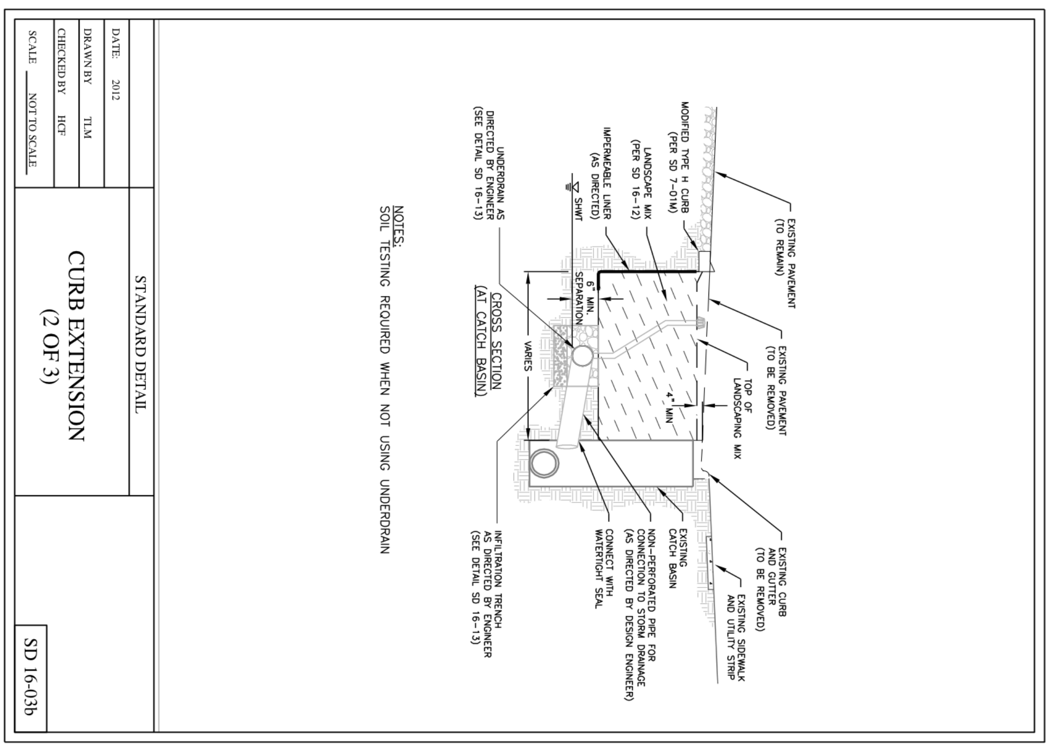
The purpose of this appendix is to provide example designs of typical stormwater runoff reduction practices that can be used within the public right of way. The measures shown are examples of the techniques and processes encouraged with the watershed management plan.

These details are intended to serve as the starting point for stormwater retrofits alongside active roadways. These details outline the major design elements of curbside stormwater management facilities. Roadside safety, pedestrian safety, maintenance, gutter spread and other factors must still be evaluated prior to implementation. Additionally, existing utilities or environmental conditions may make it necessary to modify or revise the standard designs to fit each individual BMP location. Curbside stormwater management may not be feasible in all locations.


STORMWATER FACILITY
(SEE SD 16-15)
TYPE
"A" CURB
CURB CUT AS DIRECTED
BY DESIGN ENGINEER
(SEE SD 16-04)
10'
10'
10'
5'
R=40'
18'
9'
40'
19.5'
10.5'
9'
CATCH
BASIN
(TYP)
NORMAL
CROWN
WHEELCHAIR
RAMP(TYP)
MODIFIED
TYPE "A"
CURB
R=50'
R=42'
R=20'
R=44'
SLOPE
SLOPE
SEE NOTE
STANDARD DETAIL
LOCAL "A" & "B"
CUL-DE-SAC OPTION "1"
ISLAND, RESIDENTIAL
(MODIFIED)
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
SD 1-11M


CURB CUT AS DIRECTED
BY DESIGN ENGINEER
(SEE SD 16-04)
STORMWATER FACILITY
(SEE SD 16-15)
10'
10'
10'
5'
R=40'
26'
13'
50'
27.5'
14.5'
13'
CATCH
BASIN
(TYP)
WHEELCHAIR
RAMP(TYP)
MODIFIED
TYPE "A"
CURB
R=50'
R=44'
R=20'
R=42'
TYPE "A" OR
"D" CURB
SEE NOTE
STANDARD DETAIL
LOCAL "A" & "B"
CUL-DE-SAC OPTION "2"
ISLAND, RESIDENTIAL
(MODIFIED)
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
SD 1-13M


STREET TREES SPACED PER CITY OF WILMINGTON SPECIFICATIONS (OPTIONAL)
TRIPLE SHREADED HARDWOOD MULCH OR SOD. 2" THK. (TYP.)
MODIFIED TYPE 'A' CURB (SEE DETAIL SD-7-01M)
SPLASH PAD
REVERSE CROWN OF PAVEMENT TO DIRECT DRAINAGE TO ISLAND (ELEVATIONS AS DIRECTED BY DESIGN ENGINEER)
2" MIN.
5:1 MAX
2' MIN
5:1 MAX
1:1 MAX (TYP.)
EX. SUB-GRADE
NON-COMPACTED LANDSCAPE MIX (SEE DETAIL SD 16-12)
COMPACTED SUB-GRADE (1 SIDE ONLY)
6" MIN. SEPARATION
SHWT
IMPERMEABLE LINER (AS DIRECTED BY DESIGN ENGINEER)
NON-COMPATED SUB-GRADE
UNDERDRAIN AS DIRECTED BY DESIGN ENGINEER (SEE DETAIL SD 16-13)
INFILTRATION TRENCH AS DIRECTED BY DESIGN ENGINEER (SEE DETAIL SD 16-13)
NOTES:
1. 10-YR STORM VELOCITY NOT TO EXCEED 2 FT/S.
2. UTILITY LINES MAY NEED TO BE SLEEVED OR RELOCATED.
3. SOD OR TRIPLE SHREDDED MULCH SHALL BE A MINIMUM OF 2" BELOW THE GUTTER LINE TO ALLOW FOR UNIMPEDED FLOW INTO ISLAND.
4. UNDERDRAIN AND IMPERMEABLE LINER TO BE USED ON CASE BY CASE BASIS, AT DESIGN ENGINEER'S DISCRETION.
5. SOIL TESTING REQUIRED WHEN UNDERDRAIN IS NOT USED.
6. DRAINAGE STRUCTURE MAY BE REQUIRED TO PREVENT FLOODING DURING LARGE STORMS.
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
STANDARD DETAIL
STORMWATER ISLAND CROSS SECTION
SD 16-15

