Storm Water Master Plan for the 1998
Annexation Area of the City of Wilmington
Volume II Appendix C:

Hewletts Creek Restoration Plan For Recreational and Shellfish Waters

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Dewberry & Davis, Inc.
A Dewberry Company

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ACRONYMS AND ABBREVIATIONS

AEC	Area of Environmental Concern
BMP	Best Management Practice
BST	Bacterial Source Tracking
CAMA	Coastal Area Management Act
CFU	Colony Forming Unit
CMSR	Center for Marine Science Research at UNC-W
COE	US Army Corps of Engineers
CRC	North Carolina Coastal Resources Commission
DCM	Division of Coastal Management, DENR
DEH	Division of Environmental Health, DENR
DENR	North Carolina Department of Environment and Natural Resources
DMF	Division of Marine Fisheries, DENR
DWQ	Division of Water Quality, DENR
EMC	North Carolina Environmental Management Commission
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
ICW	Intracoastal Waterway
mL	Milliliter
NCWRP	North Carolina Wetlands Restoration Program
NHC	New Hanover County
NPDES	National Pollutant Discharge Elimination System
PUD	Planned Development Units
ROW	Right of Way
SA	Waters Designated by DWQ for Shellfish Harvesting
SSO	Sewer System Overflow
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UNC-W	University of North Carolina at Wilmington
USGS	U.S. Geological Survey
1998 Area	1998 Annexation Area
303(d) List	List of waters not meeting water quality standards and uses. The list is published by DWQ as per requirements in section 303(d) of the federal Clean Water Act.

QUICK REFERENCE

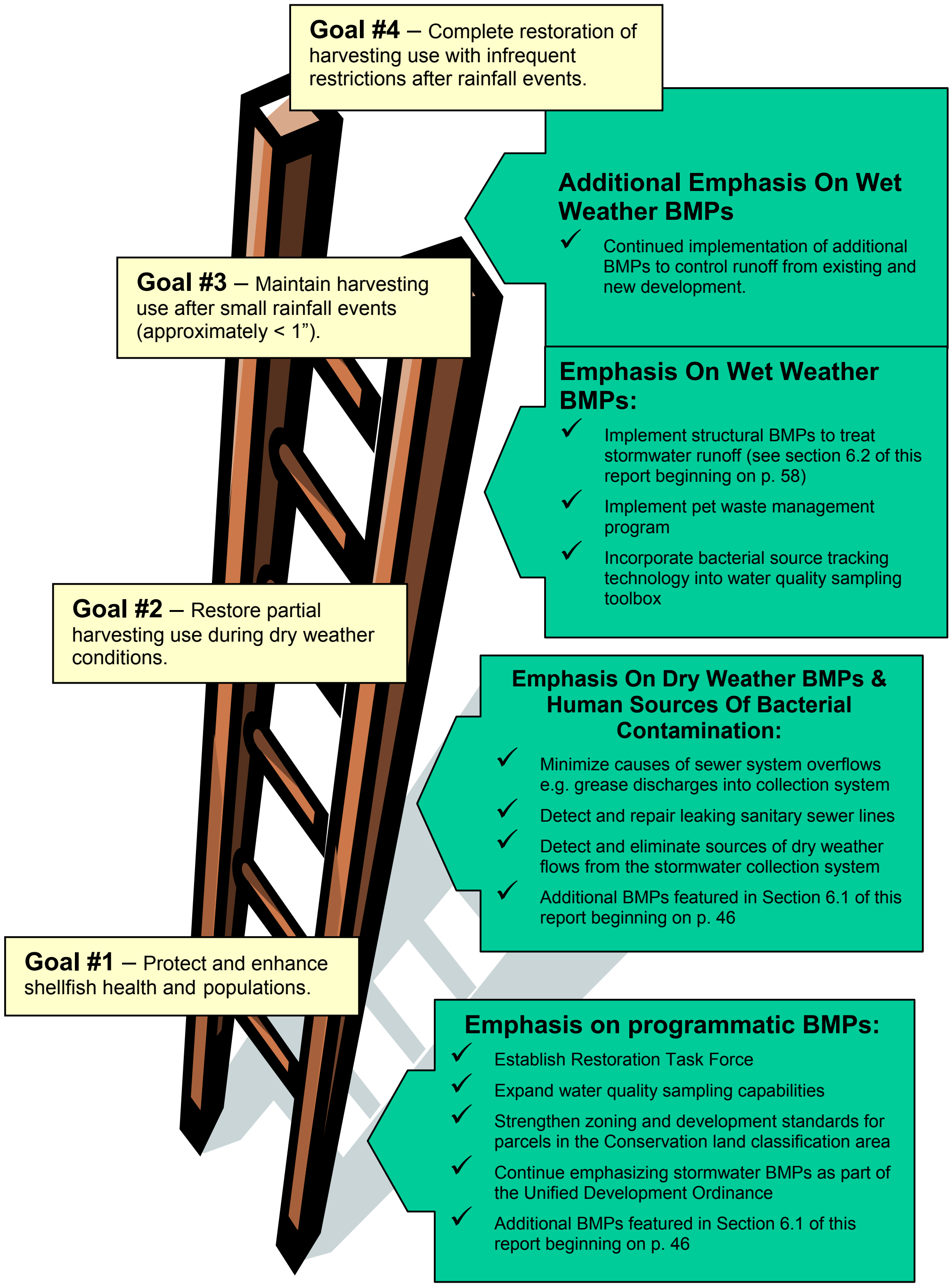
- **NC Division of Environmental Health's Shellfish Growing Area Classifications:**

DEH Classification	Description
Approved Area	Waters determined to be suitable for the harvesting of shellfish for direct market purposes. These areas are generally open to harvesting even after moderately heavy rainfall events. Very large rainfall events can result in temporary closures.
Conditionally Approved – Open Area	These waters are normally open to harvesting but are closed on a temporary basis in accordance with DEH management plan criteria. These criteria generally specify a rainfall amount within a given duration, which if exceeded, with will trigger an automatic closure of the waters (no sampling conducted). Water column and shellfish tissue sampling is conducted however before the waters are reopened.
Conditionally Approved – Closed Area	These waters are normally closed to shellfish harvesting due to elevated fecal coliform concentrations even after relatively small rainfall events. However, waters may be reopened on a temporary basis in accordance with management plan criteria and favorable sampling results. In practice procedures for reopening these waters are generally initiated after a request from commercial harvesters or other interested parties.
Prohibited Area	These waters are generally unsuitable for the harvesting of shellfish for direct market purposes. Prohibited areas are closed to harvesting due to either chronically elevated fecal coliform concentrations, other unsuitable water quality conditions e.g. low salinities, or the presence of man-made facilities e.g. marinas or wastewater outfalls.

- **Area within Hewletts Creek currently classified by DEH as *Prohibited* and thus closed to shellfish harvesting*:*** Approximately 121 acres extending upstream from near the mouth of the estuary. This area includes the March 2002 closure of 51 acres in the lower estuary which was previously classified as *Approved*.

- **NC's 2000 303(d) List of Impaired Waters:** Sixty-six (66) acres in the estuary have been given an Impaired use support rating on the 2000 303(d) List. With the next use support update (mid 2004) the full 121 acre closure area is expected to be deemed Impaired by the State. DWQ is currently reevaluating its listing procedures for shellfish waters. In the 2000 303(d) list all shellfish waters impaired by fecal coliform were grouped in a special section (Part 6) reserved for waters in which the technical basis for developing a TMDL were believed to not yet exist. With updates to the 303(d) list fecal coliform impaired shellfish waters will be slated for TMDL development.

- **Relationship Between Restoration Goals and Management Strategies:**



The graphic above is intended to illustrate the general sequence of implementation actions to reach each of the restoration goals. Implementation should start by building a foundation of strong city/county “inhouse” capabilities and local involvement. These programmatic-type BMPs will serve to direct the implementation of additional BMPs as we progress up the ladder. However, it is important to emphasize that many of the BMPs illustrated higher up the ladder would also help to reach the goals at the lower end of the latter, especially Goal #1. Hence, managers and stakeholders should continually evaluate implementation of a variety of BMPs as opportunities arise.

EXECUTIVE SUMMARY

Since its incorporation in 1740 the City of Wilmington's economic vitality has relied on the unique water resources of the lower Cape Fear River basin. From its founding as a principal seaport for the transport of goods, the City's economy has diversified tremendously. Tourism has become a major industry and the region enjoys over $300,000,000 annually in tourism revenues according to statistics from the NC Department of Commerce. Water related activities and destinations are some of the areas top attractions. The same water resources which attract tourists also draw business and industry to the area. As a result Wilmington has grown to the 9th largest municipality in North Carolina and continues to be one of the fastest growing cities in the state.

Unfortunately, Wilmington's steady growth has had a negative impact on the very water resources which were so vital in the early history of Wilmington and for which the City has become renowned. This report documents the decline in the water quality of Hewletts Creek, a tidal estuary draining the fast growing eastern portion of Wilmington, and focuses specifically on the loss of shellfish harvesting and the threats to the recreational use of the estuary.

The Problem

For years fisherman, tourist, and local residences have been prohibited by the State from harvesting oysters and clams living in the upper half of Hewletts Creek due to the unacceptable risk of disease from eating these shellfish. In March of 2002, the State extended the area restricted to harvesting due to excessive bacteriological contamination in the water. Currently, only a small area near the mouth of the estuary is safe for the consumption of shellfish. This area is meeting bacteriological water quality standards for the harvesting of shellfish by only the smallest of margins. In a recent shellfish sanitation report for the area, the NC Division of Environmental Health recommended close monitoring of the small remaining portion of the estuary safe for shellfish consumption for indications of continued degradation in water quality.

This disturbing trend in water quality is not unique to Hewletts Creek. Many other tidal creeks in the county have also experienced increased water quality problems. Recognizing the need for action and better information to manage this growing problem, the New Hanover County Tidal Creeks Program was formed and in 1993 a broad-based water quality sampling program was initiated. This program was initially funded by New Hanover County, the Northeast New Hanover County Conservancy, and the University of North Carolina at Wilmington (UNCW). Since that time the City of Wilmington has joined forces to support and expand the program.

With almost a decade of water quality data now available from sampling stations strategically located throughout the Hewletts Creek watershed, UNC-W scientists have published a series of reports documenting several key findings about water quality in Hewletts Creek. One principal finding is that bacteriological contamination is wide-spread throughout the watershed and that bacteria concentrations tend to increase as one travels upstream. In the mid and upper watershed bacteria concentrations at several stations have approached and even exceeded State standards set for safe recreational use of the waters.

The Goals

In response to this documented declining trend in water quality, Wilmington's Stormwater Services has developed this plan to protect and restore the recreational and shellfish harvesting uses of waters in the Hewletts Creek watershed. Since State water quality standards to protect human health from the consumption of shellfish are stricter than those standards set for protecting us during recreational use of the waters, this plan focuses principally on the restoration of the shellfish harvesting use as the goal yielding the greatest benefit.

At the heart of this plan is a set of hierarchical goals which guides the prioritization of management actions. The plan recommends striving for restoring the shellfish harvesting use of the waters during dry weather periods as the first priority. Since wet weather sources of bacterial contamination are generally more difficult to control, maintaining the harvesting use after rainfall events will require broader based actions.

The Strategy

A key finding from the analysis is that the City will have to employ new, long-term water resource protection measures in order to meet water quality enhancement goals. Although the City is already undertaking many activities to accommodate more stringent environmental regulations, such as CAMA and NPDES Phase II stormwater rules, these efforts do not specifically address and minimize the wide variety of sources contributing to bacterial contamination in the estuary. Relying on existing regulations alone will not be effective in reversing the declining trend in water quality within Hewletts Creek.

As a basis for recommending long-term restoration strategies the plan evaluates a variety of potential sources of bacterial contamination to the estuary. Information has been compiled on sources such as sanitary sewer system overflows, failing septic systems, illicit discharges to the stormwater drainage system, among others. Given the dominance of residential land uses in the watershed, the plan reveals that pets, particularly dogs, appear to be a significant source of bacterial pollution. Dog waste polluting waterways is not a new problem nor is it unique to Hewletts Creek. In a recent article (6/6/02) published in USA TODAY entitled *"Dog Waste Poses Threat To Water"* the reporter describes that at some beaches and swimming areas across the country visitors must stay out of the water for their safety. Dog waste is known to harbor such disease causing organisms as E. coli, salmonella, and giardia. Typically these organisms are transported from the dog waste to the waterway via untreated stormwater runoff.

While encouraging pet owners to clean up after their dogs is an important component of the overall restoration strategy, aggressive and proactive stormwater management will also be essential to ensure success. Structural stormwater treatment facilities such as detention ponds, stormwater wetlands, and bioretention areas need to be constructed at key locations throughout the watershed to treat runoff contaminated with disease causing organisms. While CAMA regulations require new development to treat runoff, much of the existing development in the watershed predates these rules. Numerous older residential and large commercial developments, such as Long Leaf Mall, have no stormwater treatment facilities to speak of. Retrofitting these developments with controls to provide at least partial stormwater treatment will need to be a long-term priority of the restoration effort.

This plan details eleven potential stormwater retrofit projects as part of the overall restoration strategy. Anticipated benefits include the stabilization of eroding stream banks, reduction in bacterial, harmful nutrient, and other pollutant loadings to the estuary, as well as recreational and environmental education opportunities. These retrofit projects however tend to be more costly than stormwater controls incorporated from the outset into new developments. The retrofit projects outlined in this plan are estimated to cost over $5.9 M which does not include any land acquisition costs.

While the cost of restoring the estuary is high, the long term cost to the community of a continuing decline in water quality is even higher. The 1995 Money Magazine "Best Places to Live" survey reported that clean water and air were the two most important factors for choosing a place to live. Real estate values are higher when home buyers, community, and business leaders perceive local waterbodies to be clean and safe. A study of real estate values on Lake Champlain in the northeastern US found that houses in an area with good water quality fetch 20% more than houses in an area with poorer water quality.

The decline in the water quality of Hewletts Creek did not occur over night nor will the process of restoring it. However, there are many reasons to be optimistic that significant improvements can be made. A number of North Carolina communities, such as the Charlotte/Mecklenburg County area, have made tremendous progress over recent years reducing bacterial contamination of their waterways. These successes have been the result of a coordinated effort by numerous local government agencies, universities, and interested citizen groups. Fortunately, these same type organizations in the Wilmington area are already in place, mobilized, and educated on water quality issues, which gives us a big head start towards tackling this problem. With strong and coordinated support from these organizations the restoration and protection of Hewletts Creek can be achieved thereby ensuring the future use and enjoyment of its waters for years to come.

Part 1

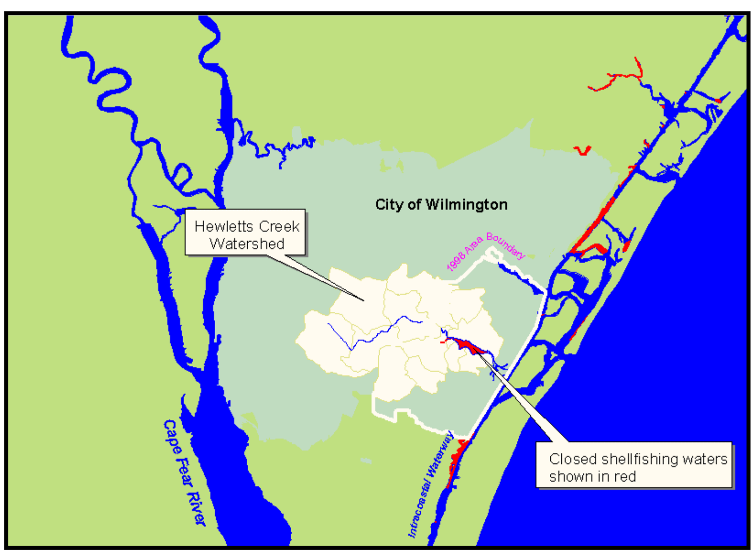
INTRODUCTION

Why is this plan needed?

The City of Wilmington is the 9th largest NC municipality and one of the fastest growing cities in the state. Between 1990 and 2000 Wilmington has experienced an average growth rate of approximately 36% over the period compared to a statewide average of 21%.[1] The City is located in New Hanover County between the Cape Fear River to the west and the Intracoastal Waterway to the east. These water bodies, along with the tidal creeks and nearby beaches, have been one of the primary reasons why the Wilmington area is such a desirable place to live and work. However, impacts from this growth have stressed these valuable water resources, especially the ecologically sensitive tidal creeks and estuaries.

Hewletts Creek is one of these threatened tidal creeks. Its watershed includes central and eastern portions of the City (Figure 1.1). Hewletts Creek is classified by the Division of Water Quality (DWQ) as SA-High Quality Waters. The SA designation means that the best intended use of the waters is for shellfishing harvesting for market purposes. The upper half of the Hewletts Creek estuary has been closed to shellfish harvest for many years due to excessive bacterial (fecal coliform) contamination. The NC Division of Environmental Health (DEH) is the lead state agency responsible for protecting public health from the consumption of contaminated shellfish. The most recent compilation and analysis of water quality sampling data collected by DEH forced the agency to recommend closure of an addition 51 acres in the lower estuary in March 2002.

Figure 1.1 Hewletts Creek watershed and vicinity.



Source: NC Division of Water Quality

[1] Population data from the North Carolina State Data Center.

In 1998 Wilmington annexed a 9.2 mi^2 portion of New Hanover County east of the City. The 1998 Annexation Area includes approximately 40% of the Hewletts Creek watershed as shown in Figure 1.1 (p. 1). With an established county sanitary sewer system already serving much of the 1998 Area, in combination with additional city water, sewer, and sanitation services now extending throughout the watershed, continued growth pressures are assured.

Looking into the future will citizens be able to harvest shellfish from Hewletts creek in 5, 10, or 20 years? What will water quality be like if all property owners along the creek build as allowed per existing local zoning and development ordinances? This plan was developed to address these questions and to serve as a springboard for collaborative efforts between local and state agencies to implement protective and restoration measures.

The Hewletts Creek restoration plan has been developed as an integrated subcomponent of a larger masterplan study to address stormwater issues in the 1998 Annexation Area (1998 Area). The 1998 Area is bounded to the north by Bradley Creek, to the south by Whiskey Creek, and includes approximately 40% of Hewletts Creek watershed. For the purposes of this study issues affecting shellfish health and harvesting for the entire Hewletts Creek watershed, both inside and outside the 1998 Area, are being considered.

What are the benefits and challenges?

Given that the City is already doing a lot to meet state environmental regulations, such as CAMA and the upcoming NPDES Phase II stormwater rules, why should they consider doing more? A key finding of our analysis is that the City needs to employ new, long-term water resource protection measures if it wants to meet the water quality and shellfish habitat protection goals established for the watershed by the City, County, and various State agencies. In certain respects the existing regulations are insufficient to prevent bacterial contamination, a key pollutant of interest in this report. In other cases development has occurred before regulations were promulgated and little to no Best Management Practices (BMPs) are in place to protect water quality.

Benefits

Locally Driven Goals And Management Strategies

Many environmental regulations implemented at the local level are driven by USEPA and NCDENR requirements. Typically these regulations are designed to be broadly applied over numerous jurisdictions to meet statewide or general water quality targets. For example, NPDES Phase II regulations will require subject local governments to develop a general public education and outreach program to educate citizens on the impacts of stormwater runoff. This plan, however, is based on targeted local water quality goals and on locally crafted management options to meet specific local needs.

Maximizing Locally Available Resources

The City of Wilmington is very fortunate to have many of the key personnel and resources needed to achieve the goals of the plan geographically located within the city. For example, the City already has an agency, Stormwater Services, specifically charged with managing stormwater related water quality and quantity issues. Stormwater Services has a dedicated funding source through its stormwater utility and provides an essential leadership role in water quality protection initiatives.

The University of North Carolina at Wilmington (UNC-W) has numerous professors, graduate students, and technicians actively pursuing research projects directly related to water quality and shellfish habitat protection. Research originating from UNC-W provided the scientific basis for a number of the recommendations in this plan.

The New Hanover County Tidal Creeks Program was initiated in 1993 in response to continued closures of shellfish waters in the county. The program is composed of representatives from the New Hanover County Planning Department, UNC-W, Northeast New Hanover Conservancy, City of Wilmington, local business and industry, and other organizations. A core function of the project is to routinely monitor water quality in the county's tidal creeks and other water bodies of interest. A Tidal Creeks Citizen Advisory Board has been formed and is responsible for seeking and developing plans to protect or enhance the aquatic resources of the tidal creeks. The board makes recommendations on how best to utilize Clean Water Management Trust Fund monies for these purposes. These recommendations are then presented to the New Hanover County Board of Commissioners for approval. The Tidal Creeks Program provides the City with a conduit for reaching other organizations with common goals.

The NC Division's of Marine Fisheries, Water Quality, and Environmental Health all have field offices located in Wilmington. These state agencies have experienced personnel and resources which can contribute towards meeting the goals of the plan.

Targeting And Prioritizing Grant Applications

The plan provides the technical support for selecting and prioritizing implementation of Best Management Practices. This information can be used to provide the necessary support for future grant requests to state and federal agencies.

Preserving Quality Of Life

The City and County's water resources, which include the tidal creeks, are without question one of the key natural features of the area that provide for the high quality of life Wilmington citizens enjoy. However, our desire to live and work near the water has resulted in significant deterioration of the very natural resources that drew us to the area in the first place. The recommendations in this plan help to preserve the water resources and quality of life so important to citizens by outlining specific actions the City and interested stakeholders can take to minimize further impacts as growth continues.