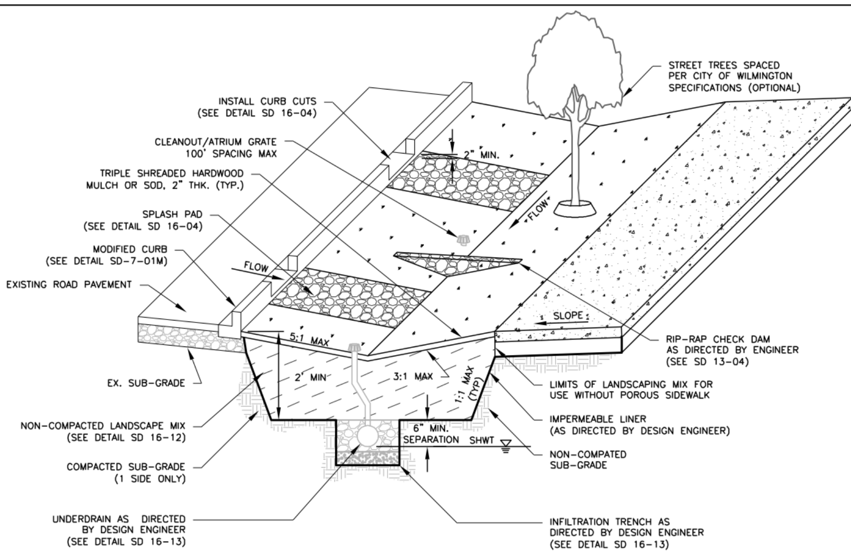

EXISTING PAVEMENT (TO REMAIN)
MODIFIED TYPE H CURB (PER SD 7-01M)
LANDSCAPE MIX (PER SD 16-12)
IMPERMEABLE LINER (AS DIRECTED)
SHWT
UNDERDRAIN AS DIRECTED BY ENGINEER (SEE DETAIL SD 16-13)
EXISTING PAVEMENT (TO BE REMOVED)
TOP OF LANDSCAPING MIX
4" MIN
6" MIN. SEPARATION
VARIES
CROSS SECTION (AT CATCH BASIN)
EXISTING CURB AND GUTTER (TO BE REMOVED)
EXISTING SIDEWALK AND UTILITY STRIP
EXISTING CATCH BASIN
NON-PERFORATED PIPE FOR CONNECTION TO STORM DRAINAGE (AS DIRECTED BY DESIGN ENGINEER)
CONNECT WITH WATERTIGHT SEAL
INFILTRATION TRENCH AS DIRECTED BY ENGINEER (SEE DETAIL SD 16-13)
NOTES:
SOIL TESTING REQUIRED WHEN NOT USING UNDERDRAIN
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
STANDARD DETAIL
CURB EXTENSION (2 OF 3)
SD 16-03b

STANDARD DETAIL

SIDEWALK SWALE WITH CURB & GUTTER

DATE: 2012
DRAWN BY: TLM
CHECKED BY: HCF
SCALE: NOT TO SCALE

SD 16-01



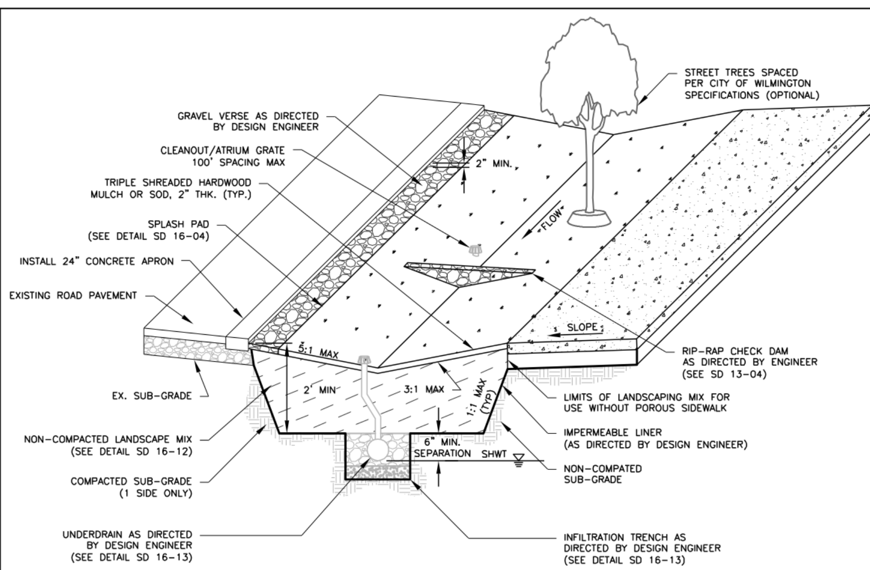
NOTES:
1. SWALE DEPTH SHALL BE DEEP ENOUGH TO PASS 10-YR STORM FLOW WITHOUT SURCHARGING GUTTER OR FLOODING PAVEMENT.
2. 10-YR STORM VELOCITY NOT TO EXCEED 2 FT/S.
3. UTILITY LINES MAY NEED TO BE SLEEVED OR RELOCATED.
4. TREES AND SHRUBS SHALL BE PLANTED AT LEAST 2' FROM CENTERLINE OF SWALE.
5. USE THE RAISED AREAS OF NEAR TREE PLANTINGS AS A BARRIER TO ENCOURAGE SHALLOW PONDING.
6. SOD OR TRIPLE SHREDDED MULCH SHALL BE A MINIMUM OF 2" BELOW THE GUTTER LINE TO ALLOW FOR UNIMPEDED FLOW INTO SWALE.
7. TOP OF LANDSCAPING MIX SHALL BE A MINIMUM OF 4" BELOW THE GUTTER LINE.
8. UNDERDRAIN AND IMPERMEABLE LINER TO BE USED ON CASE BY CASE BASIS, AT DESIGN ENGINEER'S DISCRETION.
9. SOIL TESTING REQUIRED WHEN UNDERDRAIN IS NOT USED.