Economic Rewards For The Community

The economies of Wilmington and New Hanover County depend in large measure on clean water; and we all pay when its polluted. Each year Money Magazine conducts a "Best Places to Live' survey. In the 1995 survey clean water and air were the two most important factors for choosing a place to live and were more important than low crime rates and low taxes.[2] Real estate values are higher when home buyers, community and business leaders perceive area waterbodies to be clean and safe. A study of real estate values on Lake Champlain (northeastern US) found that houses in an area with good water quality fetch 20% more than houses in an area with poorer water quality.[1]

While the commercial market value of the shellfish in Hewletts Creek is likely very modest, other direct and indirect economic benefits of an unpolluted Hewletts Creek are very significant.[3] Beaches, rivers, lakes, and estuaries are the top vacation choices of Americans.[1] According to NC Department of Commerce statistics the Wilmington/New Hanover County area rated 9th in travel impact of the 100 counties in 2001. County-wide over $300,000,000 in tourism revenues were generated supporting over 5,590 jobs directly attributable to the travel and tourism industry. Water related activities and destinations are some of the areas top attractions, thus clean water is critical to ensuring the flow of tourism dollars.

In addition to tourism and real estate values, NC's commercial marine fisheries yields depend highly on clean water. Estuaries such as Hewletts Creek provide critical nursery areas for the development of young fish and shellfish. Ninety percent (90%) of NC's fisheries depend on these nursery areas for at least a portion of their life cycles. The Hewletts Creek estuary is designated by the NC Division of Marine Fisheries as a Primary Nursery Area. Other designations include Secondary Nursery Areas and Special Secondary Nursery Areas. NC averages over $100,000,000 worth of commercial finfish and shellfish landings annually. The amount and value of this harvest is inextricably linked to clean water and good estuarine habitat.

Challenges

Balancing Competing Needs

As more development occurs within the Hewletts Creek watershed there becomes a greater need to manage stormwater runoff in order to prevent flooding of homes and businesses. Increases in the area of impervious surfaces, such as parking lots and roof tops, often translates into a need for greater drainage capacity of the stormwater conveyance system. While increased drainage capacity helps to minimize property damage from flooding it also unfortunately helps to maximize pollutant loading delivered to downstream shellfish waters. Hence, managers are faced with a difficult balancing act

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[2] US EPA. 1996. Liquid Assets: A Summertime Perspective On The Importance Of Clean Water To The Nation's Economy. EPA-800-R-96-002. Office of Water, US Environmental Protection Agency, Washington, DC.

[3] "Evaluating the Socioeconomic Impacts of Temporary Shellfishing Closures". 2001. Angela Corridore. Masters Project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University.

of providing for the necessary drainage to protect property while also minimizing water quality impacts directly attributable to enhanced drainage.

The recommendations in the City's July 2001 Final Report of the Watershed Protection Roundtable outline actions the City and County can take to minimize water quality impacts from stormwater runoff. Incorporating these recommendations into relevant sections of the City and County's Unified Development Ordinance will help attain the goals outlined in this plan.

Public Involvement

Structural Best Management Practices (BMPs), e.g. wet detention ponds and constructed wetlands, are important components in the plan to achieve our goals. However, these BMPs alone will not be enough. Changes in people's behavior, e.g. cleaning up after their pets, also play a critical role in reducing bacterial contamination of shellfish waters. Encouraging citizens to adopt water quality "friendly" practices into their everyday lives requires a well organized and targeted effort. Mass media, such as radio and TV, can be the most effective means of reaching people most likely to change certain water quality "unfriendly" behaviors. However, these media outlets can be very expensive to employ and require a sustained campaign in order to be effective. The City will need to take advantage of all its public outreach resources in order to engage the public at the level needed to achieve the goals of this plan.

Urban Stormwater Retrofitting

Stormwater retrofitting refers to the process of evaluating and constructing BMPs in existing developed areas not currently served by any stormwater treatment practices. Ideally, retrofit situations involve little to no major modifications to the existing development. Space is almost always the initial factor which limits whether or not a stormwater retrofit BMP is considered further for a given urban area. If space is not available then managers typically have three options to choose from:

1) Do nothing
2) Construct an on-line BMP (BMP built within the stream or waterbody itself); or
3) Acquire property to make space for an off-line BMP

Obviously, 1 and 3 are not very satisfactory or politically feasible options. Option 2 is not without controversy either. US EPA and certain other state and federal agencies often discourage on-line BMPs on perennial and intermittent streams for a variety of reasons. While in some cases it is possible to get an on-line BMP permitted, the process can be very lengthy and costly.

Limited retrofitting options emphasize the need for strong public involvement and local program initiatives to control sources of pollution before our waterways become impacted.

Broad-based, Sustained, Long-term Management

Given that it can take several years to identify, obtain funding for, design, and ultimately construct a single structural stormwater BMP, successful restoration of water quality in the watershed will require broad-based, sustained management effort. Management measures must be integrated into the activities of multiple organizations within Development Services, Public Utilities, and Public Services and Facilities. To accomplish this means elevating the goals of this plan beyond Stormwater Services.

Who should read this plan?

The existing and future problems identified in this plan warrant a broad-based management effort. Any group that influences or is affected by water quality management or land use decisions should read this report. In addition to City and County units of government, State agencies can use this plan to enhance their understanding of local watershed issues and use the information to more effectively coordinate their planning and management activities. Key readership groups might include:

✓ City & County Land Use Planners	✓ Northeast New Hanover Conservancy
✓ Special Events Coordinators	✓ UNC-W Researchers
✓ Sanitary Sewer System Managers	✓ Tidal Creeks Advisory Board Members
✓ County Public Health Department Staff	✓ NCDEH Shellfish Sanitation Section Staff
✓ NCDWQ Stormwater Permitting Staff	✓ NCDMF Coastal Habitat Protection Planners

Part 2

GOALS AND OBJECTIVES

A watershed management goal represents a vision or desired state for future water quality conditions and uses of the resource. In order to measure progress towards meeting a goal indicators or benchmarks are established which allow managers to evaluate the effectiveness of decisions.

Sign posted in the Hewletts Creek watershed advertising availability of local oysters.

To foster interagency cooperation and maximize the potential resources available to the City a set of goals and indicators has been crafted to address the issues identified in this plan. These goals were carefully formulated to be consistent with the program objectives of the following local and State initiatives:

- City of Wilmington/New Hanover County CAMA Land Use Plan
- New Hanover County Tidal Creeks Program
- NC Division of Marine Fisheries' Oyster Fishery Management Plan
- NC Division of Marine Fisheries' Coastal Habitat Protection Plan
- NC Division of Water Quality's TMDL and NPDES Phase II Programs

Tiered Goal Approach

The current water quality problems in Hewletts Creek did not occur overnight, nor will they be fixed in a day, week, or even a year. A long-term, sustained management effort by many parties will be required to reach our ultimate objectives. In order to keep these parties actively engaged in the restoration efforts a tiered goal setting approach is proposed. The hierarchical system of goals outlined below has been designed to recognize the following factors:

- Shellfish reefs are an important habitat type in intertidal and subtidal zones. These reefs often are the only structural habitat feature in these zones and afford small aquatic organisms protection from predation. Shellfish reefs are an integral component of a healthy estuarine ecosystem.

- As filter feeders, shellfish have the capacity to cleanse the water of pollutants which would otherwise contribute to additional water quality problems. While this cleansing action can contribute to the accumulation of pollutants within the shellfish, which is altogether another problem with respect to consuming the shellfish, water quality improvements have been scientifically documented from the presence of healthy shellfish.

- The shellfish fishery provides important economic benefits to the community. Shellfish harvesting, both commercial and recreational, is an activity which contributes to the quality of life in the Wilmington area.

Oyster harvest in a Wilmington tidal creek.
Source: Wilmington Morning Star

Goal #1 – Protect and enhance shellfish health and populations in Hewletts Creek.

Indicators of goal attainment *– Researchers at the UNC-W Benthic Ecology Lab have developed a series of measures of overall shellfish (specifically oyster reef) health which are relatively easy to collect in the field. Only a modest amount of training is required in order to learn the proper data collection techniques. These measures are designed to be collected on an annual basis in order to monitor changes in shellfish health over time. While collecting the data is relatively straight foreword, interpreting it is more complicated. Therefore, it is recommended that a qualified benthic biologist review and interpret the data every 2-3 years and provide a summary of the findings to the City. UNC-W researchers have agreed in principal to assist the City in establishing and maintaining this monitoring program. In order to track attainment of this goal benchmarks need to be established which provide a means of comparison between the existing and desired condition of the shellfish population. Since these benchmarks would likely be a function of the ecological carrying capacity of the estuary, it is recommended that the City work with UNC-W to define target benchmarks (e.g. oyster reef coverage, density, and structure) customized specifically for Hewletts Creek.*

Shellfish provide a number of ecologically significant functions. There is a growing body of scientific research documenting the water cleansing capabilities these filter feeders have on water quality. In addition, shellfish reefs have been shown to provide important habitat for a variety of flora and fauna in the intertidal and subtidal zones. Hence, the protection and enhancement of healthy shellfish populations provides the foundation upon which additional goals build upon.

Goal #1 is consistent with objectives outlined in the NC Oyster Fishery Management Plan (Draft 3 July 2000), NC Hard Clam Fishery Management Plan (Draft 2 March 2000), NC Coastal Habitat Protection Plan (DENR Draft January 2002), and the Cape Fear River Basinwide Water Quality Plan (July 2000).

Goal #2 – Improve water quality so as to restore the partial harvesting use of the waters during dry weather periods.

Indicators of goal attainment – *Upgrade the upper portion of the Hewletts Creek estuary from a DEH growing area classification of Prohibited to Conditionally Approved – Closed (see description of DEH shellfish growing area classifications in the Quick Reference section on p. iii).*

This is the first of three hierarchical goals (#2 - #4) designed to address the commercial and recreational harvesting use of the shellfish resource. Most of the State's water quality and shellfish resource management programs are centered around harvesting as the best intended use of these waters. As of this report the upper portion of the Hewletts Creek estuary is classified by DEH as *Prohibited* and the lower portion is classified as *Approved*. A *Prohibited* classification means that the waters are managed to protect public health by posting the *Prohibited* area as closed to harvesting year-round (with the possible exception of relay harvesting by special permit). DEH does not conduct routine water quality and shellfish tissue sampling in *Prohibited* waters.

The lower Hewletts Creek estuary is classified as *Approved* and are generally open to harvesting the vast majority of the commercial harvesting season. *Approved* waters generally meet bacterial water quality standards even after small to moderate rain events and hence are not often closed. The DWQ assigns a Fully Supporting shellfishing Use Support rating to *Approved* waters.

Our goal of upgrading the classification of the upper Hewletts Creek estuary from Prohibited to Conditionally Approved – Closed is designed to restore the partial use of the waters to harvesting. A Conditionally Approved – Closed classification means that the waters are managed to protect public health by keeping the waters generally closed to harvesting with the exception of after extended periods of dry weather. Fecal coliform bacteria do not survive very long in salt water. During extended periods of dry weather little additional bacteria loadings from the watershed are washed into the estuary from stormwater runoff. Hence, water quality standards for bacteria are often met during dry weather creating a potential situation were shellfish can be harvested and consumed raw with a reduced risk to public health.

While Conditionally Approved – Closed waters are closing to harvesting most of the year, the re-opening of waters for limited periods of time during dry weather does represent a step forward towards restoring the harvesting use.

Goal #3 – Improve water quality so as to maintain the harvesting use of the waters during most periods with the exception of after significant rain events (approximately >1”).

Indicators of goal attainment – *Upgrade the upper portion of the Hewletts Creek estuary from a DEH growing area classification of Conditionally Approved – Closed (Goal #2) to Conditionally Approved – Open.*

A *Conditionally Approved – Open* classification means that the waters are managed to protect public health by keeping them generally open to harvesting with the exception of after rain fall events of a certain magnitude. When rainfall exceeds a predetermined threshold at an official local gaging station the Conditionally Approved – Open waters are automatically closed typically without water quality sampling. For most Conditionally Approved – Open waters along NC’s coast a rainfall threshold in the range of 1 to 2 inches triggers the automatic closure as per the DEH management plan for the growing area. In order to reopen the temporarily closed waters DEH conducts both water quality and shellfish tissue sampling. When sampling results indicate that shellfish are again safe for consumption then the waters are reopened.

Achieving goal #3 for the upper Hewletts Creek estuary would represent a very significant restoration of the use of the waters for shellfishing.

Goal #4 - Complete restoration of the harvesting use of the waters without restrictions after rain events (exceptions might still apply after very large rain events or during coastal-wide preemptive closures before and after hurricanes).

Indicators of goal attainment – *Upgrade the upper portion of the Hewletts Creek estuary from a DEH growing area classification of Conditionally Approved – Open (Goal #3) to Approved.*

DEH assigns Approved classifications to waters which require relatively few restrictions to harvesting. Waters generally maintain good water quality even after moderate rain fall events. Exceptionally large rain fall events could trigger a temporary closure of Approved waters.

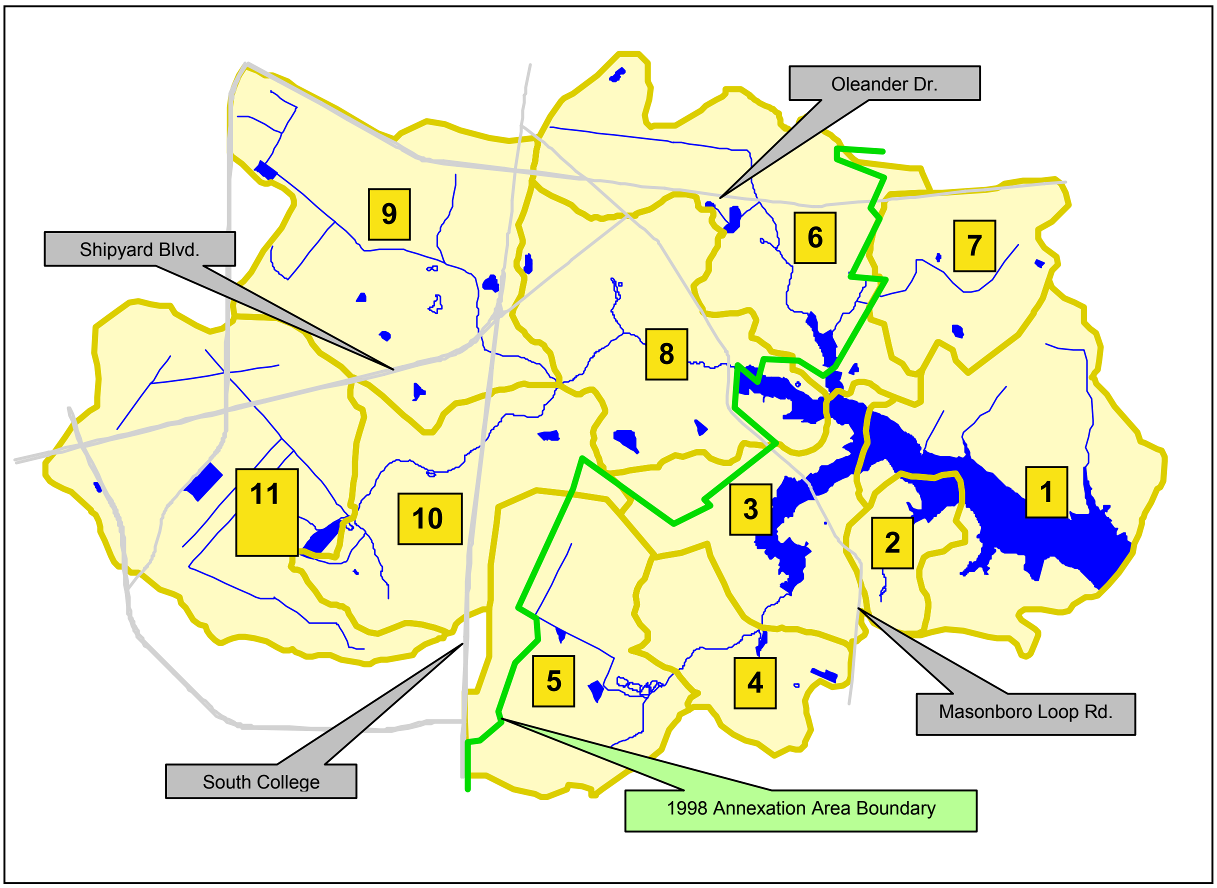
Part 3

GENERAL DESCRIPTION OF THE WATERSHED

3.1 Watershed and Subwatersheds

The Hewletts Creek watershed covers 9.9 square miles in central and eastern Wilmington. Approximately 40% of the watershed is within the 1998 Annexation Area. For the purposes of this report the watershed as been delineated into eleven subwatersheds ranging in size from 0.2 to 1.5 square miles (Figure 3.1). Drainage areas for each subwatershed are summarized in Appendix A.

Figure 3.1 Hewletts Creek subwatersheds.



Between 1990 and 2000 the population in the Hewletts Creek watershed grew by 31% from 12,447 to 16,334 according to US Census data. With the annexation of the lower 40% of the watershed in 1998, City services such as water, sewer, and stormwater management are expected to stimulate additional development. Table 3.1 summarizes population statistics for the watershed. Note that three of the four subwatersheds with High Future Growth Potential are within the 1998 Annexation area (subwatersheds 1, 2, and 3).

Table 3.1 Population statistics (US Census) for the Hewletts Creek watershed by subwatershed.

Subwatershed Number	2000 Population	1990 Population	Number of Households (2000)	Growth Rate (1990-2000)	Future Growth Potential [1]
1	1,039	696	382	49%	*High*
2	276	103	104	168%	*High*
3	1,091	931	425	17%	*High*
4	1,155	703	391	64%	*Low*
5	2,813	1,475	938	91%	*Low*
6	2,355	2,047	1,058	15%	*Low* [2]
7	806	738	320	9%	*High*
8	1,260	1,127	535	12%	*Medium* [3]
9	1,930	1,589	938	21%	*Medium* [4]
10	1,554	1,546	708	0.5%	*Low* [5]
11	2,055	1,492	876	38%	*High* [6]
Totals	*16,334*	*12,447*	*6,675*	*31% (watershed-wide average)*	

1 *The Future Growth Potential ratings presented above are intended to give the reader a sense for where future development in the watershed is likely to be concentrated. The ratings reflect the approximate percentage change in developed land area between existing (year 2000) and estimated ultimate build out conditions. For example, although subwatershed 5 experienced the second largest population growth rate during the 1990s, this subwatershed is largely built out now and significant additional development is not anticipated (i.e. Low Future Growth Potential). For this analysis commercial, residential, and institutional land uses were considered developed land use categories (see section 3.2 for more details on land use in the Hewletts Creek watershed).*

***Low** growth potential means that the subwatershed is at or near build out conditions (<20% change in developed land area)*
***Medium** growth potential means that a 20% to 30% change in developed land area might be expected as allowable per current zoning.*
***High** growth potential means that >30% change in developed land area might be expected as allowable per current zoning.*

2 *Low growth potential for the upper and middle portions of subwatershed 6, however, there is a Medium growth potential for the lower subwatershed due to presence of under developed parcels.*

3 *Medium growth potential predominantly concentrated in the lower portion of the subwatershed. The upper portion of the subwatershed has a Low growth potential.*

4 *While the majority of the subwatershed is built out, there are several large undeveloped parcels in the southwestern portion of the subwatershed.*

5 *Low growth potential for the upper portion of the subwatershed, however, there is a Medium growth potential for the lower portion of the subwatershed due to the presence of several large undeveloped parcels.*

6 *High growth potential in the upper portion of the subwatershed. The lower portion of the subwatershed is mostly built out (Low growth potential).*

3.2 Land Use and Land Cover (Existing and Future)

On average the Hewletts Creek watershed under existing conditions is primarily dominated by residential land uses (46%), with subwatershed 5 having the highest percentage of residential land uses (76%). Subwatersheds 6, 7, and 9 contain the highest percentage of commercial development – mostly concentrated adjacent to Oleander Drive (subwatersheds 6&7) and at Independence and Long Leaf Malls (subwatershed 9).

Table 3.2 outlines the land use/land cover categories used in this report. These land use/land cover categories were selected to be consistent with those reported in the 1995 Area Stormwater Masterplan.[4] The methodology used for creating the land use/land cover data used in this report is presented in Appendix A.

Table 3.2 Land use/land cover categories.

Category	Description
Apartment (APT)	Includes multifamily dwellings e.g. apartments and town homes.
Low Density Residential (LRES)	< 1/3 acre lots
Medium Density Residential (MRES)	1/3 – ¾ acre lots
High Density Residential (HRES)	> ¾ acre lots
Commercial (COMM)	Includes both commercial and industrial land uses.
Institutional (INST)	Includes schools, churches, and hospitals
Golf Course (GC)	Includes golf course fairways and associated adjacent land covers, e.g. wooded areas.
Recreational (REC)	Includes recreational areas such as baseball & soccer fields, tennis & basketball courts.
Right-of-way (ROW)	Includes roads and adjacent shoulder area.
Vacant (VAC)	Includes non-forested, undeveloped land, e.g. bare or grassy areas.
Cemetery (CEM)	Includes predominately large cemeteries and associated land cover. Small cemeteries adjacent to churches were generally categorized as Institutional.
Forest (FOR)	Includes undeveloped, forested parcels. Note that a ½ acre residential parcel with a house and mostly woods surrounding the house would be categorized as Medium Density Residential. Therefore, the acreages of Forest presented in this report are underestimates of the actual amount of tree cover in the watershed.
Water (WAT)	Includes open water bodies and marsh.

1 Stormwater Master Plan for the 1995 Annexation Area of the City of Wilmington, North Carolina. July 2001. Prepared by Dewberry & Davis, Inc for the City of Wilmington Stormwater Services.

Existing Land Use/Land Cover

Figure 3.2 illustrates existing land use/ land cover conditions in the watershed based on 1998 New Hanover County orthophotography and Wilmington parcel data.

Figure 3.2 Existing land use/land cover in Hewletts Creek watershed.