STANDARD DETAIL

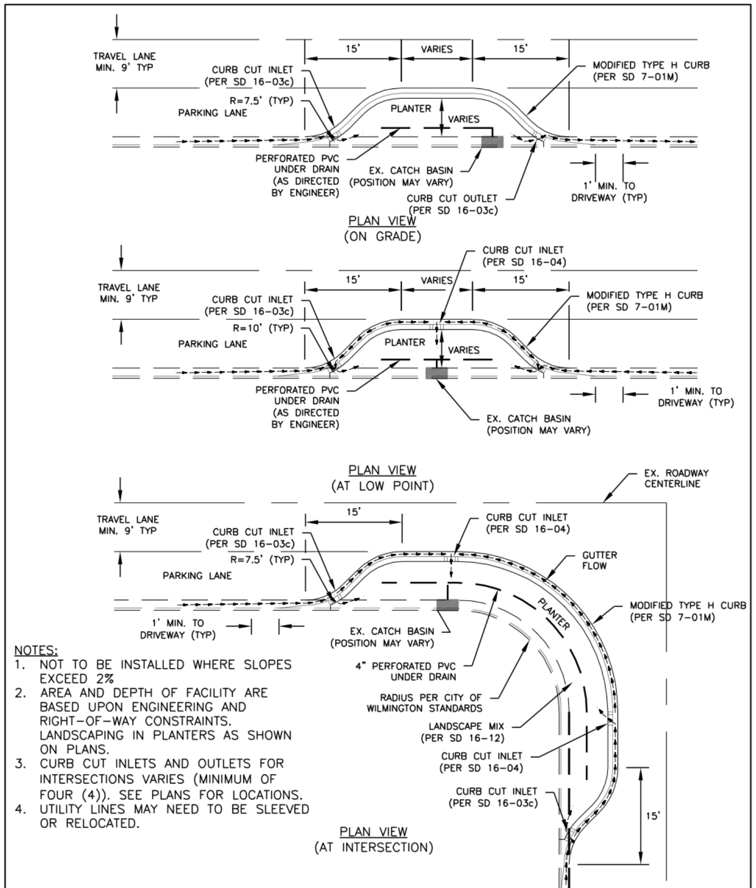
SIDEWALK SWALE WITHOUT CURB & GUTTER

DATE: 2012
DRAWN BY: TLM
CHECKED BY: HCF
SCALE: NOT TO SCALE

SD 16-02



NOTES:
1. SWALE DEPTH SHALL BE DEEP ENOUGH TO PASS 10-YR STORM FLOW WITHOUT SURCHARGING GUTTER OR FLOODING PAVEMENT.
2. 10-YR STORM VELOCITY NOT TO EXCEED 2 FT/S.
3. UTILITY LINES MAY NEED TO BE SLEEVED OR RELOCATED.
4. TREES AND SHRUBS SHALL BE PLANTED AT LEAST 2' FROM CENTERLINE OF SWALE.
5. USE THE RAISED AREAS OF NEAR TREE PLANTINGS AS A BARRIER TO ENCOURAGE SHALLOW PONDING.
6. SOD OR TRIPLE SHREDDED MULCH SHALL BE A MINIMUM OF 2" BELOW THE CONCRETE APRON TO ALLOW FOR UNIMPEDED FLOW INTO SWALE.
7. TOP OF LANDSCAPING MIX SHALL BE A MINIMUM OF 4" BELOW THE CONCRETE APRON.
8. UNDERDRAIN AND IMPERMEABLE LINER TO BE USED ON CASE BY CASE BASIS, AT DESIGN ENGINEER'S DISCRETION.
9. SOIL TESTING REQUIRED WHEN UNDERDRAIN IS NOT USED.



NOTES:

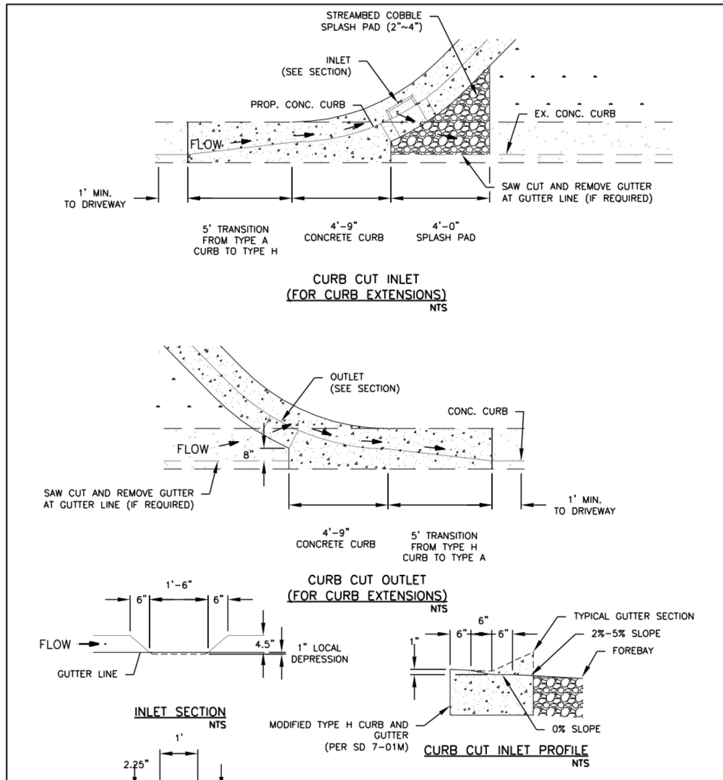
1. NOT TO BE INSTALLED WHERE SLOPES EXCEED 2%
2. AREA AND DEPTH OF FACILITY ARE BASED UPON ENGINEERING AND RIGHT-OF-WAY CONSTRAINTS. LANDSCAPING IN PLANTERS AS SHOWN ON PLANS.
3. CURB CUT INLETS AND OUTLETS FOR INTERSECTIONS VARIES (MINIMUM OF FOUR (4)). SEE PLANS FOR LOCATIONS.
4. UTILITY LINES MAY NEED TO BE SLEEVED OR RELOCATED.

STANDARD DETAIL

DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE

CURB EXTENSION
(1 OF 3)

SD 16-03a



NOTES:

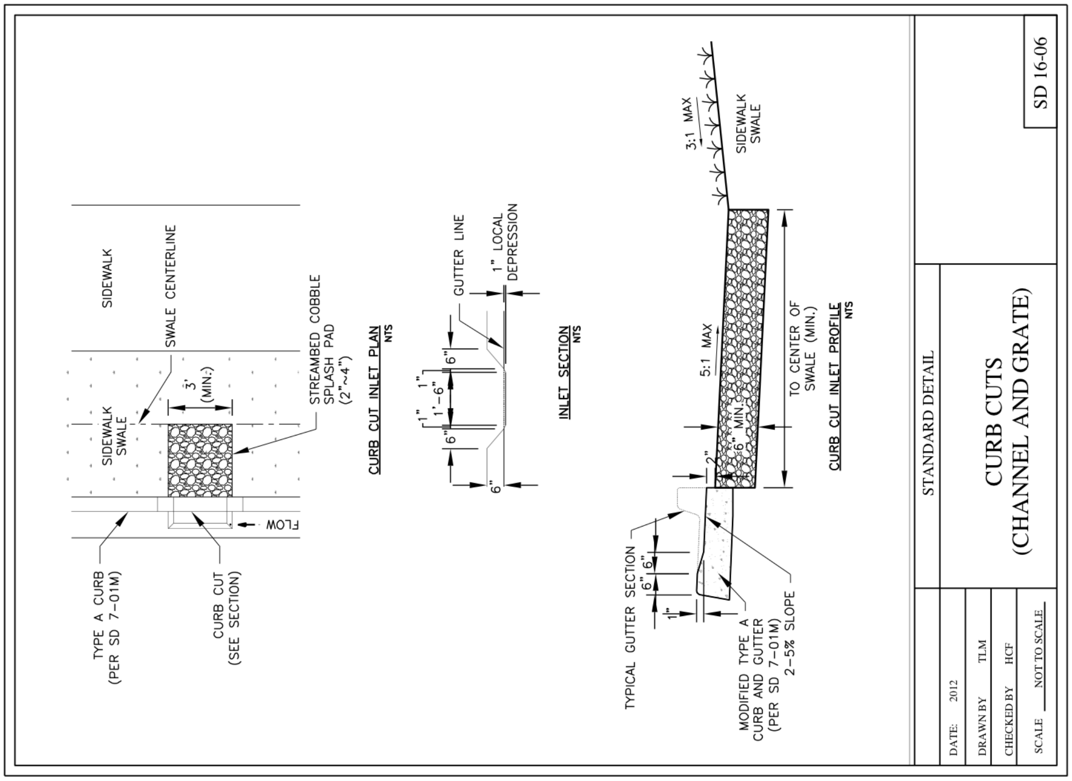
1. TO PREVENT PONDING, POSITION INLET CLOSER TO EXISTING CURB IF THE STREET CROSS-SLOPE IS >2%. ADDITIONAL INLETS CAN BE ADDED AS APPROVED BY THE CITY OF WILMINGTON.

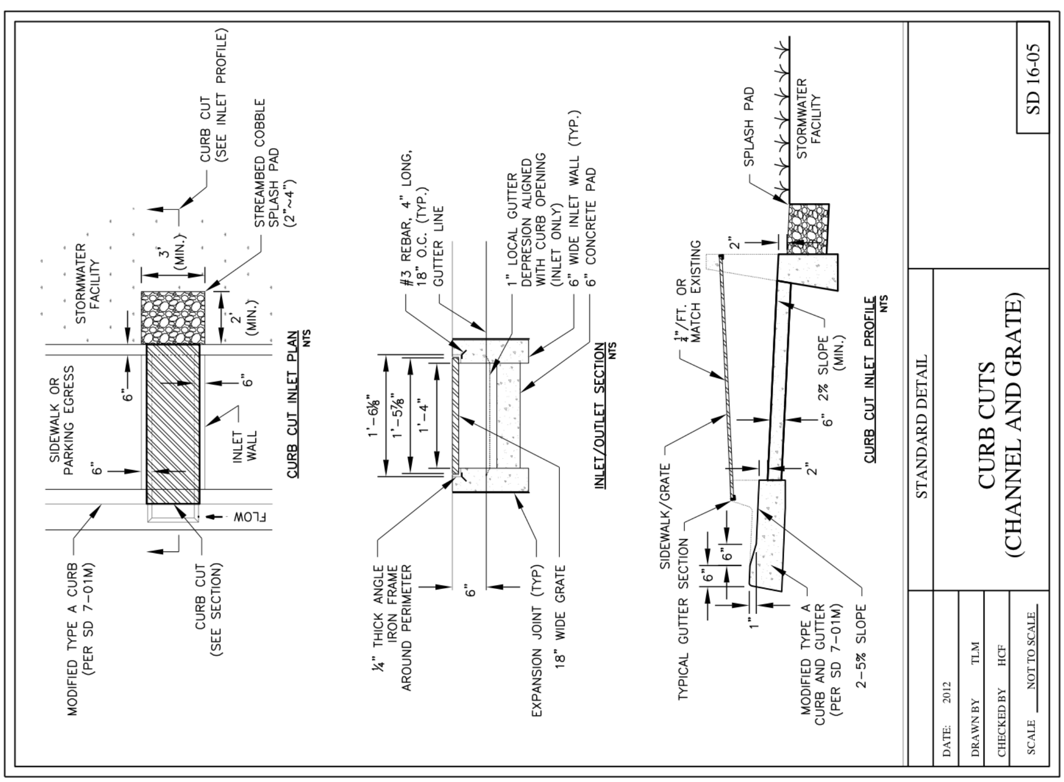
STANDARD DETAIL

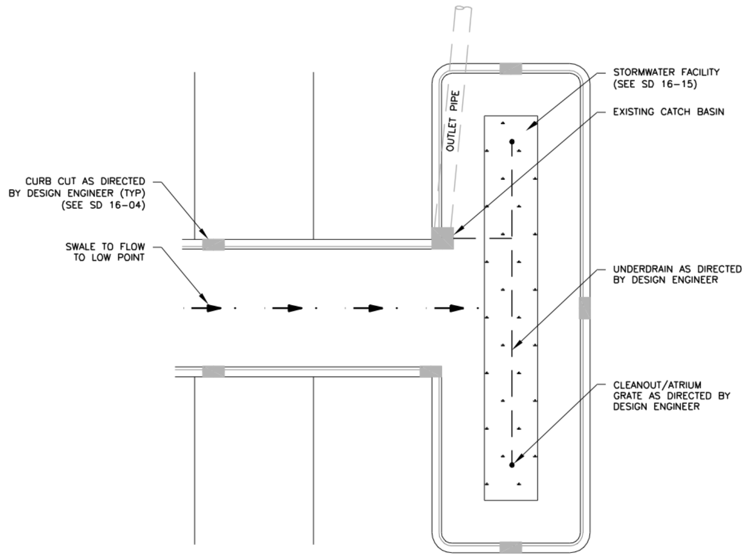
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE

CURB EXTENSION
(3 OF 3)

SD 16-03c


SIDEWALK
SWALE CENTERLINE
SIDEWALK SWALE
3' (MIN.)
STREAMBED COBBLE SPLASH PAD (2"~4")
TYPE A CURB (PER SD 7-01M)
CURB CUT (SEE SECTION)
FLOW
CURB CUT INLET PLAN
NTS
GUTTER LINE
1" LOCAL DEPRESSION
6"
1"
1'-6"
INLET SECTION
NTS
TYPICAL GUTTER SECTION
MODIFIED TYPE A CURB AND GUTTER (PER SD 7-01M)
2-5% SLOPE
2"
6" MIN.
5:1 MAX
3:1 MAX
SIDEWALK SWALE
TO CENTER OF SWALE (MIN.)
CURB CUT INLET PROFILE
NTS
STANDARD DETAIL
CURB CUTS
(CHANNEL AND GRATE)
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
SD 16-06


SIDEWALK OR PARKING EGRESS
STORMWATER FACILITY
3' (MIN.)
2' (MIN.)
6"
CURB CUT (SEE INLET PROFILE)
STREAMBED COBBLE SPLASH PAD (2"~4")
MODIFIED TYPE A CURB (PER SD 7-01M)
CURB CUT (SEE SECTION)
INLET WALL
FLOW
CURB CUT INLET PLAN
NTS
#3 REBAR, 4" LONG, 18" O.C. (TYP.)
GUTTER LINE
1" LOCAL GUTTER DEPRESION ALIGNED WITH CURB OPENING (INLET ONLY)
6" WIDE INLET WALL (TYP.)
6" CONCRETE PAD
1'-6⅝"
1'-5⅞"
1'-4"
¼" THICK ANGLE IRON FRAME AROUND PERIMETER
EXPANSION JOINT (TYP)
18" WIDE GRATE
INLET/OUTLET SECTION
NTS
SIDEWALK/GRATE
TYPICAL GUTTER SECTION
¼"/FT. OR MATCH EXISTING
2"
2% SLOPE (MIN.)
SPLASH PAD
STORMWATER FACILITY
MODIFIED TYPE A CURB AND GUTTER (PER SD 7-01M)
2-5% SLOPE
CURB CUT INLET PROFILE
NTS
STANDARD DETAIL
CURB CUTS
(CHANNEL AND GRATE)
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
SD 16-05