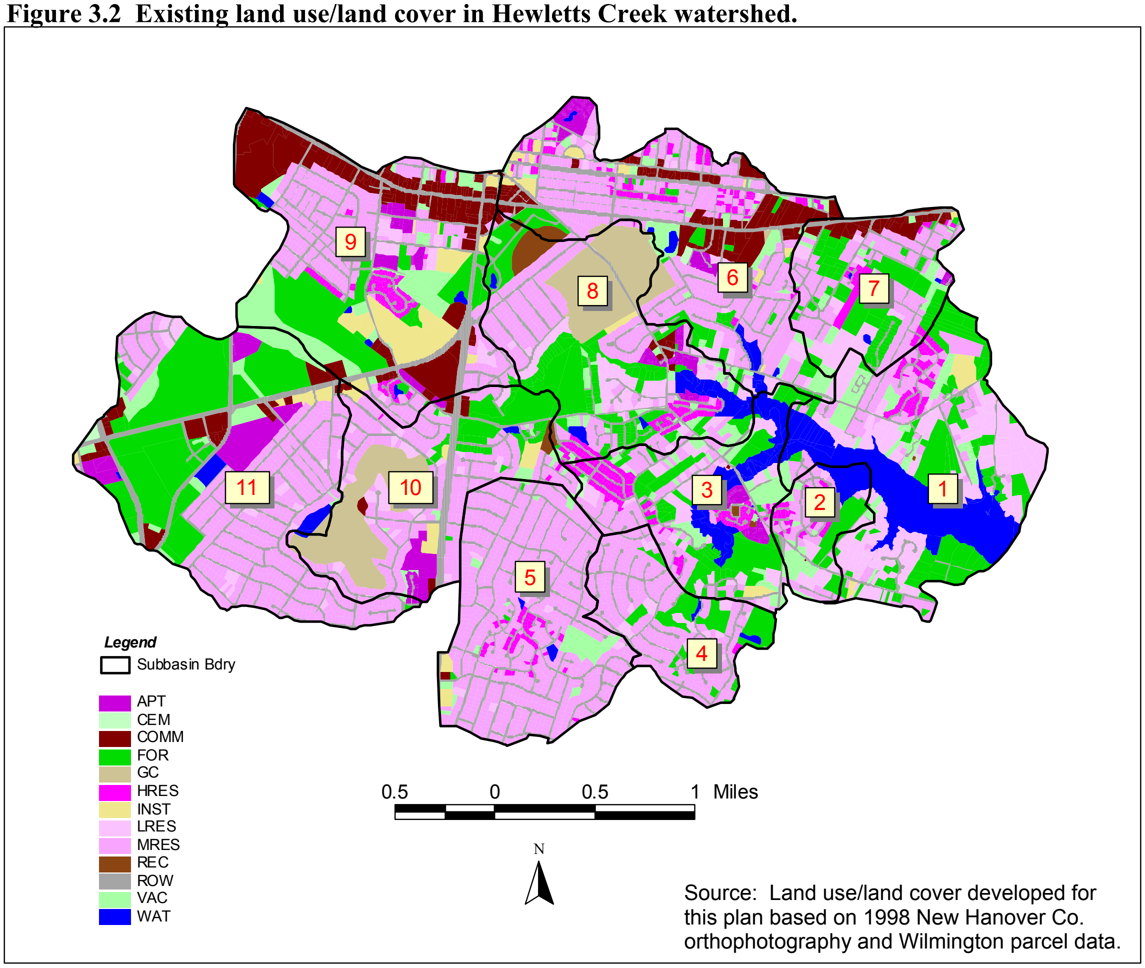


Table 3.3 Existing land use/land cover distribution by subwatershed. See Table A1 in Appendix A for the area of each land use/land cover type by subwatershed. Appendix A also contains a description of how these data were developed.

Subwatershed	COMM	FOR	APT	HRES	LRES	MRES	ROW	VAC	WAT	INST	CEM	REC	GC	Totals
1	0.0%	20.5%	0.0%	2.8%	28.2%	11.5%	5.6%	6.7%	22.8%	1.7%	0.0%	0.0%	0.0%	**100%**
2	0.0%	17.4%	0.0%	6.8%	11.4%	27.0%	11.2%	12.0%	14.2%	0.0%	0.0%	0.0%	0.0%	**100%**
3	0.1%	23.0%	3.1%	8.3%	12.6%	16.8%	10.1%	9.2%	15.1%	0.9%	0.4%	0.4%	0.0%	**100%**
4	0.0%	17.8%	0.0%	0.4%	6.0%	61.2%	13.4%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	**100%**
5	0.2%	0.2%	0.0%	2.9%	1.1%	72.1%	17.2%	4.7%	0.5%	1.1%	0.0%	0.0%	0.0%	**100%**
6	12.8%	5.7%	3.1%	4.3%	4.5%	38.2%	17.9%	6.0%	2.2%	2.2%	0.3%	0.8%	2.0%	**100%**
7	8.6%	26.4%	0.5%	4.8%	9.8%	30.7%	12.4%	6.1%	0.5%	0.2%	0.0%	0.0%	0.0%	**100%**
8	1.3%	20.5%	2.3%	3.4%	8.9%	21.9%	10.5%	4.4%	4.7%	0.5%	0.0%	3.0%	18.6%	**100%**
9	22.1%	13.7%	2.5%	3.2%	2.9%	21.6%	14.2%	10.3%	0.8%	8.7%	0.0%	0.0%	0.0%	**100%**
10	1.9%	12.0%	4.4%	0.2%	5.7%	34.0%	12.9%	1.8%	0.4%	3.0%	0.1%	0.7%	22.8%	**100%**
11	4.4%	29.0%	6.2%	0.0%	2.3%	35.1%	14.2%	5.6%	1.6%	1.0%	0.2%	0.0%	0.4%	**100%**
% of Total Watershed Area	**6.1%**	**16.7%**	**2.5%**	**2.9%**	**8.0%**	**32.3%**	**12.9%**	**6.1%**	**5.3%**	**2.3%**	**0.1%**	**0.5%**	**4.2%**	**100%**

Future Land Use/Land Cover

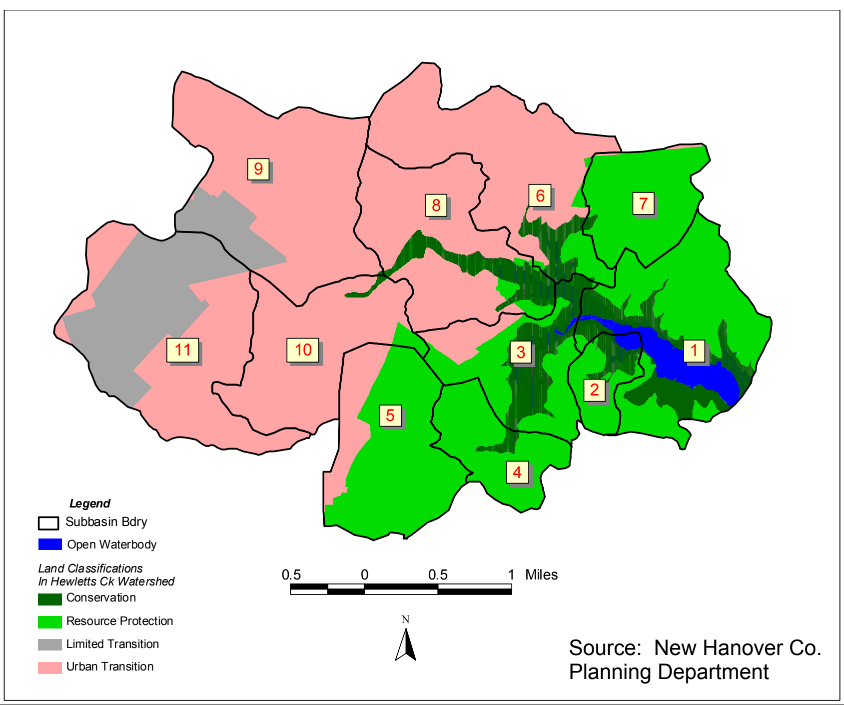
Describing future land use patterns helps managers identify potential problem areas which might contribute to further water quality degradation. Estimating future land use assumes that land parcels will be developed in accordance with comprehensive land use planning and current zoning designations. Ideally, land use planning is supported and complemented by zoning, subdivision ordinances, and other land use management tools. In this section two future land use scenarios are presented. The first describes land use conditions using a combination of zoning and comprehensive planning objectives. The second scenario describes future land use based on what is allowable per current zoning.

Comprehensive Land Use Plan

The 1974 Coastal Area Management Act (CAMA) requires local governments within twenty coastal North Carolina counties to prepare land use plans which provide for the protection of natural resources and to assist in managing development within their respective jurisdictions. Wilmington and New Hanover County have agreed to prepare a joint Comprehensive Plan to meet CAMA planning requirements. The Comprehensive Plan has been updated several times since first published in 1976. The most recent update covers the period 1997-2010.

Local planners have devised and delineated the county into seven land classifications which are: Developed; Urban Transition; Limited Transition; Community; Rural; Conservation; and Resource Protection. The land classification system is designed to facilitate the implementation of the Comprehensive Plan guidance and policies. Figure 3.3 illustrates the land classifications which apply within the Hewletts Creek watershed.

Figure 3.3 Wilmington-New Hanover County land use plan land classifications in the Hewletts Creek watershed.



Land Classification System Categories Applicable to Hewletts Creek Watershed

The Land Classification System is intended to provide a broad based framework by which future development trends are directed. Below are descriptions, reproduced from New Hanover County's Comprehensive Planning website, of the four land classification categories which apply to the Hewletts Creek watershed. Additional information on these categories can be found at: http://www.co.new-hanover.nc.us/PLN/landclass.htm

URBAN TRANSITION

The purpose of the Urban Transition class is to provide for future intensive urban development on lands that have been or will be provided with necessary urban services. The location of these areas is based upon land use planning policies requiring optimum efficiency in land utilization and public service delivery.

Residential development can exceed 2.5 units per acre within the Urban Transition area provided the development is adequately designed to be compatible with existing and proposed surrounding land uses and it is served by:

1. Sewer - the development shall be served by City or County sewer systems or private package treatment systems that meet the most stringent State requirements.

2. Municipal or County water system - the development shall be served by City or County water systems or a private water system constructed in accordance with City of Wilmington standards.

3. Direct access to a minor arterial or larger access road, as classified under the New Hanover County Thoroughfare Classification System - the development may be required to fully provide or to share in the cost of the provision of roadway improvements needed to adequately serve the proposed development and the community in general.

LIMITED TRANSITION

The purpose of the Limited Transition class is to provide for development in areas that will have some services, but at lower densities than those associated with Urban Transition.

Residential density should be no more than 2.5 units/acre, with lower density being more desirable. The use of clustering and Planned Unit Developments (PUD) is encouraged.

These areas were previously designated as Transition and were intended to provide for more intensive future urban development. However the provision of public services has been scaled back and less intensive urban development is planned.

CONSERVATION

The purpose of the Conservation class is to provide for effective long-term management and protection of significant, limited or irreplaceable natural resources. Management of these areas may be required for a number of reasons, including natural, cultural, recreational, productive or scenic values.

Lands placed in the Conservation class are generally the least desirable for development because:

1. They are too fragile to withstand development without losing their natural value; and/or
2. They have severe or hazardous limitations to development; and/or
3. Though they are not highly fragile or hazardous, the natural resources they represent are too valuable to endanger by development.

Generally, estuarine areas of environmental concern (AEC's) as defined by the State of North Carolina and adjacent lands within the 100-year floodplain have been classified as Conservation.

Conservation areas should be preserved in their natural state. Woodland, grassland and recreation areas not requiring filling are the most appropriate uses. Exceptions to this standard are limited to water-dependent uses (i.e., uses that cannot function elsewhere), shared industrial access corridors, and those exceptional development proposals which are sensitively designed so as to effectively preserve the natural functions of the site. The following guidelines clarify these Conservation area objectives:

1. Water dependent uses - may include: utility easements, docks, wharves, boat ramps, dredging, bridge and bridge approaches, revetments, bulkheads, culverts, groins, navigational aide, moorings, pilings, navigational channels, simple access channels and drainage ditches. In some instances, a water-dependent use may involve coverage of sizeable land areas with limited opportunities to integrate the use with the site's natural features. This would require reclassification of the site. By contrast, water dependent uses which can be designed to preserve a site's natural features may not require reclassification. This would be the preferred type of development.

2. Shared industrial access corridors - as discussed in the U.S. Army Corps' of Engineers' The Wilmington Harbor: Plan for Improvement, would provide necessary access to the channel of the Northeast Cape Fear River for industries located on high ground while minimizing the adverse environmental impacts of such access.

3. Exceptional developments preserving natural features are projects which are sensitively designed so as to harmonize with the site's natural features. Such projects minimize erosion, impervious surfaces, runoff and siltation; do not adversely impact estuarine resources; do not interfere with access to or use of navigable waters; do not require extraordinary public expenditures for maintenance; ensure that ground absorption sewage systems, if used, meet applicable standards; and do not damage historic, architectural or archeological resources.

In no case shall residential density in the Conservation class be permitted to exceed 2.5 units per acre, regardless of the existence of public urban services. Residential densities may be required to be as low as 1.0 unit/acre or less, depending on the environmental constraints within a particular area. While certain Conservation areas may be served by public sewer in order to eliminate septic system pollution, this should not be misconstrued as an incentive to facilitate increased development density.

RESOURCE PROTECTION

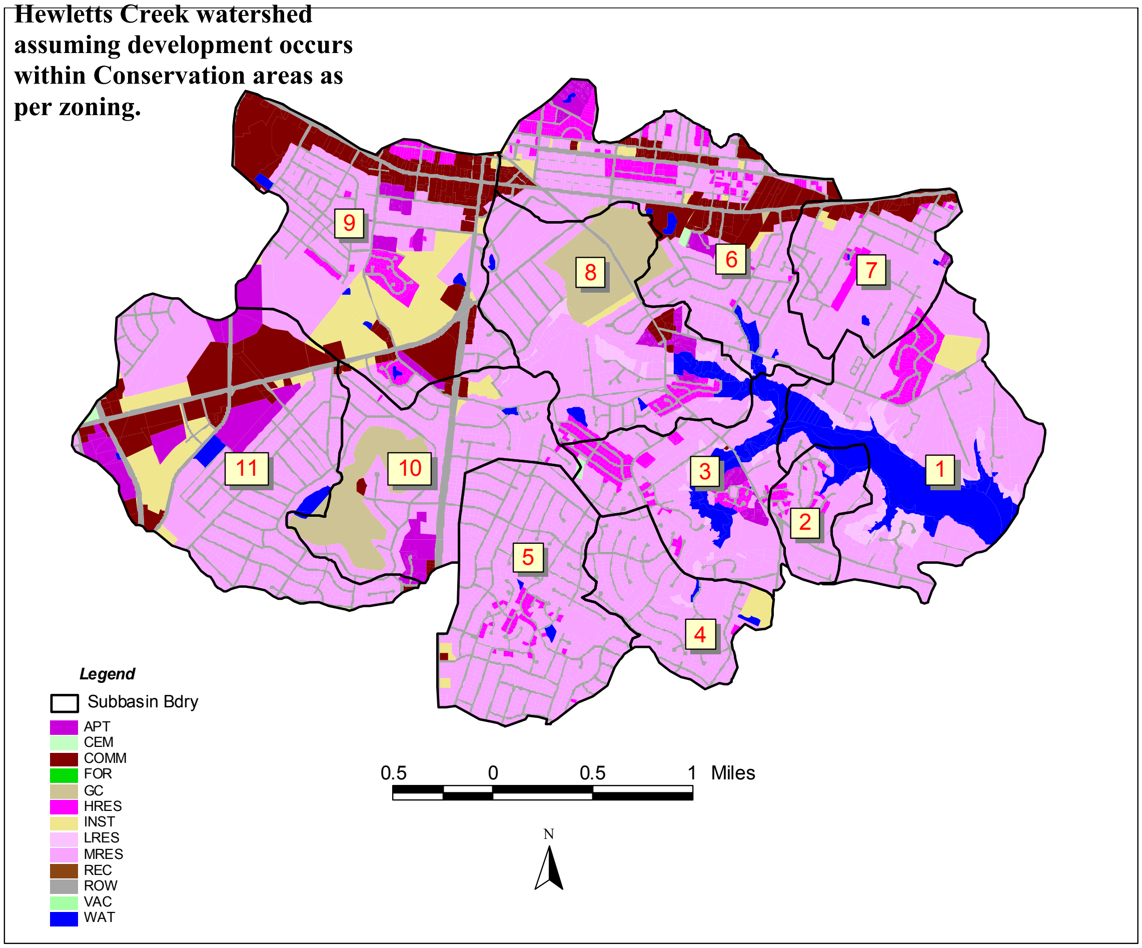
The purpose of the Resource Protection class is to provide for the preservation and protection of important natural, historic, scenic, wildlife and recreational resources. The Resource Protection class has been developed in recognition of the fact that New Hanover County, one of the most urbanized counties in the State, still contains numerous areas of environmental or cultural sensitivity which merit protection from urban land uses.

The Resource Protection class includes land adjacent to the estuarine waters which are classified SA by the North Carolina Division of Environmental Management. The class also includes land in the Castle Hayne area where the protection of farmland, a rural lifestyle, and the aquifer system are highly important issues. Residential densities greater than 2.5 units per acre shall not be permitted in the Resource Protection class. Residential densities may be required to be as low as 1.0 unit/acre or less, depending on the development constraints within a particular area. Compatible commercial and industrial development may be located within the Resource Protection class as long as important resources are not adversely impacted. It is important to note that the County sewer service being provided to portions of this area is intended for the purpose of eliminating septic pollution and not for encouraging increased density of development.

Future Land Use Without Preservation of Undeveloped Parcels Within the Conservation Class

Although the intent of the Conservation Classification is to preserve undeveloped areas in their natural state, zoning regulations do allow development in these areas. The result is a net shift of undeveloped forested parcels into predominantly medium density residential (MRES) as compared to existing conditions. Figure 3.4 illustrates predicted future land use conditions assuming development progresses as allowed by zoning within Conservation areas.

Figure 3.4 Future land use (ultimate build out) in the Hewletts Creek watershed assuming development occurs within Conservation areas as per zoning.



Source: Future lan
cover data develop
based on allowable
City zoning and Co
classifications.

Table 3.4 Future land use distribution by subwatershed assuming development occurs within Conservation areas as per zoning. See Table A3 in Appendix A for the area of each land use/land cover type by subwatershed. Appendix A also contains a description of how these data were developed.

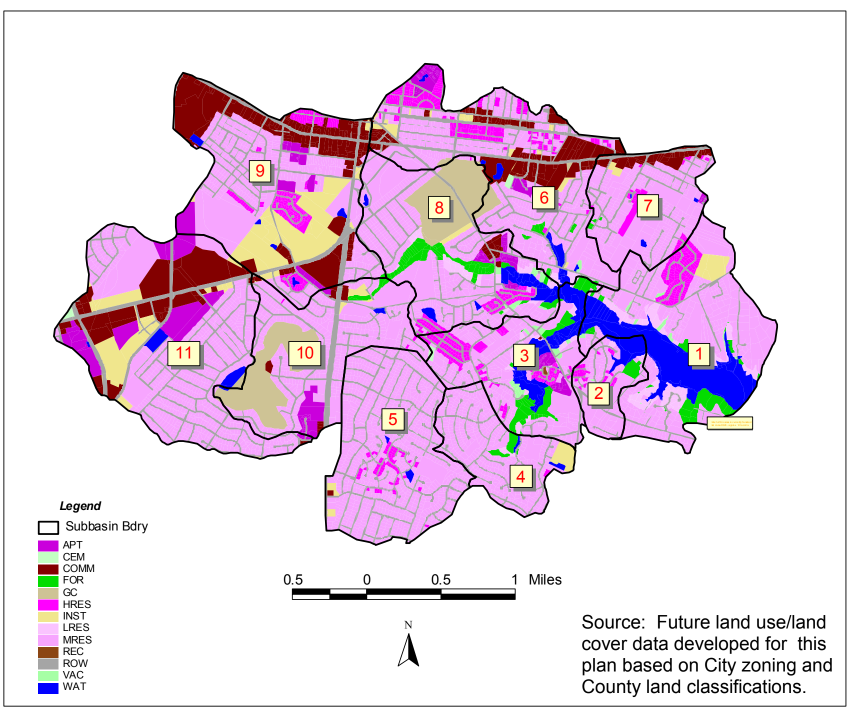
Subwatershed	COMM	Forest	APT	HRES	LRES	MRES	ROW	VAC	WAT	INST	CEM	REC	GC	Totals
1	0.0%	0.0%	0.0%	5.3%	7.5%	56.2%	5.6%	0.0%	22.8%	2.6%	0.0%	0.0%	0.0%	**100.0%**
2	0.0%	0.0%	0.0%	6.8%	1.6%	66.3%	11.2%	0.0%	14.2%	0.0%	0.0%	0.0%	0.0%	**100.0%**
3	0.1%	0.0%	3.1%	9.5%	4.0%	57.7%	10.1%	0.0%	15.1%	0.1%	0.4%	0.0%	0.0%	**100.0%**
4	0.0%	0.0%	0.0%	0.4%	0.8%	79.4%	13.4%	0.0%	1.1%	5.0%	0.0%	0.0%	0.0%	**100.0%**
5	0.2%	0.0%	0.0%	2.9%	0.0%	78.6%	17.2%	0.0%	0.5%	0.7%	0.0%	0.0%	0.0%	**100.0%**
6	15.8%	0.0%	3.1%	9.0%	0.6%	47.3%	18.0%	0.0%	2.2%	1.9%	0.3%	0.0%	2.0%	**100.0%**
7	9.1%	0.0%	0.5%	5.1%	0.0%	71.4%	12.4%	0.0%	0.5%	1.0%	0.0%	0.0%	0.0%	**100.0%**
8	1.7%	0.0%	2.5%	3.6%	3.6%	54.0%	10.5%	0.0%	4.7%	0.8%	0.0%	0.0%	18.6%	**100.0%**
9	23.5%	0.0%	4.4%	5.5%	0.0%	35.6%	14.2%	0.0%	0.8%	16.0%	0.0%	0.0%	0.0%	**100.0%**
10	1.9%	0.0%	4.7%	0.2%	0.0%	55.4%	12.9%	0.0%	0.4%	1.6%	0.1%	0.0%	22.8%	**100.0%**
11	17.3%	0.0%	9.9%	0.0%	0.0%	48.8%	14.2%	0.0%	1.6%	7.5%	0.2%	0.0%	0.4%	**100.0%**
% of Total Watershed Area	**8.6%**	**0.0%**	**3.4%**	**4.2%**	**1.7%**	**55.1%**	**13.0%**	**0.0%**	**5.3%**	**4.5%**	**0.1%**	**0.0%**	**4.2%**	**100.0%**

Source: Future land use/land cover data developed for this plan based on allowable uses as per City zoning and County land classifications.

Future Land Use With Existing Undeveloped Parcels Within Conservation Areas Remaining Undeveloped

While development may be allowed within Conservation areas, this future land use scenario assumes that existing undeveloped parcels within Conservation areas will remain undeveloped as per planning guidance. The primary effect of this scenario is to limit the conversion of undeveloped forested parcels into medium density residential land uses. See Table A2 in Appendix A for the area of each land use/land cover type by subwatershed.

Figure 3.5 Future land use (ultimate build out) in the Hewletts Creek watershed assuming existing undeveloped parcels within Conservation areas remain undeveloped.



3.3 Impervious Surfaces

Impervious surfaces, such as parking lots and rooftops, prevent rainfall from infiltrating into the ground. The result is an increase in runoff volumes and pollutant loads delivered to the estuary. A summary of the method developed for estimating the amount impervious surfaces is presented in Appendix A.

Table 3.5 Summary of impervious surfaces in the Hewletts Creek watershed.

	Percentage of Impervious Surface		
Subwatershed	**Existing Conditions**	**Future Conditions w/ Conservation**	**Future Conditions w/o Conservation**
1	9.4 %	16.6 %	17.8 %
2	13.9 %	20.5 %	21.5 %
3	13.4 %	18.8 %	21.1 %
4	20.2 %	25.4 %	26.0 %
5	25.4 %	26.6 %	26.6 %
6	29.8 %	33.8 %	34.0 %
7	21.0 %	29.6 %	29.7 %
8	14.6 %	18.8 %	20.5 %
9	32.4 %	40.1 %	40.1 %
10	18.9 %	21.9 %	22.3 %
11	20.8 %	36.5 %	36.5 %
Entire Watershed	*21.1 %*	*27.9 %*	*28.5 %*

Source: Data developed for this plan based on New Hanover Co. orthophotography and Wilmington planimetric GIS data.

Researchers at UNC-W have analyzed fecal coliform and impervious surface data for five New Hanover County tidal creek watersheds (Hewletts, Bradley, Howe, Pages, and Futch Creeks).[5] These data indicate a strong linear correlation between average watershed-wide impervious surface coverage and watershed-wide geometric mean fecal coliform concentrations (see equation below). This research demonstrates a statistical link between increased urban development, as measured by impervious surfaces, and declining bacteriological water quality.

$\mathbf{y = 5.39(x) - 29.03}$ (R2 = 0.95, P = 0.005)

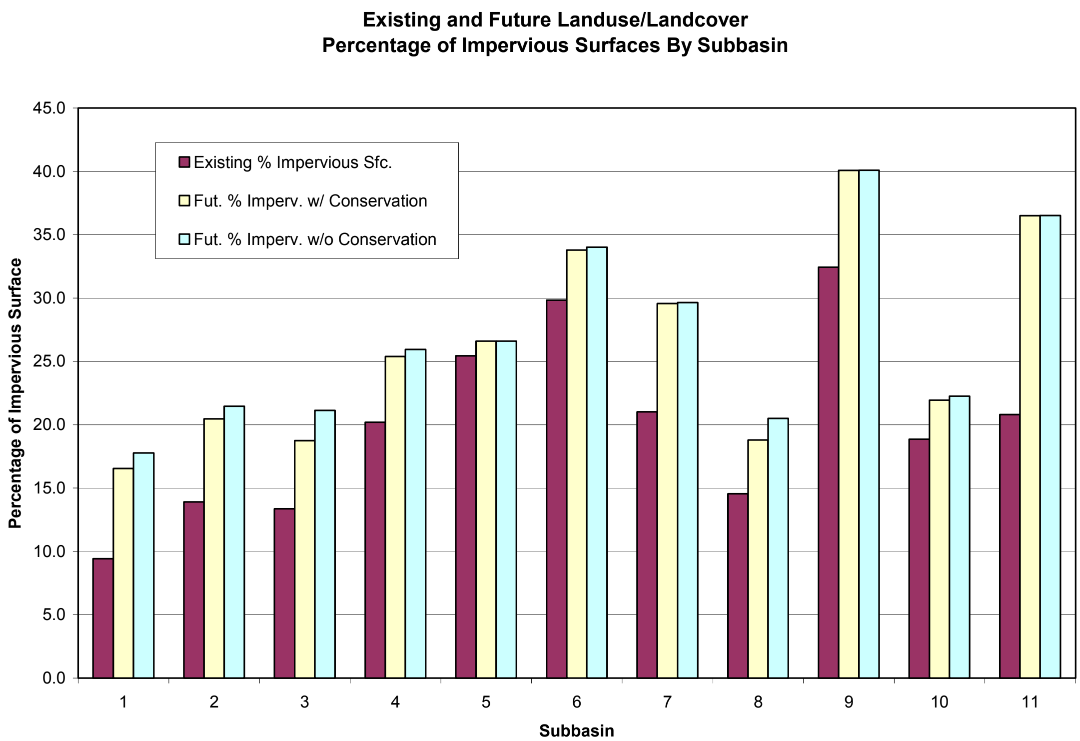
where: y = watershed-wide geometric mean fecal coliform concentration (cfu/100mL)
x = watershed-wide average percent impervious surface coverage (%)

It is important to note that the above equation was developed by averaging fecal coliform sampling data collected within a given watershed and comparing it to the watershed's average percentage of impervious cover. As such it is not appropriate to apply this equation as a predictive tool for a given <u>subwatershed</u> or for a specific point in the estuary. The maximum impervious surface coverage used in developing the relationship was approximately 22% (Bradley Creek).

[5] Mallin, Michael A. et al. 2000. Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds. Ecological Applications, 10(4), pp 1047-1056.

Figure 3.6 is a graphical representation of the data presented in Table 3.5 (p. 20). Note the relatively minor difference in the percentages of impervious surfaces between the two future conditions scenarios.

Figure 3.6 Summary of impervious surfaces under existing and future conditions.



Source: Data developed for this plan based on New Hanover Co. orthophotography and land classifications and Wilmington GIS planimetric data.

Table 3.6 Predicted future increase in impervious surfaces over existing conditions.

	Percent Increase in Impervious Surfaces Over Existing Conditions	
Subwatershed	**Future Conditions w/ Conservation**	**Future Conditions w/o Conservation**
1	43.1 %	47.0 %
2	32.0 %	35.2 %
3	28.7 %	36.7 %
4	20.4 %	22.1 %
5	4.4 %	4.4 %
6	11.7 %	12.3 %
7	28.9 %	29.1 %
8	22.6 %	29.0 %
9	19.1 %	19.1 %
10	14.0 %	15.2 %
11	43.0 %	43.0 %
Entire Watershed	*24.3 %*	*25.9 %*

Source: Data developed for this plan based on New Hanover Co. orthophotography and land classifications and Wilmington GIS planimetric data.

Note from the above two tables and figures that the implementation of land use policies associated with the Conservation land classification are not predicted to result in a significant reduction in the percentage of impervious surfaces on either a watershed or subwatershed scale. Therefore, on a subwatershed-wide scale preserving undeveloped land in the Conservation area is not anticipated to significantly reduce the volume of stormwater runoff generated. However, preserving undeveloped land in the Conservation area can provide very effective opportunities for treating contaminated runoff from the watershed. Conservation areas can serve as naturally vegetated riparian buffers which might be used to convert concentrated runoff into sheet flow for infiltration. Minimizing development within the Conservation areas also increases the distance between future potential sources of fecal coliform and shellfishing areas.

3.4 Bacteriological Water Quality in Hewletts Creek

Fecal Coliform Bacteria

Fecal coliform is the test organism commonly sampled in NC to measure bacterial water quality. Fecal coliform bacteria originate in the digestive track of warm blooded animals such as humans, dogs, birds, raccoons, to name a few. The presence of fecal coliform in a water body suggests that fecal waste from these sources might have come in contact with the water at some point in time. While fecal coliform is not highly pathogenic to humans, other viruses, bacteria, and protozoans, also associated with fecal waste, can sometimes cause illness. Since direct sampling for these human pathogens can be expensive and time consuming, fecal coliforms are sampled as a relatively quick and inexpensive substitute test for the presence of potential human pathogens. In practice the common assumption is that the higher the concentration of fecal coliform in the water column the greater the risk to human health.

Bacterial Water Quality Standards

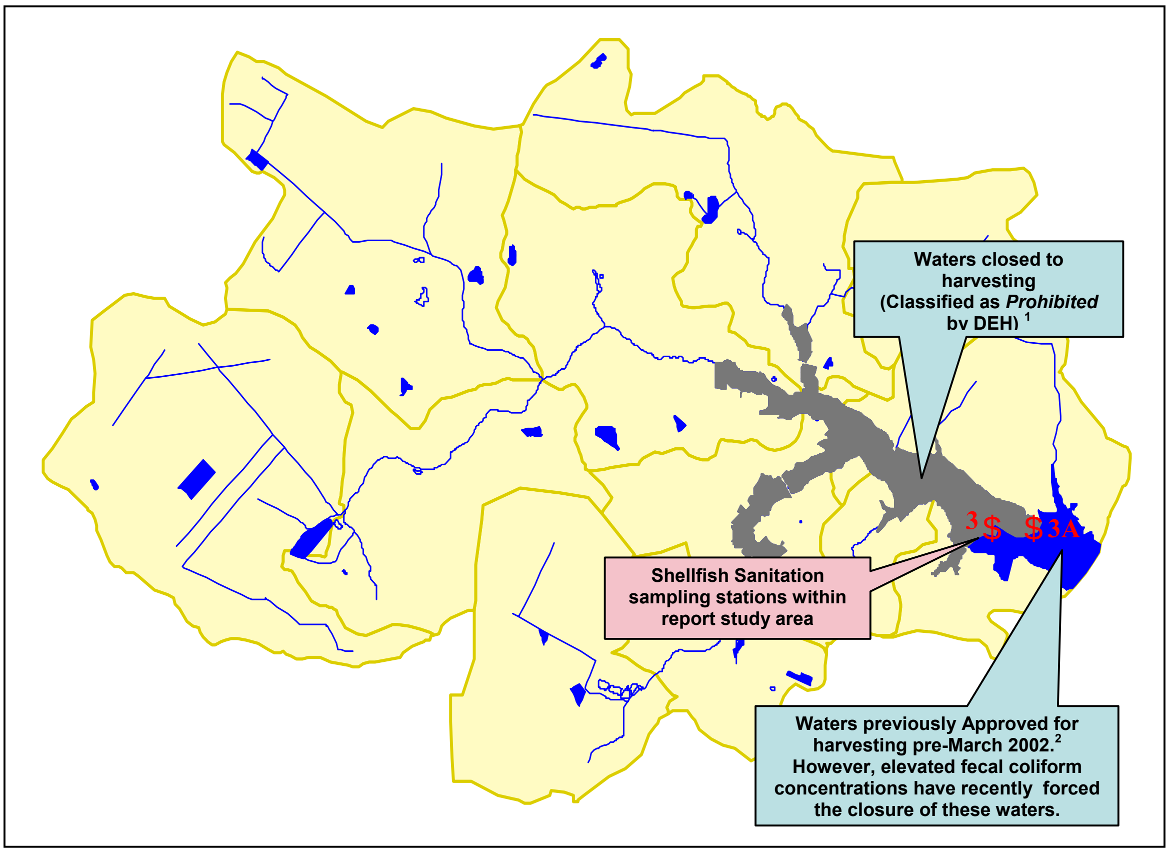
The State of NC has adopted bacteriological water quality standards for the protection of human health resulting from body contact with the water, as well as the consumption of shellfish. Different standards apply to different water bodies depending on their best designated uses. In the Hewletts Creek watershed all streams including the estuary are classified as SA High Quality Waters by the Division of Water Quality. This means that the best intended use of the waters is for the harvesting of shellfish for direct market purposes, i.e. human consumption.

The standard for fecal coliforms in SA waters is a median concentration not to exceed 14/100mL, and not more than 10% of the samples shall exceed a count of 43/100mL in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions. When sampling conducted by the Shellfish Sanitation Section of the NC Division of Environmental Health (DEH) indicates that the standard has been violated, then DEH staff will recommend closure of an area to the NC Division of Marine Fisheries (DMF).[6] DMF has the legal authority to close waters to harvesting as well as enforcement responsibilities. Figure 3.7 (p. 24) illustrates the approximate area currently closed to shellfish harvesting.

[6] DEH's Shellfish Sanitation program is based in part on policies and standards established by the US Food and Drug Administration (FDA). In contrast, DWQ's policies and standards are established in part by the US EPA. As a result there are some differences in the bacterial water quality standard used by DWQ and DEH, such as the required laboratory method for measuring fecal coliform concentrations. However, for the purposes of this plan these differences can be considered minor and do not affect the recommendations.

Figure 3.7 illustrates the area in the upper portion of the estuary which as been closed to harvesting for many years. The lower portion of the estuary shown in blue in the figure below was recently closed to harvesting in March 2002. Concurrent with this closure was a reclassification of 51 acres from Approved to Prohibited. Recall from Part 1 that Goal #2 of this plan is to improve the bacteriological water quality of the estuary in order to support a reclassification from Prohibited to Conditionally Approved – Closed. This reclassification would permit the restoration of the harvesting use during dry weather periods.

Figure 3.7 Portion of Hewletts Creek estuary closed to shellfish harvesting due to chronic elevated fecal coliform concentrations.



Source: NC Division of Environmental Health

1 *Waters classified by the NC Division of Environmental Health as Prohibited mean that they are closed to harvesting year round.*

2 *Waters classified as Approved are generally open to harvesting. Approved waters may be temporarily closed after large rainfall events. The estuarine waters shown in blue where typically open to harvesting before March 2002. However, sampling at stations 3 and 3A has indicated elevated fecal coliform concentrations over the past several years. As a result 51 acres of previously open waters in this area are now closed to harvesting as of March 2002.*

Local and State Water Quality Sampling Programs

Three organizations periodically conduct water quality sampling in the Hewletts Creek watershed: UNC-Wilmington Center for Marine Science Research, NC Division of Environmental Health - Shellfish Sanitation Section, and the NC Division of Water

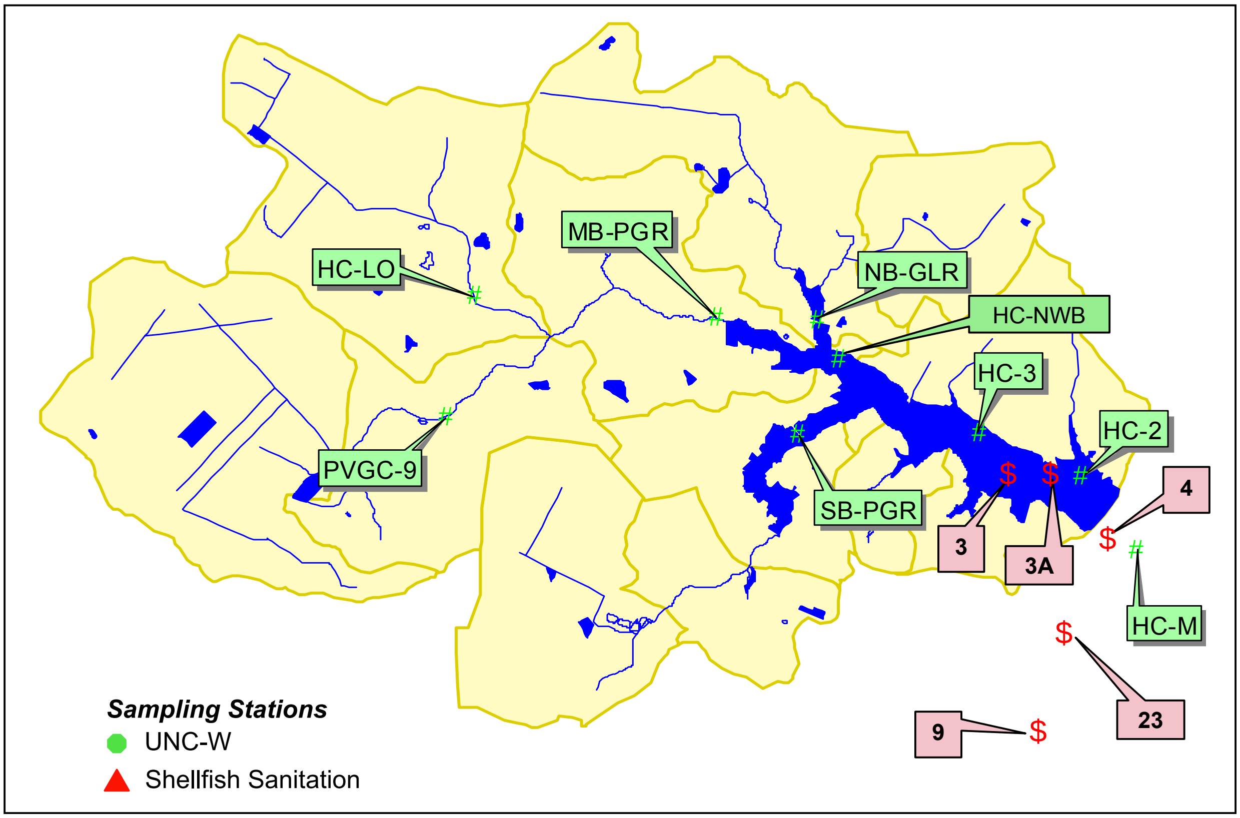
Quality - Environmental Sciences Branch. The frequency, parameters, and sampling objectives vary between organizations.

Since 1993 UNC-W has conducted the most comprehensive sampling program in the watershed with respect to the number of parameters sampled and the spatial distribution of sampling sites. UNC-W currently publishes an annual report which describes sampling results for a number of major watersheds in New Hanover County including Hewletts. Copies of these reports are available on the New Hanover County Tidal Creeks Program website: http://www.UNC-Wil.edu/cmsr/aquaticecology/TidalCreeks/Index.htm

Shellfish Sanitation routinely samples fecal coliform, salinity, and approximate tidal stage at two stations (3, 3A) within the study area of this report. They also sample three other nearby stations (4, 23, 9) as shown in Figure 3.8 (p. 26). Typically Shellfish Sanitation focuses its sampling efforts in waters open to harvesting and along the borders of open and closed waters. To optimize resources they do not routinely sample closed waters which is why Shellfish Sanitation does not have sampling stations positioned in the upper watershed. More information concerning Shellfish Sanitation's program is presented in the next section.

The NC Division of Water Quality currently does not routinely sample fecal coliforms in the Hewletts Creek watershed. DWQ has however sampled benthic macro invertebrates at four locations within the watershed over the past ten years. DWQ's water quality indices based on macro invertebrates have yielded ratings of *Moderate* impact in the upper estuary. It is important to note though that DWQ's indices for both salt water sampling as well as swamp-like water sampling have not been finalized. This means that ratings based on benthic sampling in these areas are considered provisional and are not used by the Division as a basis for Use Support ratings or major management decisions. More information about DWQ's sampling program can be found in the July 2000 Cape Fear River Basinwide Water Quality Plan. The Hewletts Creek watershed is discussed in Ch 24 (subwatershed 03-06-24).

Figure 3.8 Fecal Coliform sampling stations in the Hewletts Creek watershed.



Source: UNC-Wilmington Center for Marine Science Research and the NC Division of Environmental Health.

Table 3.7 Description of sampling stations depicted in Figure 3.8.

Station	Organization	Location
HC-M	UNC-W	Mouth of Hewletts Ck.
HC-2	UNC-W	Hewletts Ck nr. Windlea Run Rd.
HC-3	UNC-W	Hewletts Ck. nr. Leeward Rd.
HC-NWB	UNC-W	Hewletts Ck. mid way between North and South Branches
NB-GLR	UNC-W	North Branch at Greenville Loop Rd.
SB-PGR	UNC-W	South Branch at Pine Grove Rd.
MB-PGR	UNC-W	Middle Branch at Pine Grove Rd.
HC-LO	UNC-W	Tributary nr. Longleaf Mall
PVGC-9	UNC-W	Hewletts Ck. at Pine Valley Golf Course
3	Shellfish Sanitation	750 yds north of sta. #4
3A	Shellfish Sanitation	500 yds north of sta. #4
4	Shellfish Sanitation	Mouth of Hewletts Ck.
23	Shellfish Sanitation	700 yds N-NW of Day Beacon #130, by docks
9	Shellfish Sanitation	400 yds west by north of Channel Marker #132, in cove nr Intracoastal Waterway

Source: UNC-Wilmington Center for Marine Science Research and the NC Division of Environmental Health.

UNC-W Sampling Results

Table 3.8 (p. 27) presents a summary of fecal coliform sampling for the period 1993-2001. These data indicate that concentrations tend to increase as one travels up the estuary and into feeder tributaries. This trend may be due to a combination of factors which include:

- Upstream sampling stations may be closer to the major sources of fecal coliforms. Salt water is not a favorable environment for coliforms, hence these bacteria tend to die off at an exponential rate once leaving the warm blooded host organism.
- Less available dilution as you go from the open estuary into the smaller streams.
- UNC-W sampling indicates that turbidity levels in the water column tend to increase as you go upstream. Higher turbidity levels upstream effectively protect the bacteria from UV radiation from the sun which is known to increase the mortality rate.
- Given that salt water is not a favorable environment for coliforms, lower salinity levels as you go upstream tend to reduce the mortality rate.

Both UNC-W and Shellfish Sanitation sampling indicate that fecal coliform concentrations tend to be highest at mid to low tide and have the lowest abundances near high tide. Possible explanations include:

- Decreased salinities due to freshwater inflows from the watershed during outgoing tidal situations provide for a more favorable environment for coliforms.
- The predominant sources of coliforms may be in the watershed (as opposed to sources associated with open water e.g. aquatic birds) and the outgoing tide enhances the transport of bacteria to the sampling stations.
- Tidal resuspension of fecal coliform from the sediments is more acute at lower tides.