NOTES:

1. DESIGN ENGINEER TO PROVIDE DIMENSIONS OF ISLANDS.
2. SWALE DEPTH SHALL BE DEEP ENOUGH TO PASS 10-YR STORM FLOW WITHOUT SURCHARGING GUTTER OR FLOODING PAVEMENT.
3. 10-YR STORM VELOCITY NOT TO EXCEED 2 FT/S.
4. MAXIMUM PONDING DEPTH SHALL BE 6".
5. UTILITY LINES MAY NEED TO BE SLEEVED OR RELOCATED.
6. TREES AND SHRUBS SHALL BE PLANTED AT LEAST 2' FROM CENTERLINE OF SWALE.
7. SOD OR TRIPLE SHREDDED MULCH SHALL BE A MINIMUM OF 2" BELOW THE GUTTER LINE TO ALLOW FOR UNIMPEDED FLOW INTO SWALE.
8. TOP OF LANDSCAPING MIX SHALL BE A MINIMUM OF 4" BELOW THE GUTTER LINE.
9. UNDERDRAIN AND IMPERMEABLE LINER TO BE USED ON CASE BY CASE BASIS, AT DESIGN ENGINEER'S DISCRETION.
10. SOIL TESTING REQUIRED WHEN UNDERDRAIN IS NOT USED.

DATE: 2012	STANDARD DETAIL
DRAWN BY TLM	STORMWATER PARKING ISLAND
CHECKED BY HCF	
SCALE NOT TO SCALE	SD 16-16

RECOMMENDED PLANTS LIST FOR ALL STORMWATER DETAILS:

SCIENTIFIC NAME	COMMON NAME
CERCIS CANADENSIS	RED BUD
CORNUS FLORIDA	DOGWOOD
ILEX ATTENUATA	FOSTER'S HOLLY
ILEX VOMITORIA	YAUPON HOLLY
LAGERSTROEMIA INDICA	CRAPE MYRTLE
MAGNOLIA SOULANGIANA	SAUCER MAGNOLIA
MAGNOLIA STELLATA	STAR MAGNOLIA
NYSSA SYLVATICA	BLACK GUM
TAXODIUM DISTICHUM	BALD CYPRESS

NOTE:

OTHER PLANTS, INCLUDING TREES, SHRUBS, AND GROUND COVERS, MAY BE PERMITTED ON A CASE BY CASE BASIS AS APPROVED BY CITY STAFF.

DATE: 2012	STANDARD DETAIL
DRAWN BY TLM	RECOMMENDED STORMWATER PLANTING LIST
CHECKED BY HCF	
SCALE NOT TO SCALE	SD 16-14

NATURAL SOIL INFILTRATION
IN-SITU INFILTRATION MEDIA SHALL MEET THE REQUIREMENTS FOR INFILTRATION SYSTEMS AS DEFINED BY NCDWQ IN THE CURRENT VERSION OF THE BMP MANUAL. SOIL TESTS SHALL BE COMPLETED AND SUBMITTED WITH THE DESIGNS TO CONFIRM COMPLIANCE WITH THE SEPCIFICATIONS.

IN SITU SOIL SHALL MEET THE FOLLOWING SPECIFICATIONS

1. INFILTRATION RATE SHALL EXCEED 0.52 IN/HR, >3 IN/HR PREFERRED
2. P INDEX SHALL BE BETWEEN 10 AND 30
3. PARTICLE SIZE DISTRIBUTON
   a. COARSE / VERY COARSE SAND 70% TO 80%
   b. GRAVEL 10% TO 20%
   c. CLAY / SILTS < 10%
4. SOIL SHALL BE FREE OF CONTAMINATION FROM HEAVY METALS
5. SEASONAL HIGH WATER ELEVATION SHALL BE AT LEAST 2' BELOW FINISHED SURFACE
6. AREAS USED FOR EROSION CONTROL SHALL BE CLEANED OF ALL ACCUMULATED SILTS, FINES, SEDIMENTS, AND DEBRIS PRIOR TO CONVERSION

LOW FLOW MEDIA MIXES
FOR INSTALLATIONS REQUIRING ENGINEERED MEDIA WITH INFILTRATION RATES BETWEEN 0.52 IN/HR AND 10 IN/HR, THE GENERAL STANDARDS OF "BIORETENTION MIX" AS DEFINED IN THE CURRENT VERSION OF THE NCDWQ BMP MANUAL SHALL APPLY.

THE ENGINEER SHALL PROVIDE SOILS SAMPLES, AND RESULTS OF LABORATORY SOIL TESTS DOCUMENTING COMPLIANCE WITH THE SOIL SPECIFICATIONS PRIOR TO FINAL PROJECT APPROVAL.

HIGH FLOW MEDIA MIXES
FOR URBAN INSTALLATIONS OR OTHER INSTALLATIONS WHERE HIGHER INFILTRATION RATES ARE NECESSARY, ENGINEERED HIGH FLOW MEDIA MIXES MAY BE REQUIRED. HIGH FLOW FILTER MEDIA IS SPECIALLY DESIGNED TO OPTIMIZE THE CAPTURE AND REMOVAL OF NUTRIENTS FROM URBAN RUNOFF THROUGH THE USE OF A HIGH PERFORMANCE PEAT / SAND FILTER MEDIA. THE MEDIA SUPPORTS MICROBIOLOGICAL ACTIVITY THAT CAPTURES NUTRIENTS FROM STORMWATER RUNOFF TO SUPPORT PLANT LIFE WHILE ALLOWING RUNOFF TO FLOW THROUGH THE MEDIA LAYERS AT A HIGH RATE.

ENGINEERED HIGH FLOW MEDIA SHALL MEET THE FOLLOWING SPECIFICATIONS
1. PEAT MOSS 15% BY VOLUME
   a. LISTED BY ORGANIC MATERIALS REVIEW INSTITUTE
   b. 100% NATURAL PEAT (NO COMPOSTED, SLUDGE, YARD OR LEAF WASTE)
   c. TOTAL CARBON >85%
   d. CARBON TO NITROGEN RATIO 15:1 TO 23:1
   e. LIGNIN CONTENT 49% TO 52%
   f. HUMIC ACID >18%
   g. PH 6.0 TO 7.0
   h. MOISTURE CONTENT 30% TO 50%
   i. 95% TO 100% PASSING 2.0MM SIEVE
   j. > 80% PASSING 1.0MM SIEVE

2. POLLUTANT REMOVAL MINIMAL PERFORMANCE
   a. TSS 80%
   b. TOTAL NITROGEN 43%
   c. HEAVY METALS 58-82%
   d. PHOSPHORUS 50 %
   e. BACTERIA > 95%

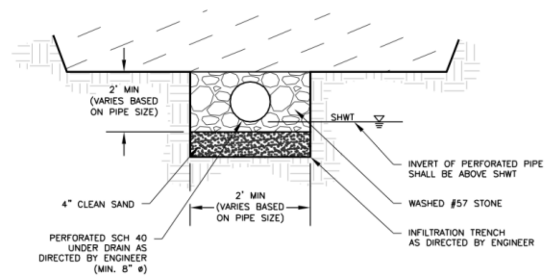
3. GENERAL SAND PARTICLE SIZE DISTRIBUTION NECESSARY TO SUPPORT FLOW RATES OF > 50INCHES / HOUR AT THE TIME OF INITIAL INSTALLATION.
   a. SAND - FINE <5%
   b. SAND - MEDIUM 10%- 15%
   c. SAND - COARSE 15% TO 25%
   d. SAND - VERY COARSE 40 % TO 45%
   e. GRAVEL 10% TO 20%
   f. CLAY / SILTS < 2%

STANDARD DETAIL

LANDSCAPE MIX SPECIFICATIONS

DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE

SD 16-12

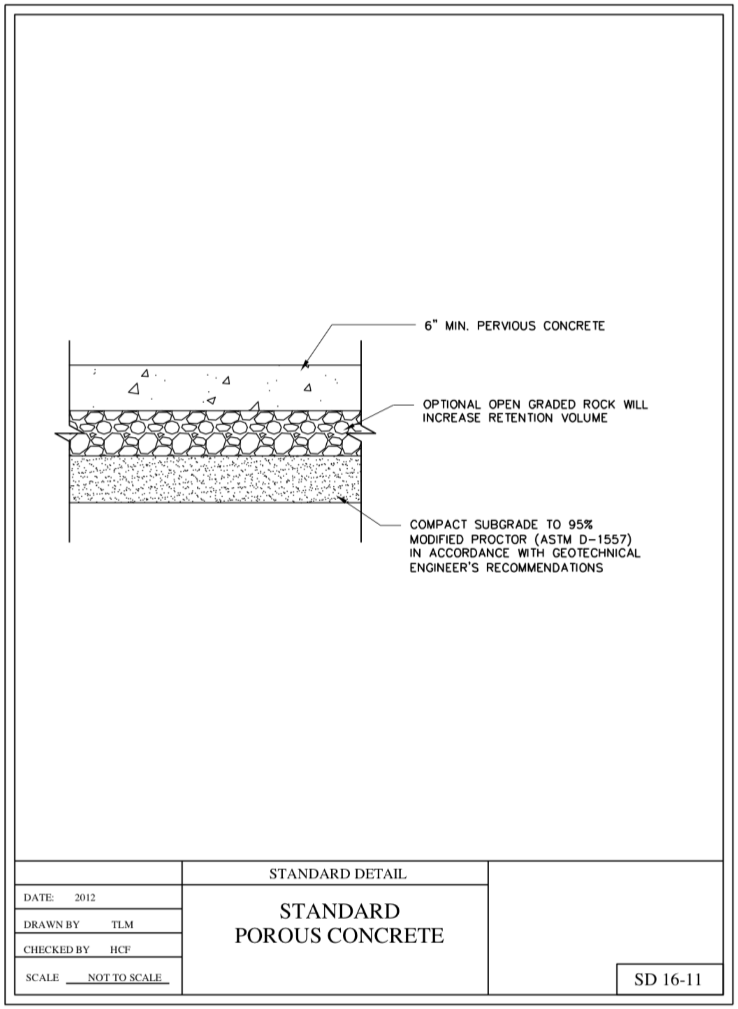


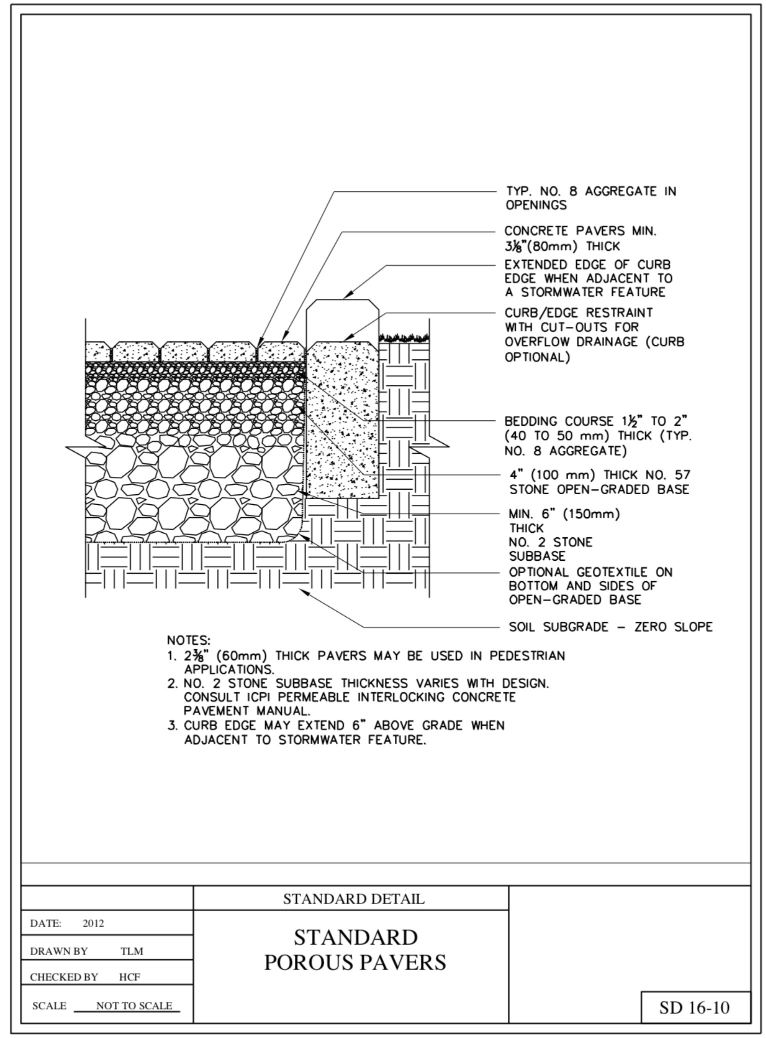
STANDARD DETAIL

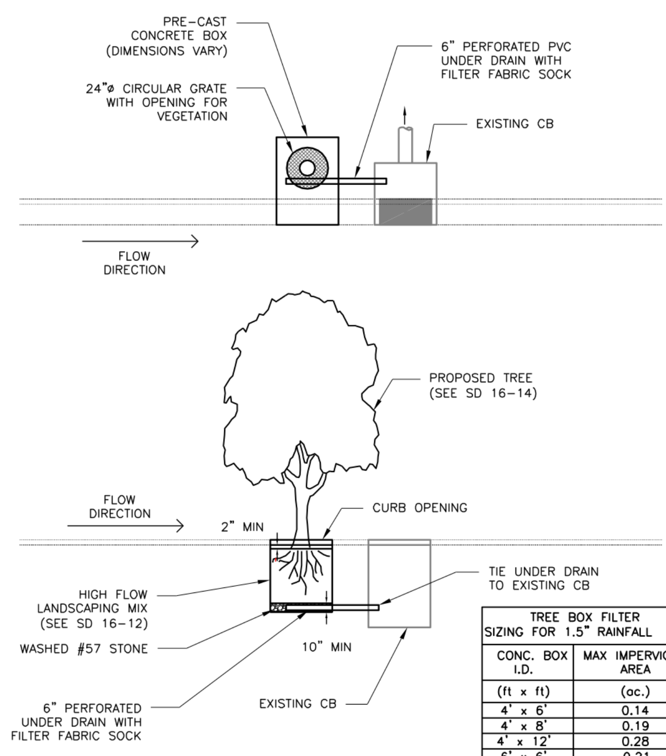
STANDARD UNDERDRAIN AND TRENCH

DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE

SD 16-13


6" MIN. PERVIOUS CONCRETE
OPTIONAL OPEN GRADED ROCK WILL INCREASE RETENTION VOLUME
COMPACT SUBGRADE TO 95% MODIFIED PROCTOR (ASTM D-1557) IN ACCORDANCE WITH GEOTECHNICAL ENGINEER'S RECOMMENDATIONS
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
STANDARD DETAIL
STANDARD
POROUS CONCRETE
SD 16-11


TYP. NO. 8 AGGREGATE IN OPENINGS
CONCRETE PAVERS MIN. 3⅛"(80mm) THICK
EXTENDED EDGE OF CURB EDGE WHEN ADJACENT TO A STORMWATER FEATURE
CURB/EDGE RESTRAINT WITH CUT-OUTS FOR OVERFLOW DRAINAGE (CURB OPTIONAL)