Table 3.8 Summary of UNC-W fecal coliform sampling data as reported in the New Hanover County Tidal Creeks Program reports.

	Geometric Mean of Fecal Coliform Samples (#/100mL) Collected per Sampling Period			
Station	**1993-1997**	**1997-1998**	**1999-2000**	**2000-2001**
PVGC-9			303	362
HC-M				2
HC-2	10			2
HC-3	55			11
HC-NWB	126			68
NB-GLR	266			68
MB-PGR	378			266
SB-PGR				118
HC-LO		35		0

Source: UNC-Wilmington Center for Marine Science Research

NC's Shellfish Sanitation Program and Sampling Results

The NC Division of Environmental Health's Shellfish Sanitation Section is charged with protecting the health of the consuming public through management and water quality sampling of waters suitable for the growth and propagation of shellfish. Shellfish Sanitation's management strategy generally follows national guidelines established by the National Shellfish Sanitation Program which is administered by the US Food and Drug Administration. Per these guidelines all potential shellfish growing waters are delineated into one of four classifications as outlined in Table 3.9.

Table 3.9 DEH shellfish growing area classifications for North Carolina coastal waters. Currently, the Approved (mouth of estuary) and Prohibited (majority of estuary above the mouth) classifications apply to Hewletts Creek. Descriptions adopted from the July 2000 Cape Fear Basinwide Water Quality Plan published by the NC Division of Water Quality.

DEH Classification	Description
Approved Area	Waters determined to be suitable for the harvesting of shellfish for direct market purposes. These areas are generally open to harvesting even after moderately heavy rainfall events. Very large rainfall events can result in temporary closures.
Conditionally Approved –Open Area	These waters are normally open to harvesting but are closed on a temporary basis in accordance with DEH management plan criteria. These criteria generally specify a rainfall amount within a given duration, which if exceeded, with will trigger an automatic closure of the waters (no sampling conducted). Water column and shellfish tissue sampling is conducted however before the waters are reopened.
Conditionally Approved – Closed Area	These waters are normally closed to shellfish harvesting due to elevated fecal coliform concentrations even after relatively small rainfall events. However, waters may be reopened on a temporary basis in accordance with management plan criteria and favorable sampling results. In practice procedures for reopening these waters are generally initiated after a request from commercial harvesters or other interested parties.
Prohibited Area	These waters are generally unsuitable for the harvesting of shellfish for direct market purposes. Prohibited areas are closed to harvesting due to either chronically elevated fecal coliform concentrations, other unsuitable water quality conditions e.g. low salinities, or the presence of man-made facilities e.g. marinas or wastewater outfalls.

Source: Descriptions adopted from the July 2000 Cape Fear Basinwide Water Quality Plan published by the NC Division of Water Quality.

Note that harvesting by special permit can be conducted in closed waters during a select six week period in early spring. This type of harvesting is known as Relaying and permits fisherman to collect shellfish living in polluted waters and transplant them into Approved waters with acceptable bacteriological water quality. The shellfish are then cleansed in the Approved waters for a given length of time before being harvested again for market purposes.

Within the Hewletts Creek watershed two classifications apply: Prohibited and Approved. Figure 3.7 (p. 24) illustrates the approximate areas where these classifications apply. Pre-March 2002 Shellfish Sanitation sampled at two stations (3, 3A) in proximity to the Prohibited and former Approved area boundary. Station 3 is within the Prohibited area and station 3A was within the former Approved area. As of March 2002 the Prohibited/Approved area boundary has been moved further downstream to near station 4. Table 3.10 is a summary of sampling data and includes three other nearby stations (4, 23, 9) as presented in the most recent (March 2001) Sanitary Survey of Growing Area B-6 which includes Hewletts Creek. Data presented in the March 2001 report was used to support DEH's recommendation to permanently close the additional 51 acres which legally went into effect in March 2002.

Note from Table 3.10 that the estimated 90th percentile fecal coliform concentration for station 4 just meets the 43/100mL criteria for waters classified as Approved. Per the March 2001 Sanitary Survey station 4 will be monitored closely for any further degradation in water quality.

Table 3.10 Summary of fecal coliform data collected by Shellfish Sanitation as reported in the March 2001 DEH Sanitary Survey of the Masonboro Sound Area (Area B-6).

Station	Sampling Period	# Samples Taken	Median (#/100mL)	Geometric Mean (#/100mL)	Estimated 90th Percentile [1] (#/100mL)
3	9/21/93-1/8/2001	30	10.2	11.9	77
3A	10/9/95-1/8/2001	30	8.6	11.5	85
4	10/9/95-1/8/2001	30	7.8	8.0	43
23	10/9/95-1/8/2001	30	6.8	7.0	26
9	10/9/95-1/8/2001	30	4.5	4.8	13

Source: NC Division of Environmental Health – March 2001 Sanitary Survey for Masonboro Sound Area (Area B-6).

1 National Shellfish Sanitation Program criteria specifies that the estimated 90th percentile value be at or below 43/100mL for Approved shellfishing waters.

3.5 Other Water Quality Issues in Hewletts Creek

While bacteriological contamination of the estuary is the focus of this plan, other water quality issues also deserve attention. Since 1993 researchers at UNC-W have been studying a variety of water quality related parameters in Hewletts Creek as part of the New Hanover County Tidal Creeks Program. Annual reports are published which summarize monitoring results and ongoing research projects from the previous year. Additional information on the Tidal Creeks Program can be found under Local and State Water Quality Sampling Programs in Section 3.4 beginning on p. 23.

Based on a review of these annual reports nutrient over enrichment of the estuary appears to be a potential concern. While nutrients in the proper concentrations are important for maintaining a healthy estuarine ecosystem, too much of a good thing can cause problems. Nitrogen and phosphorous typically are the nutrients of concern in most waterbodies as these nutrients tend to be the ones which limit the growth of algae and other flora and fauna which can cause imbalances to the ecosystem.

There are many sources of nitrogen and phosphorus containing compounds within a watershed. In urbanizing watersheds with residential dominated land uses such as Hewletts Creek, likely primary sources of nutrients are lawn and golf course fertilizers, pet waste, and human wastewater (SSOs, leaky sanitary sewer lines, septic tanks). NC currently does not have instream water quality standards for nitrogen and phosphorus, although the US EPA has pushed states to adopt nutrient standards. NC does however have a chlorophyll-a standard which is 40 ug/L. The concentration of chlorophyll-a in a waterbody is a commonly used measure of algal biomass.

Algal blooms often occur in open waterbodies enriched with nutrients. Nuisance algal blooms can cause a variety of problems. One of the more significant impacts from excessive algal blooms is their affect on dissolved oxygen concentrations in the water. While algal photosynthesis can boost dissolved oxygen concentrations during daylight hours, algal respiration consumes dissolved oxygen which can significantly drive down concentrations during the night. In addition, when the algal biomass eventually dies, settles to the bottom, and is consumed by bacteria, the decomposition process also utilizes dissolved oxygen. In some cases this situation can result in hypoxic (very low dissolved oxygen) conditions in the lower water column causing stress to aquatic organisms. Sessile fauna such as shellfish which do not have the ability to swim away to other areas with better water quality can be particularly impacted. The 2000-2001 annual Tidal Creeks report notes that several incidents of hypoxia occurred in the spring and summer months at two sampling stations (NB-GLR and SB-PGR).

The annual reports have repeatedly documented periodic algal blooms in the Hewletts Creek estuary. According to the reports the blooms exhibit a strong seasonality pattern with blooms typically occurring in the spring and again in the summer. While it is unclear at this time whether or not these blooms constitute a major long-term problem, preventing additional enrichment and working towards reducing existing nutrient loads should be component of the overall watershed management effort.

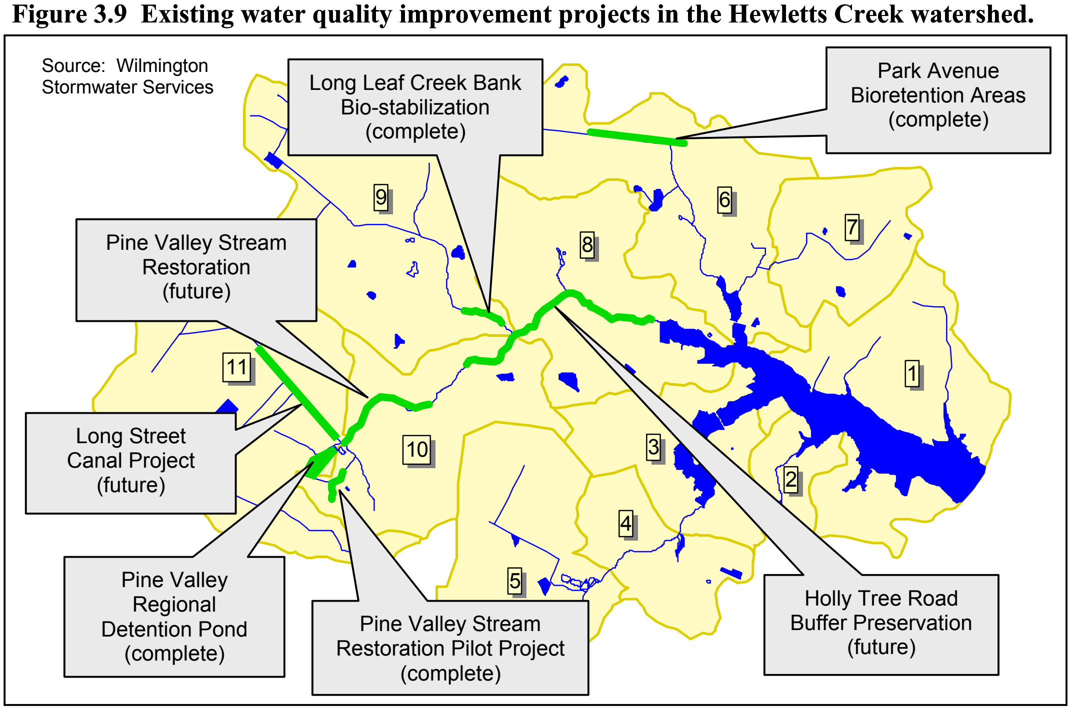
3.6 Existing Water Quality Improvement Projects

A number of water quality improvement projects have already been implemented or are in various stages of being implemented in the watershed (Figure 3.9). The stream restoration projects in the vicinity of Pine Valley Golf Course and the Long Leaf Creek Bank stabilization project have important water quality benefits. Both these projects should significantly minimize mass wasting of the banks. The severe bank erosion which has occurred at these sites results in increased turbidity levels downstream. High turbidity is favorable to the prolonged survival of fecal coliform bacteria by providing "shelter" from UV radiation from the sun. Restoring a riparian buffer along the golf course should also help to minimize the amount of nutrients from fertilizers reaching the stream.

The Pine Valley regional detention pond also helps to reduce fecal coliform loads by settling out bacteria, increasing exposure to UV radiation from the sun, and potentially increasing predation from microfauna. The pond may also provide benefits by trapping nutrients. UNC-W researchers have studied nutrient dynamics in stormwater detention ponds and are finding that these ponds probably trap nutrients in a more complex manner than they trap sediment. Research suggests that these ponds may reach a saturation level for trapping phosphorus, after which they may release as much phosphorus as they take in. Research also suggests that aquatic macrophytes (plants) play a central role in nutrient cycling and management in stormwater detention ponds. Additional information about this research can be found in the UNC-W 1997-1998 annual Tidal Creeks Program report.

Generally speaking infiltration of stormwater runoff into the ground, which is what the Park Avenue bioretention areas are designed to do, provides the most reliable and highest bacteria removal rate of all the traditional stormwater control practices for a given design storm.

Figure 3.9 Existing water quality improvement projects in the Hewletts Creek watershed.



Part 4

FECAL COLIFORM SOURCE ASSESSMENT

In order to devise effective strategies to control bacterial contamination of the estuary it is important to develop an understanding of the possible significant sources of fecal coliform in the watershed. Sources often associated with urban/suburban watersheds include:

- Pets
- Sanitary sewer system overflows
- Sanitary sewer exfiltration (leakages)
- Failing septic systems
- Non-stormwater flows within the stormwater drainage system
- Wildlife and unknown stormwater related sources

Considerable uncertainty is typically associated with source assessment evaluations for a number of reasons. First is the paucity of data on many of the sources. For example, little data is typically available for wildlife populations within urban watersheds. The same situation exists for data regarding failing septic systems. Another difficulty encountered when evaluating bacterial sources is the fact that many sources are stormwater related. Hence, the delivered pollutant load to the shellfish waters of concern varies both temporally and spatially. Despite these uncertainties gathering available information on potential sources does provide a useful starting point to formulate management strategies as well as for designing additional data collection programs.

New technologies have emerged over the past 10 years to aid in the identification of sources of fecal coliform within a watershed. These technologies, cumulatively referred to as Bacterial Source Tracking or BST, offer the ability to take a water sample and distinguish whether the contamination originated from human or nonhuman sources. More sophisticated BST tests can even identify sources to the species level (e.g. humans, dogs, raccoons, etc.). The NC Division of Environmental Health is currently working with researchers at North Carolina State University (Dr. Nancy White - Primary Investigator) on a EPA 319 funded project to develop the infrastructure to conduct BST studies to better manage shellfish waters.

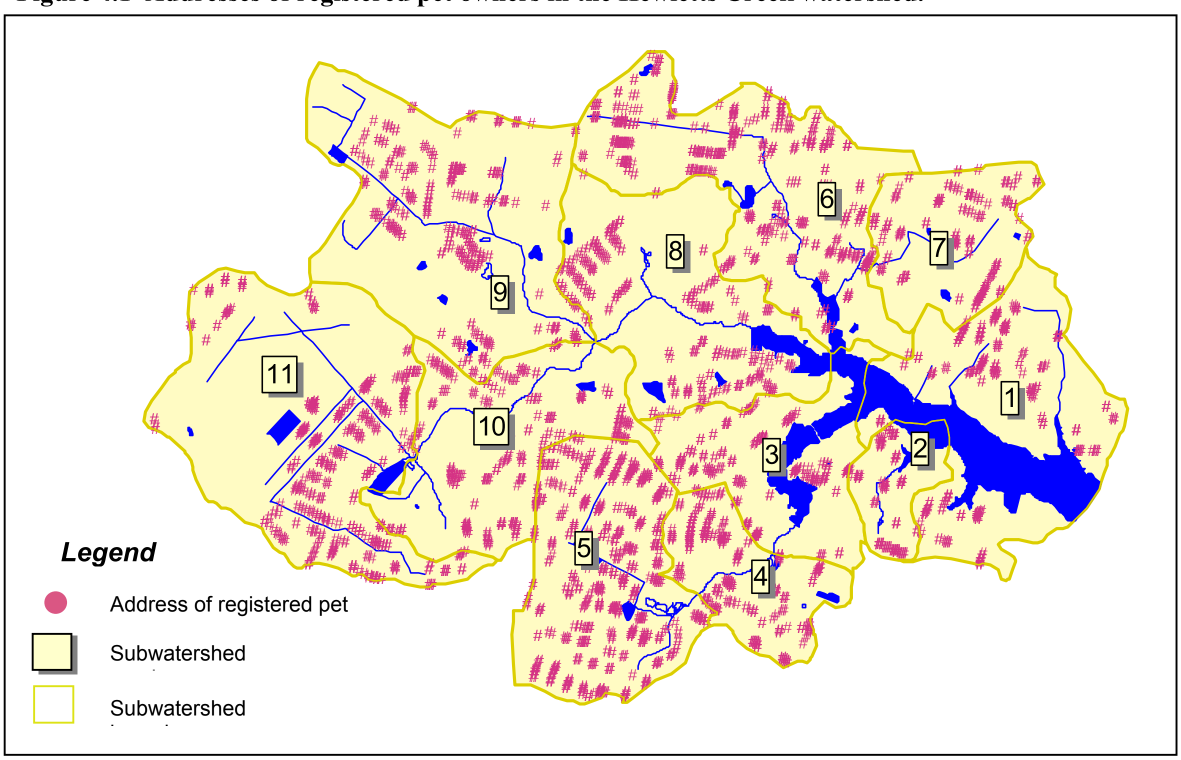
Although Bacterial Source Tracking offers the promise of reducing current bacterial contamination quicker through more efficient targeting of management strategies, it should not be viewed as a substitute for developing holistic programs to manage a variety of sources. Sources of fecal coliform can be very transient in nature. Sources causing a problem today may not be the primary source a year from now. Hence, long term management of a variety of sources is needed to restore and maintain waters open to shellfish harvesting.

4.1 Pets

Given that residential land uses dominate the Hewletts Creek watershed it is reasonable to assume that pets are potential significant sources of bacterial loading to the watershed. For the purposes of this report a pet refers to either a dog or a cat. In order to estimate the number of dogs and cats in the watershed the New Hanover County registered pet database was georeferenced based on the owners address. The countywide database contains over 43,000 records (one record for each pet). The georeferencing process was unable to place approximately 6,500 of the records due to address inconsistencies. Of the remaining 36,500 records that were georeferenced **5,240** pets are estimated to be living in the Hewletts Creek watershed. Note that this number is certainly an underestimate of the total number of dogs and cats in the watershed as it does not take into account unregistered or feral animals. Also note that the county pet database does not explicitly indicate if the registered pet is a dog or a cat. Figure 4.1 illustrates addresses of pet owners in the watershed - multiple

Waste generated from the dog pictured in the upper right-hand corner can enter the stormwater drainage system (and ultimately shellfishing waters) via this yard inlet.

Figure 4.1 Addresses of registered pet owners in the Hewletts Creek watershed.



registered pets can be living at a single address.

In order to gain an understanding of the number of cats and dogs per subwatershed a second method of estimating pet populations was employed. National marketing statistics published by the American Veterinary Medical Association indicate that the number of pets can be estimated as a function of the number of households within an area: [7]

Number of dogs = 0.534 x total number of households

Number of cats = 0.598 x total number of households

Statistics from the 2000 US Census were used to identify the number of households by subwatershed. Table 4.1 summarizes pet population statistics using both methodologies.

Table 4.1 Estimated Pet Population in Hewletts Creek Watershed.

			Pet Populations Based on National Marketing Statistics		
Subwatershed	**Registered Pets per NHC Database**	**No. of Households per 2000 US Census**	**Cats**	**Dogs**	**Total Pets**
1	383	382	228	204	432
2	164	104	62	56	118
3	321	425	254	227	481
4	444	391	234	209	443
5	916	938	561	501	1062
6	783	1,058	633	565	1198
7	356	320	191	171	362
8	359	535	320	286	606
9	488	938	561	501	1062
10	398	708	423	378	801
11	628	876	524	468	992
Totals	*5,240*	*6,675*	*3,992*	*3,564*	*7,556*
Wilmington Stormwater Services Estimate of Cat and Dog Populations for the Entire Watershed.			*2,115*	*3,100*	*5,215*

Source: Data derived from 2000 US Census data, New Hanover Co. registered pet database, and American Veterinary Medical Association pet ownership statistics. Wilmington Stormwater Services estimates of cat and dog populations are based on the New Hanover Co. registered pet database and a more detailed analysis of pet breed in order to determine the type of pet.

The Stormwater Services estimate of the total cat population in the watershed suggests that national pet ownership statistics significantly overestimate the number of cats. However, the two estimates of the total dog population compare favorably.

Based on published pet waste generation rates approximately 1,515 lb/day of feces are generated from the pet population within the watershed (517 lb/d from cats and 995 lb/d from dogs). [8]

[7] US Pet Ownership and Demographics Sourcebook, 1997. Published by the American Veterinary Medical Association.
[8] Watershed Protection Techniques Vol. 3, No. 1 – April 1999. The Stormwater Services estimate of pet populations were used in this calculation.

4.2 Sanitary Sewer System Overflows

Sewer system overflows (SSOs) are unpermitted discharges of untreated sanitary wastewater from the collection system. SSOs are commonly caused by blockages, especially from grease and debris, or excessive infiltration and inflow of stormwater resulting in a surcharge of waste flow from the system. State law requires public reporting of SSOs and since 1998 the NC Division of Water Quality has maintained a database of reported overflows. According to DWQ's database during the period of 1998 through the spring of 2002 eight SSOs have occurred in the Hewletts Creek watershed totaling 17,550 gallons spilled. Figure 4.2 and Table 4.2 summarize available SSO information in the watershed.

Figure 4.2 SSO locations in the Hewletts Creek watershed during the period 1998 – Spring 2002.

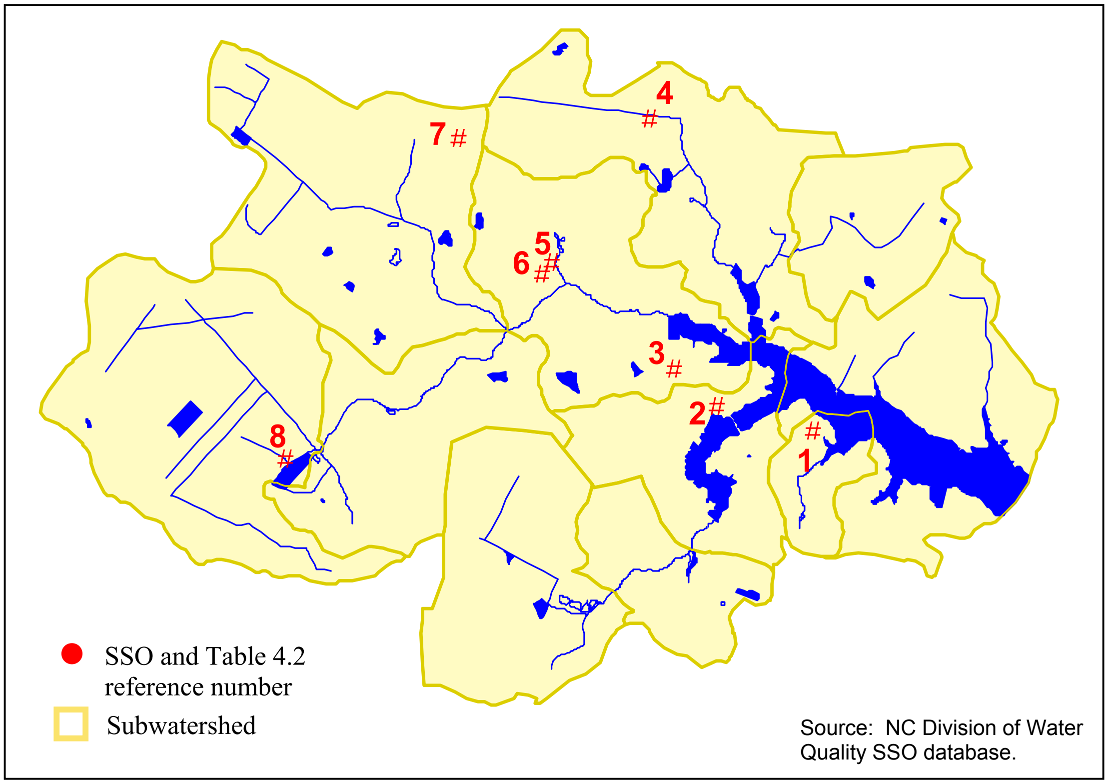


Table 4.2 Summary of SSOs in the Hewletts Creek watershed during the period 1998 – Spring 2002. Data obtained from the NC Division of Water Quality.