BEDDING COURSE 1½" TO 2" (40 TO 50 mm) THICK (TYP. NO. 8 AGGREGATE)
4" (100 mm) THICK NO. 57 STONE OPEN-GRADED BASE
MIN. 6" (150mm) THICK NO. 2 STONE SUBBASE
OPTIONAL GEOTEXTILE ON BOTTOM AND SIDES OF OPEN-GRADED BASE
SOIL SUBGRADE – ZERO SLOPE
NOTES:
1. 2⅜" (60mm) THICK PAVERS MAY BE USED IN PEDESTRIAN APPLICATIONS.
2. NO. 2 STONE SUBBASE THICKNESS VARIES WITH DESIGN. CONSULT ICPI PERMEABLE INTERLOCKING CONCRETE PAVEMENT MANUAL.
3. CURB EDGE MAY EXTEND 6" ABOVE GRADE WHEN ADJACENT TO STORMWATER FEATURE.
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
STANDARD DETAIL
STANDARD
POROUS PAVERS
SD 16-10



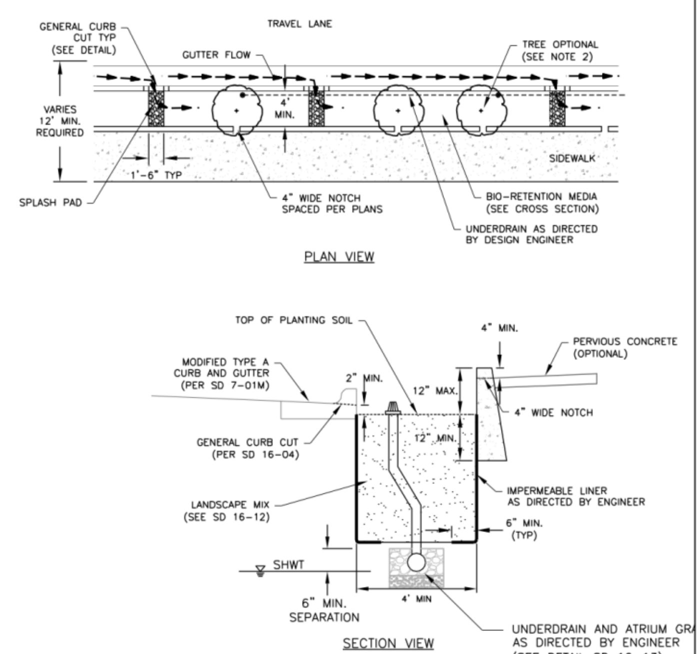
TREE BOX FILTER SIZING FOR 1.5" RAINFALL	
CONC. BOX I.D.	MAX IMPERVIOUS AREA
(ft x ft)	(ac.)
4' x 6'	0.14
4' x 8'	0.19
4' x 12'	0.28
6' x 6'	0.21
6' x 8'	0.28
6' x 10'	0.35
6' x 12'	0.42
7' x 13'	0.54

STANDARD DETAIL

DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE

STANDARD URBAN TREE PLANTER BOX

SD 16-09



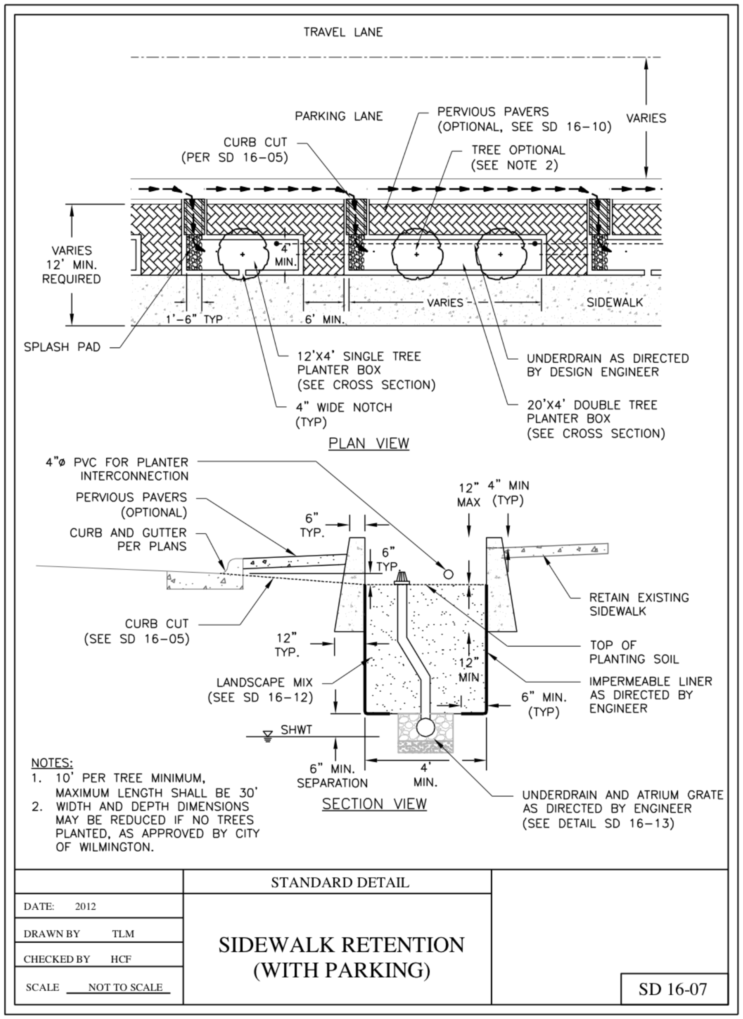
NOTES:
1. 10' PER TREE MINIMUM, MAXIMUM LENGTH SHALL BE 30'
2. WIDTH AND DEPTH DIMENSIONS MAY BE REDUCED IF NO TREES PLANTED, AS APPROVED BY CITY OF WILMINGTON.