Map Ref. No.	Location	Spill Volume (gal)	Date	Description
1	Robert E. Lee & Johnson St.	500	1/13/2002	Blockage
2	Pine Cone Rd. & Mockingbird Ln.	2,000	7/18/2000	Blockage
3	4638 Mockingbird Ln.	50	7/19/2000	Collapsed sewer main
4	4209 Oleander Dr.	500	11/4/2000	Blockage
5	5032 Park Ave.	500	12/28/2000	Blockage
6	Pine Grove Rd. & Kilarney	10,000	8/30/1999	Excessive inflow of stormwater
7	400 Blackbeard Rd.	2,000	9/14/1999	System inundated from Floyd flood waters
8	Quail Ridge Rd./Pine Grove Rd.	2,000	9/14/1999	System inundated from Floyd flood waters

Eight reported spills over the past 3-1/2 years is a relatively low number of SSOs for an urban/urbanizing area the size of Hewletts Creek watershed. However, many public health officials believe that human sources of fecal coliform represent one of the greatest risks to the shellfish consuming public due to an increased likelihood of human pathogens being associated with human wastes.

4.3 Sanitary Sewer Line Exfiltration

Compromises occur in sanitary sewer lines when pipe joints separate with age or cracks/punctures form. Tree roots growing through these breaches in the line can further damage the line. If the compromised line is below the water table then inflow into the system becomes a problem. If the line is above the water table then there is the risk of sanitary wastes leaking from the system and contaminating groundwater which may ultimately feed streams flowing to the estuary.

Municipal utility departments charged with maintaining the sanitary collection systems most often discover compromised sewer lines due to excessive infiltration of groundwater into the system. Underground leaking sewer lines are much more difficult to detect however because often there is no visual evidence that a problem is occurring. Hence, underground leaking lines often go undetected for very long periods of time.

Before the 1980's clay pipe (terra cotta or vitrified clay pipe) was commonly used for constructing sanitary sewer lines in North Carolina (PVC pipe was not widely used at the time). Clay is a rigid and brittle material which necessitated the use of relatively short sections of pipe (3' to 5' lengths common). As a result a one mile clay line might easily have over 1,000 pipe joints which represent many opportunities for leakages. Figures 4.3 and 4.4 (p. 37) illustrate two computer printouts from an innovative new technology, FELL-41 (Focused Electrode Leak Location), for detecting compromises in sanitary sewer lines. Figure 4.3 illustrates a 100' clay line in the City of Raleigh with relatively few leakages. Figure 4.4 (p. 37) however illustrates another clay line in Raleigh where approximately 79% of the joints appear to be compromised.

Figure 4.3 Example of FELL-41 leak location test results for a clay line in relatively good condition.

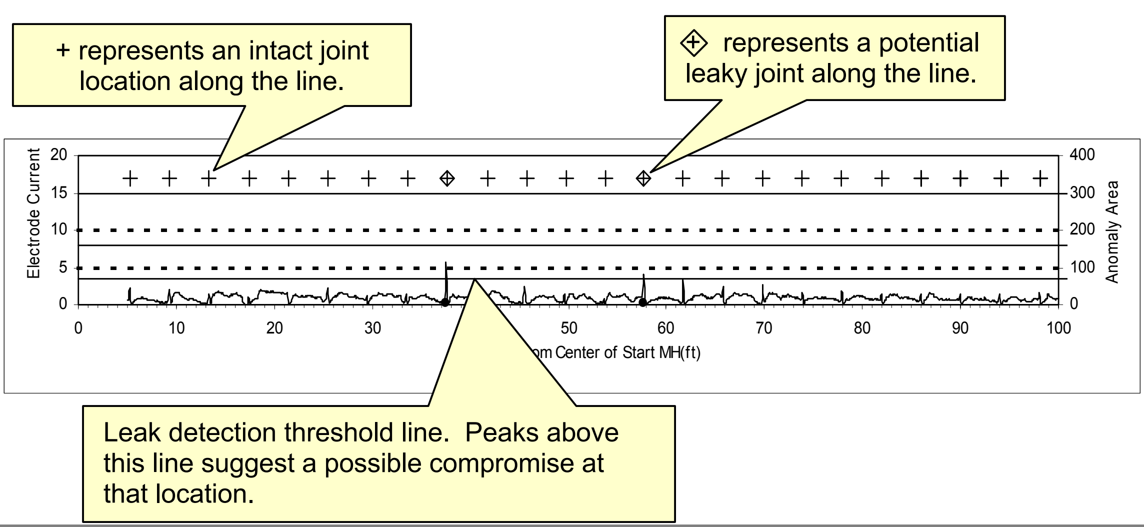


Figure 4.4 Example of FELL-41 leak location test results for a clay line in poor condition.

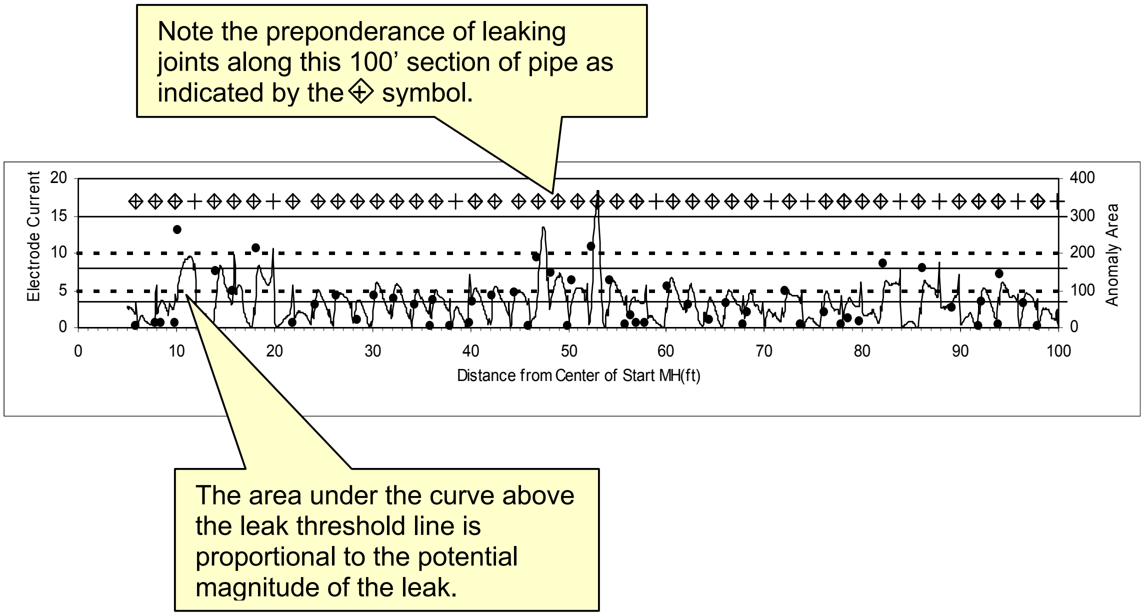


Figure 4.4 illustrates the potential for leakages to occur in an aging clay sanitary line. In another study the Mecklenburg County Department of Environmental Protection collected groundwater samples as part of an effort to support development of a fecal coliform TMDL. Four sampling sites were established at sanitary lines positioned above the groundwater table. At each site two wells were drill – one above gradient and one below gradient of the sanitary line. Fecal coliforms in the groundwater samples were detected in three of the four down gradient wells. No coliforms were detected in the up gradient wells suggesting leakages from the sanitary lines. Each well was sampled four to seven times over a one month period. Of the three sites where contamination was detected fecal coliform concentrations in the groundwater averaged 58/100mL.

No site specific data similar to the Mecklenburg County study is available for the Hewletts Creek watershed. However, information on sanitary sewer pipe materials is available, as well as data on the age of development within the watershed. These data can give managers an anecdotal feel for which areas may have an increased likelihood of leaking sewer lines - useful information for targeting future studies. Figure 4.5 (p. 38) illustrates the locations of major sanitary sewer lines made out of clay (either terra cotta or vitrified clay) outside of the 1998 Area (data were not available for the 1998 Area). Due in part to short pipe lengths (more joints) and the brittle nature of the material, clay pipe tends to be more subject to leakages over time.

Subwatersheds 9 and 11 contain the vast majority of known clay sanitary pipe in the watershed with 2.7 and 1.3 miles, respectively.

Figure 4.5 Major clay sanitary sewer lines in the Hewletts Creek watershed outside of the 1998 Annexation Area.

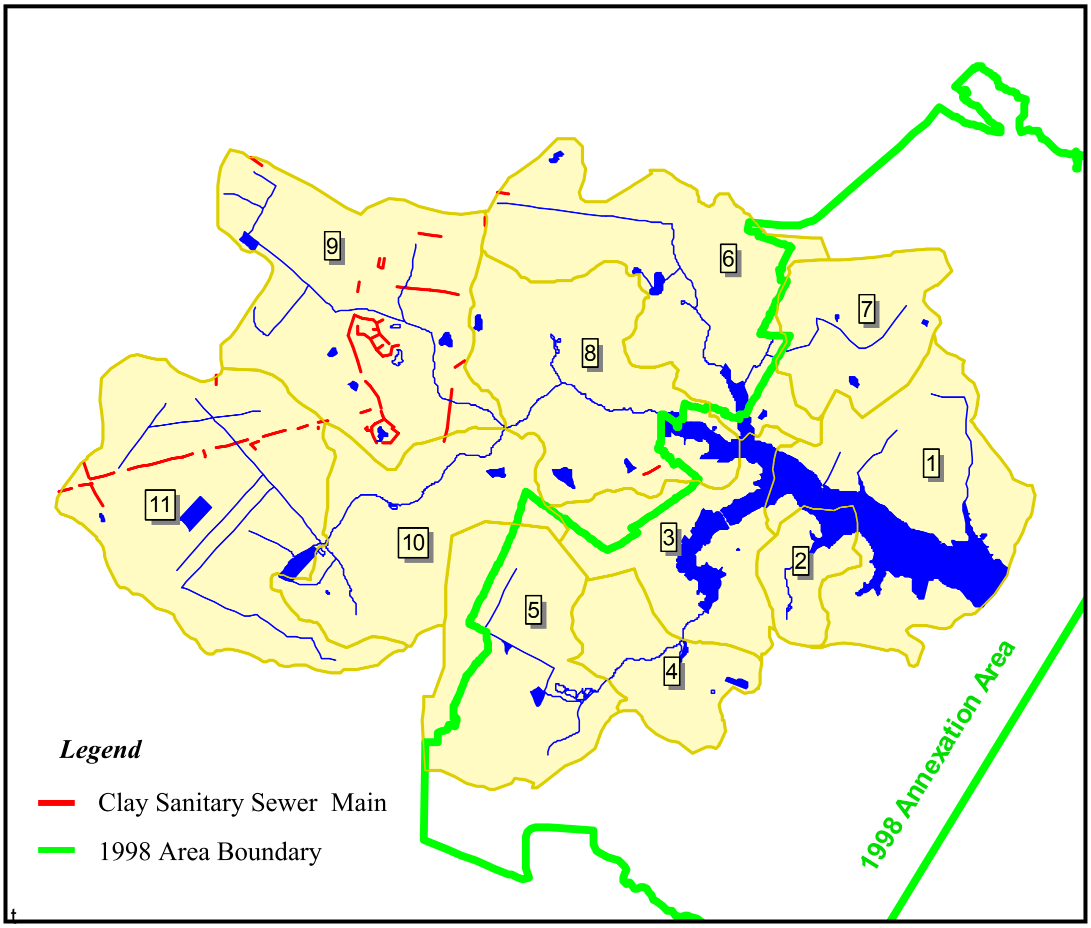
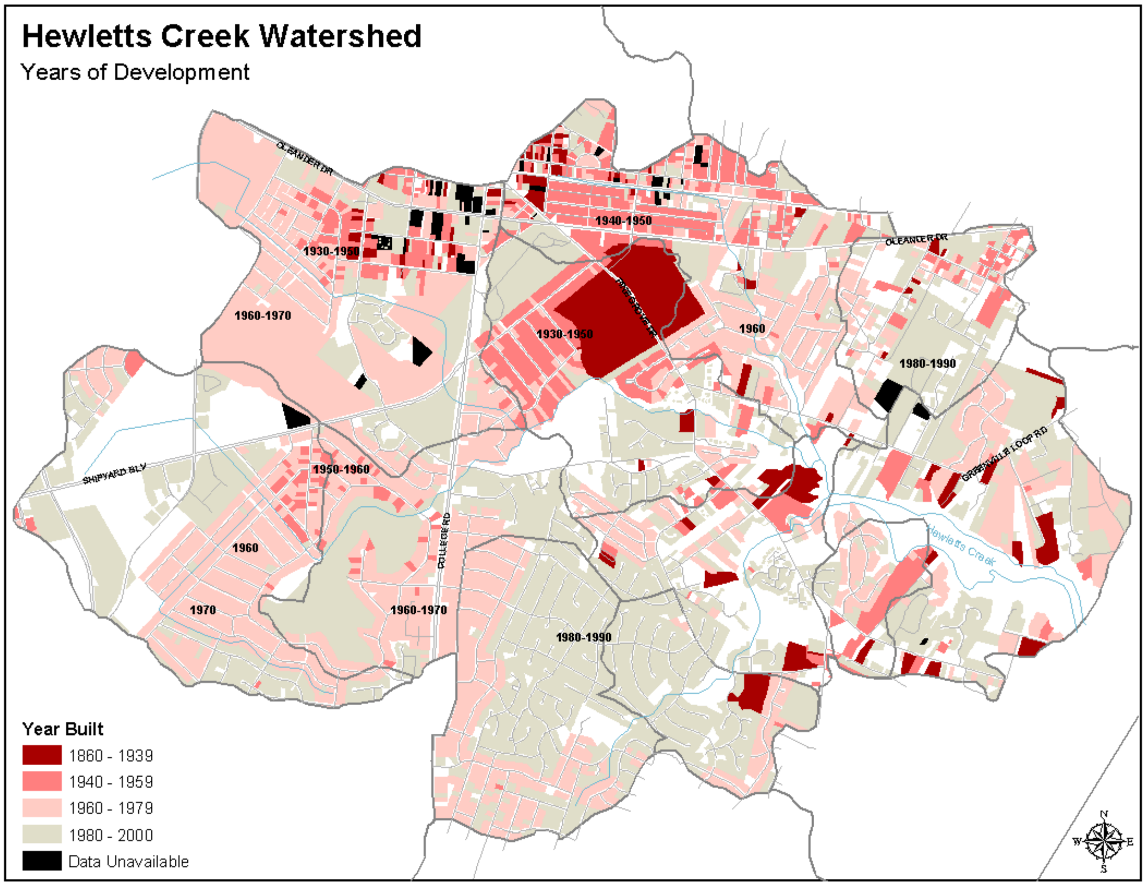


Figure 4.6 (p. 39) illustrates the year in which the current development was built. These data are based on parcel information. Assuming sanitary sewer lines were installed with the development this information may provide an indication of the age of the sanitary lines. For the purposes of targeting management action it is reasonable to assume that newer sanitary lines made from improved materials such as PCV plastic, along with improved installation practices such as low pressure testing, are less prone to leakage

Table 4.3 (p. 39) summarizes the area of developed parcels by year built date. These data can give managers an idea of when development has occurred in the watershed. However, it does not reflect density of development nor the area of impervious surfaces. Impervious surface information can be found in Section 3.3 of this report.

Figure 4.6 Age of development in the Hewletts Creek watershed.



Source: Wilmington GIS parcel data.

Table 4.3 Area of developed parcels by approximate year built date. All area values reported in acres. Data adopted from the City of Wilmington's GIS parcel coverage.

Sub-basin	Year Unk	Pre-1900s	1900-1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	*Total "Developed" Area* [9]	Total Subwatershed Area
1	123.6	10.1	32.3	14.0	9.9	75.8	71.9	122.0	98.3	5.8	**110.4**	147.9
2	21.3		2.3	7.0	22.3	0.7	29.0	8.5	17.6	1.8	**244.2**	280.7
3	145.9		29.5	18.2	7.8	8.5	41.5	39.0	58.2	12.6	**319.0**	339.1
4	26.5		11.8	0.4		3.5	29.2	117.6	38.6	16.5	**361.2**	431.9
5	29.9				0.5	62.4	116.8	147.2	129.5	2.4	**484.5**	548.6
6	100.1		37.1	61.9	100.0	122.6	72.7	61.6	77.5	8.0	**488.6**	589.6
7	102.6		3.3	0.2	28.7	22.8	20.0	47.1	88.9	5.4	**589.3**	653.1
8	122.7		135.4	8.7	111.1	28.7	20.6	96.6	52.1	13.4	**563.9**	740.1
9	89.1		13.2	16.4	51.8	199.5	266.9	80.1	91.6	5.0	**641.4**	749.1
10	47.7				16.9	138.7	68.7	157.8	38.3	16.4	**813.5**	884.6
11	307.9				26.0	125.9	156.6	95.2	133.7	11.0	**856.2**	956.3
Totals	**1,117.3**	**10.1**	**265.0**	**126.8**	**375.0**	**789.1**	**893.9**	**972.6**	**824.2**	**98.3**	**5,472**	**6,321**

Source: Wilmington GIS parcel data.

[9] Total "Developed" Area refers to the total area of parcels which have one or more structures on them. Hence, this field does not represent total impervious area as a developed parcel may also include pervious cover such as forest. In addition this field does not include ROW land uses (roads) or undeveloped parcels such as those covered by forest or water.

4.4 Septic Systems

Septic systems are a very common means of treating on-site wastewater in North Carolina, especially in rural areas not served by municipal or county sanitary collection systems. If properly designed, constructed, and maintained septic systems can provide a safe and effective means of treating and disposing of wastewater. However, failing septic systems can lead to partially or untreated wastewater reaching surface waters resulting in bacterial contamination. Systems failing due to clogged or hydrologically overloaded drain fields can result in wastewater being forced to the surface of the ground. Failing systems can also be defined as those which are hydrologically short circuiting the intended drain field resulting in waste flow traveling towards a nearby ditch or stream. This problem is most prevalent in the lower coastal plain where ditching is common.

Approximately every three years Shellfish Sanitation conducts a Sanitary Survey of the watershed adjacent to shellfishing waters. The most recent survey was completed in March 2001. As part of the survey residential subdivisions are inventoried and the number of houses served by centralized sewer and septic systems are counted. In the Hewletts Creek watershed this survey covered all of subwatersheds 1, 2, 3, 4, & 7, and the lower portions of subwatersheds 6 & 8. Within this area a total of 38 houses were identified as being on septic systems. Table 4.4 summarizes Shellfish Sanitation's septic system survey.

Table 4.4 Inventory of septic systems in the lower Hewletts Creek watershed as reported in the March 2001 DEH Sanitary Survey of the Masonboro Sound Area (Area B-6) which includes the lower Hewletts Creek watershed.

Subwatershed	Subdivision/Property Name	Number of Houses Served by Septic Systems
Boundary of 1 & 2	Still Meadow	11
6	Oak Forest	27
		Total 38

Shellfish Sanitation has conducted visual inspections of these septic systems and none were found to be failing. Hence, there is little evidence to suggest that failing septic systems within the surveyed area are a significant source of bacterial contamination to the estuary.

It is important to note that the Sanitary Survey does not include the entire watershed. For example subwatershed 5 contains a number of homes served by septic systems which were not inventoried. However, the City is currently extending the sanitary sewer collection system into this subwatershed and eventually these homes will be tied into the system.

4.5 Non-stormwater Flows From Stormwater Drainage System

While municipal stormwater conveyance systems are intended to drain and convey rain water from the landscape, there is the potential for non-stormwater flows to also enter the system. Often non-stormwater flows are transient in nature. For example, water from fire hydrant flushing, car washing activities, and landscape irrigation, can enter the stormwater conveyance system from time to time throughout a watershed. These flows can carry pollutants such as fertilizers, detergents, and general debris from the roadway into streams. Illegal tie-ins to the drainage system are another source of non-stormwater flows. Depending on the source of the flow, tie-ins can also represent a threat to water quality. Tie-ins are generally pipes from a private drainage system which have been illegally connected to the City's stormwater conveyance system, typically inside an inlet structure. Flows from tie-ins might include drainage from a household appliance such as a washing machine, or drainage from a sanitary waste system. Tie-ins have been known to discharge stormwater from private drainage systems such as french drains around the perimeter of a house. However, given the potential for tie-ins to include non-stormwater, these sources represent a particular concern to watershed managers. Of primary importance from both a water quality and public health perspective are tie-ins draining sanitary sewage into the stormwater conveyance system.

As part of the stormwater infrastructure inventory of the 1998 Annexation Area, the presence of tie-ins were recorded in the database when observed in an inlet structure or pipe. The database also includes whether or not flow from the tie-in was observed at the time of the inventory inspection. Narrative comments were also recorded in the database if any unusual odors, colored discharges, foam, etc, were noted emanating from the tie-in. The stormwater infrastructure inventory did not include any water quality sampling or flow rate monitoring of discharges from tie-ins. Hence, little to no information is available to quantify the concentrations of fecal coliform bacteria associated with a tie-in discharge. However, information regarding potential concentrations can be drawn from a special study of dry weather flow discharges from the stormwater conveyance system conducted by the Mecklenburg County Department of Environmental Protection in that county.[10] From this study Mecklenburg County managers found that fecal coliform concentrations ranged from zero to 15,000/100mL suggesting the potential for tie-ins to be a significant source of bacterial contamination. It is important to note that the study was not designed to identify the actual source of the bacteria within the watershed, just that dry weather flows can contribute fecal coliform loads to the receiving stream.

Based on an assessment of the 1998 Area stormwater inventory database 29 structures (inlets or manholes) within the watershed were noted has having tie-ins present. Recall that 1998 Annexation Area covers only roughly 40% of the Hewletts Creek watershed. Hence, 29 structures containing tie-ins is likely to be an underestimate of the total number of tie-ins to the stormwater system within the entire watershed. Figure 4.7 (p. 42) illustrates the locations of structures containing tie-ins as well as the outfall location to a receiving perennial stream or estuary from which flow from the tie-in would ultimately discharge.[11] Information regarding stream/estuary outfall locations might be useful for targeting future new instream sampling stations.

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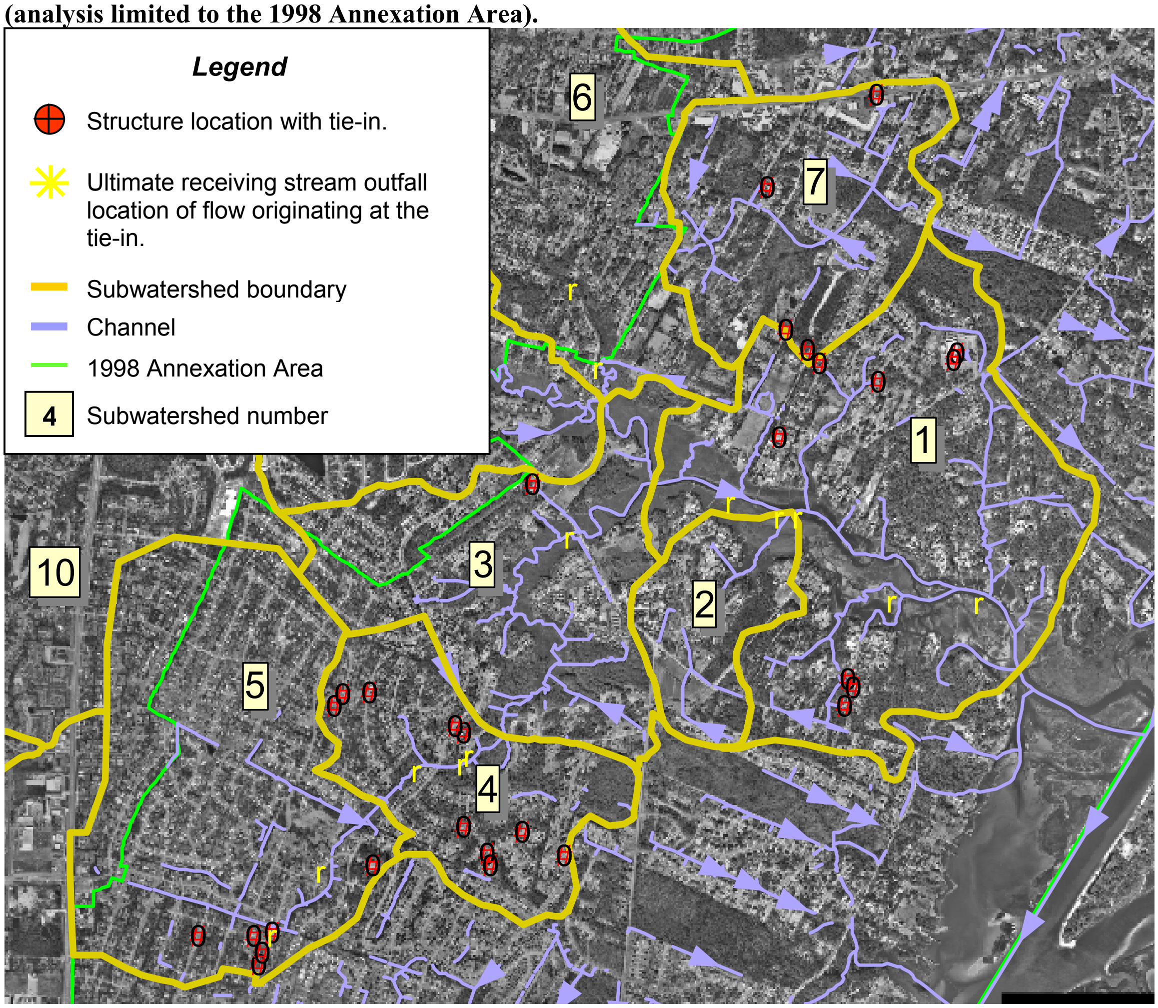
[10] Fecal Coliform Total Maximum Daily Load for the Irwin, McAlpine, Little Sugar and Sugar Creek Watersheds, Mecklenburg County. Final February 2002. Prepared by the Mecklenburg Co. Department of Environmental Protection and the NC Division of Water Quality.

[11] For the purposes of this analysis a perennial stream was defined as one which appears as a solid blue line on the corresponding USGS 7.5 minute topographic map.

Figure 4.7 Stormwater structures containing tie-ins within the lower Hewletts Creek Watershed (analysis limited to the 1998 Annexation Area).



4.6 Wildlife and Unknown Stormwater Related Sources

Warm blooded wildlife such as opossums, raccoons, rats, geese, ducks, sea gulls, etc., have the potential to contribute to fecal coliform contamination of shellfishing waters. Unfortunately, often little is known about the size and species composition of wildlife communities within urban and urbanizing areas. The March 2001 Shellfish Sanitation Survey stated that the only concentrations of domestic or wild animals found during the sanitary survey were a small number of horses located in private stables. It is important to note though that many urban wildlife populations, such as opossums, are primarily nocturnal. Hence, casual daytime visual surveys may not detect much of the wildlife present in the watershed (with the possible exception of birds).

Researchers at UNC-W conducted an investigation of fecal coliform sources in the Futch Creek watershed.[12] The study found little evidence of major anthropogenic sources of contamination such as failing septic systems. However, visual inspections of the area surrounding the most polluted stretches of Futch Creek yielded evidence of animal dung and numerous small animal trails. The researchers therefore hypothesized that wildlife, particularly raccoons, were partly responsible for the shellfish harvesting closures. Following limited dredging at the mouth of the creek to increase flushing and salinity (fecal coliform die-off rates increase with increasing salinity) portions of the Futch Creek estuary were reopened to shellfish harvesting.

Although the UNC-W study at least partially implicated wildlife populations, it is important to note that most undeveloped coastal watersheds (with presumably large wildlife populations) are open to shellfish harvesting. Hydrologic modification of the watershed from development, such as ditching and increases in impervious surfaces, may result in an increase in the rate of delivery of pollutant loads from wildlife. Development can also be an attractant to wildlife (raccoons to trash cans, sea gulls to piers) resulting in contamination problems which might not otherwise exist if wildlife populations were more naturally distributed. Therefore, careful consideration needs to be given when emphasizing wildlife populations as a problematic source of bacterial contamination.

[12] Mallin, Michael A., et al. 2000. Restoration of Shellfishing Waters in a Tidal Creek Following Limited Dredging. Journal of Coastal Research, Vol. 16, No. 1.

Part 5

"BIG PICTURE" MANAGEMENT PRIORITIES

This section of the restoration plan outlines a series of broad management priorities from which to base specific management strategies. These "big picture" priorities are intended to serve as a road map for reaching our restoration goals. While the specific management strategies presented in Part 6 of this report may change and evolve over time as more information is gathered, the overriding priorities outlined in this section will likely remain constant over time.

Brief Review of Restoration Goals

Recall from Part 2 the tiered goal setting approach outlined for this restoration plan. These goals are hierarchical such that achieving Goal #3 for instance first depends on successfully achieving Goal #2.

Goal #1 – Protect and enhance shellfish health and populations in Hewletts Creek.

Goal #2 – Improve water quality so as to restore the partial harvesting use of the waters during dry weather periods.

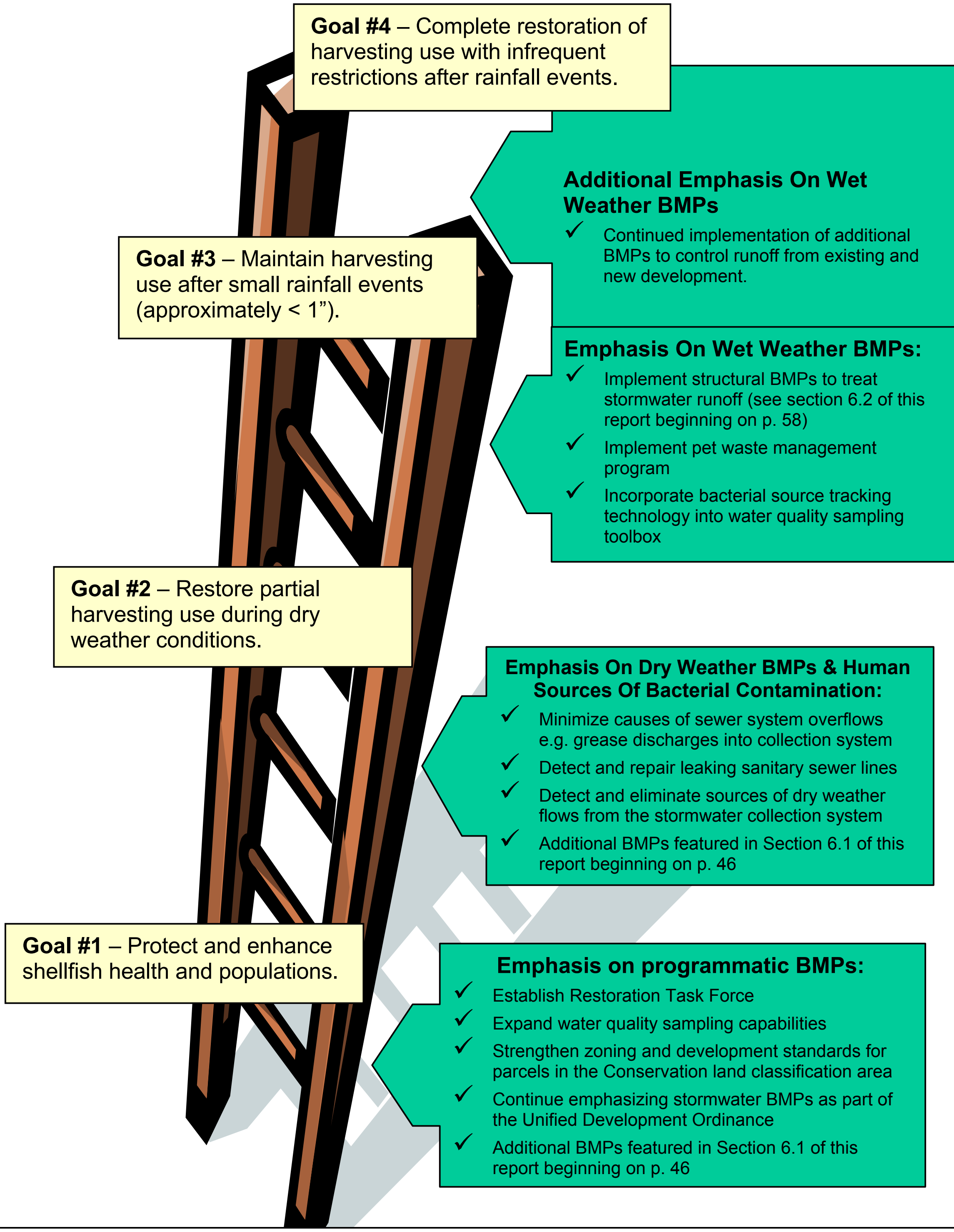
Goal #3 – Improve water quality so as to maintain the harvesting use of the waters during most periods with the exception of after significant rain events (>1").

Goal #4 – Complete restoration of the harvesting use of the waters without restrictions after rain events (exceptions might still apply after very large rain events or during coastal-wide preemptive closures before and after hurricanes).

Over the next 5-10 years the City should set a schedule for taking the necessary actions to achieve goals 1 and 2 for all of the open water portions of the estuary. This area generally includes those shellfishing waters below Pine Grove Road with salinity levels appropriate for the growth of shellfish harvested for human consumption.

Achieving goals 3 and 4 will require controlling stormwater related sources of contamination, which will be more challenging due to the nonpoint source nature of the problem. Figure 5.1 illustrates the relationship between the restoration goals and general types of management actions. Establishing an imaginary management line which roughly divides the open water estuary in half should be considered for measuring attainment with goals 3 and 4. Due in part to higher flush rates and salinity concentrations, reaching goals 3 and 4 in the lower half of the estuary will occur more quickly. Consultation with Shellfish Sanitation staff will be needed when establishing this management line as their sampling stations will need to be repositioned along this line in order to monitor water quality around the closure line. Achieving goals 3 and 4 in the upper half of the estuary is anticipated to be a much more challenging management effort than in the lower half.

Figure 5.1 Relationship Between Watershed Goals and Management Activities



The graphic above is intended to illustrate the general sequence of implementation actions to reach each of the restoration goals. Implementation should start by building a foundation of strong city/county "inhouse" capabilities and local involvement. These programmatic-type BMPs will serve to direct the implementation of additional BMPs as we progress up the latter. However, it is important to emphasize that many of the BMPs illustrated higher up the ladder would also help to reach the goals at the lower end of the latter, especially Goal #1. Hence, managers and stakeholders should continually evaluate implementation of a variety of BMPs as opportunities arise.

"Big Picture" Management Priorities

Below is an outline of recommended "big picture" priorities which should provide useful guidance when making decisions on specific management strategies.

Successfully achieving the restoration goals hinges on support and actions taken by City agencies (and others) outside of Stormwater Services. Therefore, a priority should be given towards involving other organizations in the implementation phase.

While Stormwater Services has an important role in execution of this plan, such as providing leadership and implementing specific BMPs, actions by other City and outside organizations will likely be required. Hence, a priority should be given towards elevating the issues outlined in this plan beyond Stormwater Services. The possibility of bacterial contamination from SSOs and leaking sanitary sewer lines emphasizes the need for Public Utilities and other departments to become involved in implementation efforts targeted specifically towards reducing fecal coliform loads to the estuary. This "big picture" priority is supported by the 1998 City/County CAMA Land Use Plan update which emphasizes the need for broad based actions for restoring the designated uses of all impaired shellfishing waters.

A lead staff person within Stormwater Services should be designated as the point person for moving the recommendations of this plan forward.

A key element of any successful local restoration plan which involves as many diverse issues as this one does is designating a plan manager to maintain interest and momentum. While a manager with strong technical skills is a plus, enthusiasm and general leadership skills are probably more important traits. The manager can bring into the process people with the appropriate technical skills as specific issues arise. In addition, the general public may be more responsive to outreach efforts if a specific contact is named in educational materials.

A high priority should be assigned to expanding the current water quality sampling program in the Hewletts Creek watershed.

While the current sampling program supported by the City and conducted by UNC-W researchers has provided an excellent base line of information to start from, the program is not designed for the purposes of identifying problematic sources of fecal coliform on a subwatershed and ultimately catchment (30 - 300 acre) level basis. The current UNC-W sampling contract is reviewed/renewed/updated annually. Fixed stations and sampling frequencies for a suite of water quality parameters are outlined in the contract. This plan recommends that support for the UNC-W sampling program be continued as it has provided valuable insight into a variety of environmental issues in New Hanover County. However, the City needs expanded flexibility to sample at additional locations then relocate stations as more information is gathered. Sampling also needs to vary over time in order to characterize dry and wet weather conditions. To save money and time the number of water quality parameters sampled as part of the expanded program could be reduced.

A general management priority should be placed on controlling human sources of bacterial contamination first.

Untreated sewage is the primary human source of fecal coliforms. In the Hewletts Creek watershed this means prioritizing sources such as dry weather flows from the stormwater conveyance system, SSOs, leaking sanitary sewers, and failing septic systems. Pathogens from untreated sewage are potentially more dangerous, but are generally more controllable, compared to those delivered in urban stormwater runoff.

Watershed investigations should focus on dry weather sources initially.

Recall from our tiered set of goals that restoring the shellfish harvesting use of Hewletts Creek is first targeted for dry weather conditions. Focusing initially on dry weather sources, which tend to be more controllable, should assist in meeting this goal. In addition, since dry weather sources are often of human origin added benefit can be achieved by concentrating resources on reducing bacterial loads during dry weather periods.

Wet weather source investigations should be second. A watershed-based investigatory strategy should be devised which generally proceeds in a downstream to upstream fashion.

Wet weather sources are characterized by bacterial loads being delivered to the estuary primarily via stormwater runoff. These sources tend to be more diverse both spatially and temporally and therefore will be more difficult to manage. Effectively managing these sources will be much more difficult without the expanded monitoring program discussed above. Generally speaking, wet weather source investigations should first identify tributaries/outfalls which have the combination of relatively high flow rates and high fecal coliform concentrations (i.e. high bacterial loadings). Once these are identified the investigation should proceed and systematically branch out up into the subwatershed and eventually terminate at the catchment level (< 300 ac scale).

Management approaches should be allowed to vary by subwatershed.

Although the Hewletts Creek watershed is primarily residential, there are a number of factors which vary between (and within) subwatersheds which will necessitate an adaptive management approach. These factors include variations in land use/land cover, age of development, population demographics, proximity to the estuary, etc. While certain control strategies might logically apply watershed or even city-wide, relying solely on blanket management measures will likely lead to minimal progress. Focused implementation, targeted specifically at fecal coliform hot spots will be needed to achieve watershed goals.

Periodically reassess what's working and what's not. Adopt a recurring management cycle which includes updates to this plan.

A fundamental component of watershed management is implementing a scheduled sequence of events which begins with scoping the problem, strategic data collection and analyzing information, setting priorities, selecting management strategies, and finally implementation. This sequence of events should be repeated per an established schedule which facilitates the periodic reassessment of which strategies are working and which ones aren't. Strategies deemed ineffective can be halted and resources redirected into ones showing progress.

BMPs for new development should focus on infiltration as opposed to stormwater detention-type BMPs.

BMPs which function on the principal of infiltrating stormwater through the soil as a whole tend to be more effective and reliable at removing bacteria than detention-type BMPs. While wet detention ponds and stormwater wetlands have been shown to be effective at removing bacteria, removal efficiencies vary considerably depending on the design. For example, wet detention ponds, which are very common in the Wilmington area, can be effective at settling out a variety of pollutants. However, many ponds are designed and maintained with grassed banks as opposed to naturally vegetated littoral shelves. Grassed banks are very attractive to certain waterfowl (e.g. geese) which can result in the BMP becoming a source rather than a solution.

Part 6

SPECIFIC MANAGEMENT STRATEGIES

This section outlines specific actions the City might consider taking towards meeting the restoration goals. These actions are broadly classified into two categories: non-structural best management practices (BMPs) and structural BMPs. Non-structural BMPs typically are policy and programmatic actions often designed to reduce pollutant loads at the source, i.e. source control. Structural BMPs are used to treat runoff once it has come into contact with fecal coliform. The structural BMPs presented in this section were selected to maximize the rate of bacteria mortality but should also service to improve water quality in other ways as well.

Generally speaking non-structural programmatic-type BMPs tend to be the most cost effective method for advancing watershed goals as the emphasis is on pollution prevention. The challenge with implementing these types of BMPs though is that a significant amount of staff time and interagency cooperation can be required. Sometimes these challenges can be more difficult to surmount than implementing expensive structural BMPs. Hence, a balanced implementation strategy is needed which optimizes the use of both categories of BMPs.

6.1 Non-structural BMPs

General Programmatic BMPs

- ***Designation Of A Lead Staff Person Within Stormwater Services Responsible For Moving The Recommendations Of This Plan Forward.***

  This person would serve as the Hewletts Creek shellfish waters restoration Plan Manager. The Plan Manager would serve as a liaison between other city, county, and outside organizations to keep track of ongoing activities which might help to advance the objectives of the plan. A core duty of this person would be to coordinate and distribute resources as needed to ensure that appropriate BMPs (particularly programmatic BMPs) are established and are functioning as intended.

- ***Contract With UNC-W Researchers To Establish Appropriate Measurable Benchmarks Of Long-term Sustainable Ecological Health Of Shellfish Populations In The Estuary.***

  Researchers at the UNC-W Benthic Ecology Laboratory have developed field techniques for monitoring indicators of oyster reef health (see the following bulleted recommendation of more details). While these techniques provide useful information regarding a given reef, additional benchmarks are needed for assessing the ecological health of the estuary as a whole as it specifically relates to Goal #1 (p. 7 & 41). Once these benchmarks are established managers can ascertain what actions are needed to promote improvements in the shellfish population. For example, if one of the benchmarks is a function of suitable habitat, then a request could be made to the Division of Marine Fisheries (DMF) to target Hewletts Creek as part of their Shellfish Rehabilitation Program. This program focuses on creating more hard underwater surfaces for larval oysters and clams to attach themselves to. Typically this is accomplished by dumping or spraying shell and rock, known a cultch, into the water a strategic locations.

To facilitate cooperation with DMF on this issue it is recommended that the Plan Manager contact DMF staff (Anne Deaton 910- 395-3900) responsible for developing the Southern Estuaries Coastal Habitat Protection Plan (CHPP). The DMF is undertaking an initiative to produce CHPPs for eleven coastal regions. The goal of these plans is to identify management actions to improve marine fisheries through improvements in habitat and water quality. The Southern Estuaries CHPP will cover the Hewletts Creek watershed. Measures DMF adopts for assessing the health of the shellfish fishery might be considered as one of the benchmarks for attaining Goal #1.