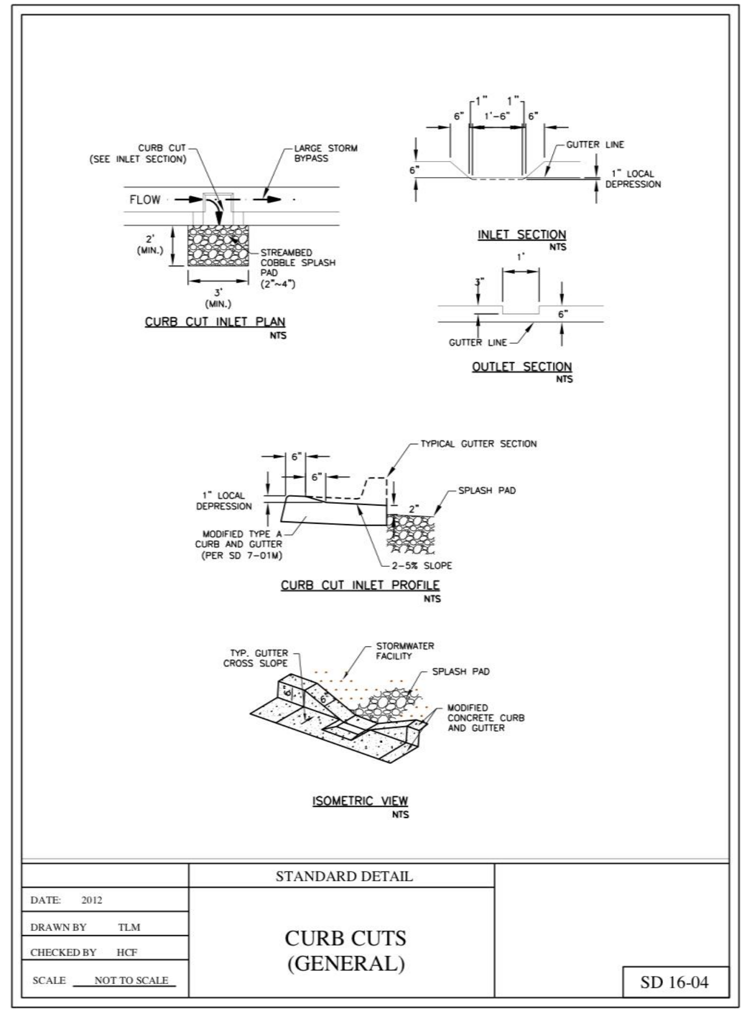
STANDARD DETAIL

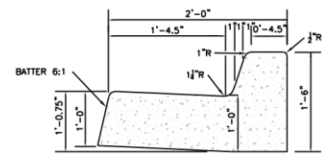
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE

SIDEWALK RETENTION (WITHOUT PARKING)

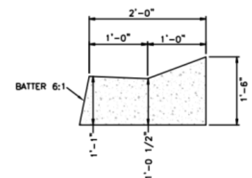
SD 16-08


TRAVEL LANE
PARKING LANE
VARIES
CURB CUT (PER SD 16-05)
PERVIOUS PAVERS (OPTIONAL, SEE SD 16-10)
TREE OPTIONAL (SEE NOTE 2)
VARIES 12' MIN. REQUIRED
4" MIN.
1'-6" TYP
6' MIN.
VARIES
SIDEWALK
SPLASH PAD
12'X4' SINGLE TREE PLANTER BOX (SEE CROSS SECTION)
4" WIDE NOTCH (TYP)
UNDERDRAIN AS DIRECTED BY DESIGN ENGINEER
20'X4' DOUBLE TREE PLANTER BOX (SEE CROSS SECTION)
PLAN VIEW
4"ø PVC FOR PLANTER INTERCONNECTION
PERVIOUS PAVERS (OPTIONAL)
CURB AND GUTTER PER PLANS
6" TYP.
6" TYP
12" MAX
4" MIN (TYP)
CURB CUT (SEE SD 16-05)
12" TYP.
12" MIN
RETAIN EXISTING SIDEWALK
TOP OF PLANTING SOIL
LANDSCAPE MIX (SEE SD 16-12)
IMPERMEABLE LINER AS DIRECTED BY ENGINEER
6" MIN. (TYP)
SHWT
6" MIN. SEPARATION
4' MIN.
SECTION VIEW
UNDERDRAIN AND ATRIUM GRATE AS DIRECTED BY ENGINEER (SEE DETAIL SD 16-13)
NOTES:
1. 10' PER TREE MINIMUM, MAXIMUM LENGTH SHALL BE 30'
2. WIDTH AND DEPTH DIMENSIONS MAY BE REDUCED IF NO TREES PLANTED, AS APPROVED BY CITY OF WILMINGTON.
STANDARD DETAIL
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
SIDEWALK RETENTION (WITH PARKING)
SD 16-07


CURB CUT (SEE INLET SECTION)
LARGE STORM BYPASS
FLOW
2' (MIN.)
STREAMBED COBBLE SPLASH PAD (2"~4")
3' (MIN.)
CURB CUT INLET PLAN
NTS
6"
1"
1'-6"
GUTTER LINE
1" LOCAL DEPRESSION
INLET SECTION
NTS
1'
3"
6"
GUTTER LINE
OUTLET SECTION
NTS
TYPICAL GUTTER SECTION
1" LOCAL DEPRESSION
SPLASH PAD
2"
MODIFIED TYPE A CURB AND GUTTER (PER SD 7-01M)
2-5% SLOPE
CURB CUT INLET PROFILE
NTS
TYP. GUTTER CROSS SLOPE
STORMWATER FACILITY
SPLASH PAD
MODIFIED CONCRETE CURB AND GUTTER
ISOMETRIC VIEW
NTS
STANDARD DETAIL
DATE: 2012
DRAWN BY TLM
CHECKED BY HCF
SCALE NOT TO SCALE
CURB CUTS (GENERAL)
SD 16-04



MODIFIED TYPE "A" CURB AND GUTTER



MODIFIED TYPE "H" CURB AND GUTTER

NOTES:
1. MODIFIED CURB AND GUTTER TO BE USED WHEN ADJACENT TO SURFACE STORMWATER FACILITIES.
2. CURB EXPOSURE IS 6". VARY ONLY AS SHOWN ON PLANS OR AS APPROVED.

DATE: 2012	STANDARD DETAIL	
DRAWN BY TLM	MODIFIED CURB AND GUTTER TYPES "A" AND "H"	
CHECKED BY HCF		
SCALE NOT TO SCALE		SD 7-01M