– ***Develop Shellfish Ecological Health And Population Monitoring Program***

There is a growing body of scientific evidence to demonstrate that the presence of shellfish, which are filter feeders, have a measurable positive affect on water quality. Goal #1 of this plan has been crafted in recognition of this fact. The objective of this monitoring program is to detect trends in ecological health of shellfish populations over time. If negative trends are detected then corrective actions should be taken. Researchers at the UNC-W Center for Marine Science Research have developed a relatively simple, low-tech monitoring procedure for tracking the ecological health of oyster populations over time. The monitoring program of randomly selected intertidal oyster reefs would have the following components:

- ✓ Sampling conducted once a year, typically in August
- ✓ Requires 2-3 days with a two person field crew
- ✓ Data collected includes:
  - Ratio of live to dead oysters
  - Density of live oysters
  - Percentage of sampled reef area covered with shells
  - Measure of new oyster set (big and small size classes)
  - Vertical relief of reef – measurement of the distance between the high point and low point of the reef. As the reef looses vertical complexity there tends to be a reduction in the reef's viability resulting in a long term downward spiral in the ecological health of the reef.
- ✓ The data should be reviewed and interpreted for the City every couple of years by a qualified benthic ecologist.

– ***Establish A Stormwater Services Intern Program.***

Conducting fecal coliform source investigations will require one or more persons to send a significant amount of time in the field. It may be difficult for the existing permanent full time staff to divert time away from current duties to conduct these investigations. Hence, supporting summer or year round part time interns might be a relatively low cost option for acquiring additional labor. The Plan Manager mentioned above would coordinate the activities of the interns and maintain a database of their findings. The UNC-W would be a logical source of interns with educational training on environmental issues. As an alternative or in addition to the intern program, Stormwater Services might consider supporting a graduate student at the UNC-W Center for Marine Science Research. The graduate student's research would focus on identifying solutions towards meeting the objectives of this plan.

– ***Establish A Restoration Task Force.***

As discussed in Part 5 one of the key "big picture" management priorities should be to engage other organizations to take the necessary actions to reduce bacterial contamination of shellfishing waters. Step one in this process is to identify which organizations should participate and get representatives to the table to discuss the issues. The format of the Task Force might be similar to the City's successful Watershed Protection Roundtable which in July 2001 published a report which identified a series of recommendations to improve water quality in the region. The Plan Manager would play a lead role in coordinating the Task Force. Participating organizations might include some or all of those listed in Table 6.1

Table 6.1 List of potential organization which might participate in a Restoration Task Force.

Organization	Area of Expertise/Responsibility
Tidal Creeks Program	BMP implementation within New Hanover Co. tidal creek watersheds.
DEH Shellfish Sanitation Section	Fecal coliform sampling and source identification in shellfishing areas across NC.
Wilmington Public Utilities Department	Operates and maintains the sanitary sewer collection system.
New Hanover County Planning Department	Comprehensive land use planning
NC Division of Coastal Management	Broad-based CAMA related management issues. Developing Coastal Habitat Protection Plans – Southern Estuaries Plan will include Hewletts Creek.
NC Division of Water Quality	NPDES Phase II stormwater permitting. TMDL development. Watershed-based planning and regulations.
NC Division of Marine Fisheries	Enforcement of shellfish harvesting regulations. Fisheries management.
New Hanover County Health Department	Public health issues. Septic system inspections.
UNC-W Center for Marine Science Research	Research and education.
Friends of Hewletts Creek	Environmental advocacy and public education.

– ***Adopt Watershed Management Units***

Watershed management units are designed to provide the spatial basis for the coordination of a wide range of city efforts designed to address water quantity and quality issues. These units are delineated based on geographic features (drainage areas) rather than an arbitrary system of quadrants for example.

It is recommended that the City and County cooperate to delineate and acknowledge management units based on commonly recognized watersheds throughout the county. Watersheds could be further delineated into subwatershed such as the ones presented in this report for Hewletts Creek. Identification codes should be assigned to each management unit for easy reference. For example, a two or three character abbreviation for the watershed name might proceed a subwatershed number (e.g. HEW02 for subwatershed 2 in the Hewletts Creek watershed). While not absolutely necessary, consideration might be given to ensure the consistency of the number of characters and numbers used to make up the identification code. ID codes with consistent numbers of characters and digits can make any future GIS or database programming initiatives easier.

Uses of management units include:

- ✓ Units for data storage and reporting
- ✓ Units for setting goals and priorities
- ✓ Analytical units for assessment and modeling
- ✓ Units for describing current and future conditions
- ✓ Management coordination units

It is recommended that watershed management units be featured in the next City/County CAMA Land Use Plan Update, as well as the annual UNC-W "Environmental Quality of Wilmington and New Hanover County Watersheds" reports. Wider use of these management units provides an enhanced means of communicating watershed-based issues.

Example of the application of watershed management units:

The City and County could use these management units to tailor implementation actions such as the one described in Policy #/Action A1.1.3 on p. 31 of the 1997-2010 Comprehensive Plan Update which states:

"Develop specific water quality standards and development performance standards for each watershed, to include max. impervious surface, buffers, permeable paving, reduced parking surfaces, and others."

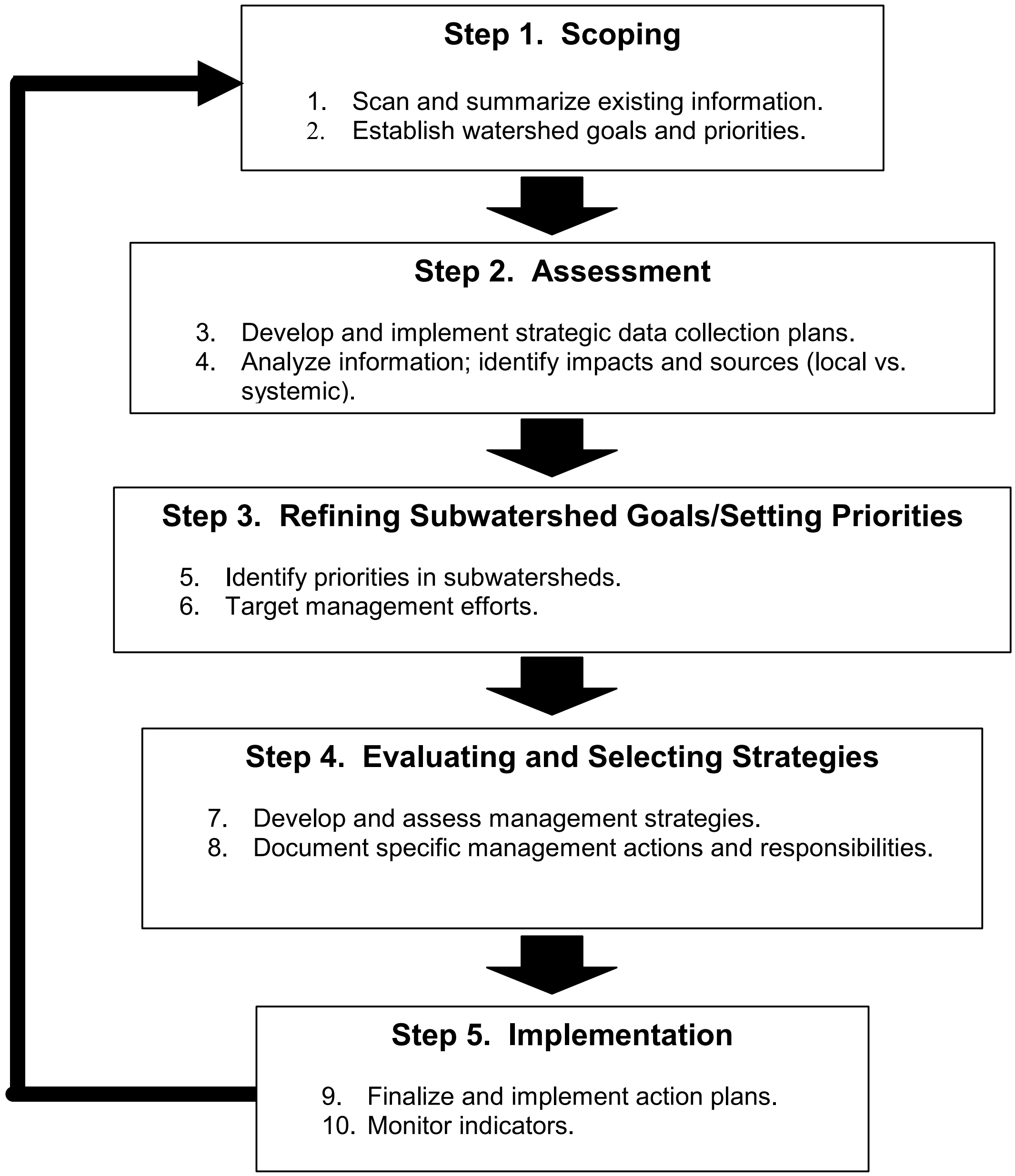
Impervious surface limits, buffer widths, and parking requirements could be varied to meet specific concerns within a given management unit. For example those subwatersheds identified in this report has having a High future growth potential could be targeted for more stringent impervious surface limits as compared to those with less growth potential.

– ***Adopt A Recurring Management Cycle For The Hewletts Creek Watershed***

While the watershed management units described above help provide the *spatial* framework for watershed planning and coordination, a watershed management cycle provides the *temporal* framework for scheduling and focusing efforts. The cycle provides an ordered set of steps to be followed to achieve the desired objective. By defining and following a management cycle, managers provide staff and stakeholders a clear timeframe for certain activities to occur, such that everyone knows how and when to participate in watershed management efforts.

The NC Division of Water Quality has adopted a 5 year recurring management cycle for each of the 17 major river basins in the state. Wilmington is wholly within the Cape Fear River basin. To date, two Cape Fear River Basinwide Water Quality Management Plans have been written by DWQ, the most recent was published in July 2000. A 5 year cycle has been demonstrated to be a suitable length of time between management plan updates. During this period a sufficient amount of time has passed for notable land use changes and other activities to have occurred.

Below on the next page is an outline of the major steps and associated activities which comprise the recommended watershed management cycle.



It is recommended that Stormwater Services develop a schedule for conducting each major step in the cycle such that staff and stakeholders know when and how to participate in management efforts. Key staff involved in each step should be identified. Managers might expect each step to take the following lengths of time:

- ✓ Scoping – 2 months
- ✓ Assessment – 18 months
- ✓ Refining subwatershed goals/setting priorities – 1 month
- ✓ Evaluating and selecting strategies – 24 months
- ✓ Implementation – 15 months and ongoing

– ***Develop In-house Water Quality Sampling Capabilities.***

The current sampling program conducted by UNC-W researchers has provided an excellent base line of information for scoping major water quality issues in Hewletts Creek and other tidal creek watersheds. However, the existing sampling program is not intended nor designed to support the detailed level of investigation that will be needed to achieve our specific restoration objectives. Therefore, it will be critical for Stormwater Services to develop additional sampling capabilities, preferably in-house. In-house sampling capabilities would maximize the City's flexibility to vary sampling stations and characterize dry and wet weather conditions over time.

Fecal coliform monitoring is frequently conducted via grab samples as opposed to deploying an automated sampling device. This is due largely to the fact that standard sampling protocols require no greater than 6 hours of holding time (fecal coliform tend to die off once they leave the host organism). Collecting manual grab samples can be time consuming. Hence, in-house sampling should be coordinated with the establishment of an intern program.

– ***Install A Rain Gage In The Hewletts Creek Watershed***

One of the core management strategies in this plan is to distinguish dry weather versus wet weather sources. This requires that staff have a record of when and how much rainfall has occurred. Fecal coliform sampling data should be segregated between dry and wet weather samples. Taking into consideration the number of days between a rainfall event and when the sample was collected provides useful information when analyzing the data.

Staff should not necessarily rely on rainfall data collected at the airport as an indication of when rainfall occurred in the watershed, especially in the summertime. Sporadic summer thunderstorms can result in dramatically different rainfall amounts over relatively short distances.

Before sighting a rain gage it is recommended that staff consult with Shellfish Sanitation. Achieving Goal #2, temporarily reopening shellfish waters to harvesting during dry weather, will require Shellfish Sanitation to develop a management plan for when and where to reopen the waters. This plan, which is required for all waters reclassified to Conditionally Approved, requires that a rain gage in the area be monitored. Installing a real-time web enabled rain gage will facilitate a variety of users access to local rainfall data.

Non-structural Source Control BMPs

– ***Develop A Pet Waste Management Program***

Pet waste, especially from dogs, represents one of the most significant potential sources of fecal coliform in the watershed. The NC Division of Water Quality recognizes the potential impact of pet wastes on shellfishing waters. As such the Division has included a pet waste management requirement in the draft April 2002 NPDES Phase II rules. This post-construction stormwater management requirement would apply to Wilmington as the City includes areas draining to SA (shellfishing) waters.

The following components might be included in a pet waste management program:

- ✓ Pass a City-wide "pooper scooper" ordinance. Wilmington's current pet waste ordinance only requires dog owners to pick up and dispose of feces within parks. This ordinance should be amended to require proper waste disposal city-wide as opposed to only in parks. In addition, the City should consider requiring persons walking dogs off the owners property to carry a bag, shovel, or pooper-scooper. This requirement makes it easier to identify persons not complying with the ordinance.

- ✓ As a basis to guide the development of a public education campaign, conduct a survey of dog owners to gage their attitudes towards picking up after their animals. Interestingly, surveys have indicated that of those dog owners who do not pick up after their pets, the threat of fines tend not to influence their behavior. Rather the most influential factor for changing behavior tends to be complaints from fellow neighbors.[13]

- ✓ Post signs in parks and residential neighborhoods, especially those adjacent to the estuary. These public education signs would be designed to help pet owners make the connection between pet waste and water quality.

- ✓ Periodically obtain and georeference a copy of New Hanover County's Pet License database in order to monitor major changes in the pet population over time. The subwatersheds delineated in this report would be an appropriate spatial unit for tracking these data.

- ✓ Establish partnerships with local pet supply stores and veterinarians to promote the program.

[13] Watershed Protection Techniques Vol. 3, No. 1, Article III – April 1999

– ***Participate With The Public Utilities Department To Minimize SSOs***

Survey's indicate that pipe blockages and infiltration & inflow of stormwater and groundwater contribute to roughly ¾ of all SSOs.[14] Maintenance and repair of the sanitary sewer system is coordinated by the City's Public Utilities Department. Although managing SSOs is not the direct responsibility of Stormwater Services, staff can still assist in efforts to minimize SSOs as part of a broad approach to protect water quality. Specific actions Stormwater Services staff might consider include:

- ✓ Establish contacts with the Public Utilities Department and routine modes of communication with Stormwater Services staff.

- ✓ Establish procedures by which Stormwater Services is notified when a SSO occurs. This notification process should also include information regarding whether or not stormwater inflow was believed to significantly contribute to the cause of the overflow.

- ✓ To the extent possible conduct up and down stream fecal coliform sampling after a spill occurs. Ensure that interns and staff collecting samples are trained in appropriate safety precautions to avoid exposure to pathogens.

- ✓ Maintain an up-to-date copy of the Public Utilities SSO database. This database will be part of the ongoing effort to assess sources in the watershed.

- ✓ Specifically identify nuisance flooding areas which are overtopping sanitary manholes resulting in the inflow of stormwater into the sanitary collection system. Public Utilities may already have a good idea of which portions of the collection system are prone to stormwater inflow. Consider assigning a higher priority to resolving these drainage problems.

- ✓ Assist in promoting public education campaigns to encourage residences to properly dispose of grease as opposed to pouring it down the drain. Grease is a leading contributor to pipe blockages resulting in overflows.

- ✓ Assist in promoting public spill response hotlines as part of stormwater public education initiatives. Particularly during heavy rainfall events, the public may mistake an SSO for stormwater.

[14] US EPA. Brochure: SSOs – What are they and how can we reduce them? 1996. EPA 832-K-96-001.

– ***Participate With The Public Utilities Department To Identify Leaking Sewer Lines***

Leaking sanitary sewer lines present a special challenge to watershed managers as often there is no visual signs of a problem. Hence, the first challenge is to identify where significant leaks are actually occurring. Bacterial Source Tracking (BST) techniques may be one of the better means for making this determination (see Part 4 for a general discussion of BST). As discussed in Part 4 a good place to start investigating for leaking sewer lines is to locate where older clay lines are still in service. For a number of reasons terra cotta and vitrified clay lines are more subject to damage. BST sampling should be conducted during dry weather when runoff sources are at a minimum and groundwater levels are lower (exfiltration out of the line). The Shellfish Sanitation Section can provide further details on the 319 funded initiative to integrate BST technology into the Shellfish Sanitation program.

Until BST technology becomes available standard instream fecal coliform sampling can provide clues as to the presence of a leaky line. Up and downstream sampling of a sewer line crossing may provide an indication as to the integrity of the line. Streams or ditches which run in close parallel to sewer lines might also be targeted for sampling. Again this sampling should be conducted during dry weather.

– ***Conduct A Dry Weather Flow Study Of The Stormwater Conveyance System***

Sources of dry weather flow typically enter the stormwater conveyance system through yard and curb inlets as well as illicit connections within an inlet structure. Dry weather flow may or may not be contaminated by pollutants. However, since the stormwater system is only intended to drain and discharge stormwater runoff (with some exceptions), dry weather flows should be treated as suspect.

Within the 1998 Area a good database of illicit connections (a.k.a. tie-ins) has been established as part of the stormwater infrastructure inventory. This area only covers approximately 40% of the watershed but would be a good place to start in terms of fecal coliform sampling of flowing tie-ins. The database includes attributes indicating whether or not flow was observed from the tie-in when the inventory inspection was performed.

- ✓ Sample flowing tie-ins for fecal coliform during dry weather periods. Visually estimate flow rates.

- ✓ Consider smoke testing non-flowing tie-ins to determine the origin of flow, e.g. roof drains. Look for evidence that flow has recently occurred.

- ✓ In addition to structures known to contain tie-ins, stormwater outfalls should also be surveyed for dry weather flow. Visual screening indicators such as unusual flow, odor, color, turbidity, deposits/stains, and floatable matter are often associated with non-stormwater. Dry weather flow from outfalls should be sampled for fecal coliforms and flow tracers. Tracers such as detergents, fluorides, and potassium have been shown to be effective in diagnosing sources of dry weather flow.[15]

Consider using innovative techniques for detecting outfalls with dry weather flow. The Mecklenburg County Department of Environmental Protection reports successfully using aerial infrared photography as a desk top method of identifying dry weather flows from outfalls.[16]

– ***Investigate Wildlife Populations In The Watershed***

As mention in Part 4 little is known about wildlife populations in urban watersheds. Therefore, it is difficult to assess the contribution wildlife has towards the closure of shellfish waters in Hewletts Creek. If wildlife does have an impact, intuitively one might suspect those warm blooded species active along the margins of the estuary.

UNC-W researchers have conducted surveys of mammals with a body mass > 2.5 kg in the Futch and Howe Creek watersheds.[17] A similar study in the Hewletts Creek watershed would add to the knowledge base of mammal populations in the area. Bacterial Source Tracking studies, however, may yield the most definitive assessment of impacts from wildlife populations. Until BST investigations of Hewletts Creek are initiated, public education efforts designed to discourage attracting potentially problematic wildlife should be considered. Educational efforts might include encouraging the use of tight fitting trash can lids to prevent attracting opossums and raccoons. Discouraging the outdoor feeding of stray cats, as well as the feeding of sea gulls and other water fowl off piers.

– ***Evaluate Existing Stormwater Infrastructure Maintenance and Clean-out Programs***

Over the years watershed managers have widely assumed that fecal coliform bacteria die off at an exponential rate once they exit their warm blooded host organism. Die off rates vary depending on environmental conditions.

[15] Watershed Protection Techniques Vol. 3, No. 1, Article V – April 1999
[16] David Kroening, Surface Water Systems Analyst – Personal communication - June 2002
[17] Mallin, Michael A., et al. 1998. A Four-Year Environmental Analysis of New Hanover County Tidal Creeks 1993-1997. UNC-W Center for Marine Science Research Report No. 98-01.

Increased salinity levels or example have been demonstrated to increase mortality in fecal coliform populations in the Hewletts Creek watershed.[18]

However, the assumption that fecal coliforms die off rather than proliferate once leaving the host organism is not always true. Researchers are finding that under certain conditions, fecal coliform populations can actually increase in the outside world if favorable environmental conditions exist. These conditions typically include warm, wet, shaded environments, high in organic matter. Such conditions can sometimes be found in stream sediments as well as in certain stormwater structures. In other words, the stormwater collection system itself can actually be a source of fecal coliforms.

The key to preventing the collection system from functioning as a breeding ground for fecal coliforms is to reduce the incidence of structures partially filled with organic sediments and standing water. Strict enforcement of local sediment and erosion control ordinances as well as routine maintenance of the collection system are BMPs which would help to create less favorable conditions for fecal coliforms inside stormwater structures.

It is recommended that the City evaluate its existing stormwater system maintenance program to determine if the resources exist to adequately conduct routine preventative maintenance. The evaluation should focus on BMPs such as street sweeping and the vacuuming out of sediment deposits from inlet structures. In order to determine what constitutes an adequate maintenance routine the City might consider monitoring over time selected inlet structures throughout the watershed known to collect significant amounts of sediments. Interns might be considered for implementing the bulk of this monitoring effort. The objective of the monitoring would be to gage if the pace of the maintenance program is keeping adequate pace with the deposition of sediments.

[18] Mallin, Michael A., et al. 2000. Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds. Ecological Applications, 10(4), pp 1047-1056.

6.2 Structural BMPs

Summary of Structural BMPs

Structural BMPs are engineered devises designed to detain, retain, infiltrate, and/or filter stormwater runoff. Each BMP has advantages and disadvantages which should be considered when evaluating stormwater treatment options for a specific site. Tables 6.2 and 6.3 (p. 62) provide a summary of various non-proprietary structural BMPs used in NC. These data offer supplementary information for each of the BMP recommendations in the following section.

It is important to keep in mind that pollutant removal efficiencies are highly variable and depend on many factors (as evidenced by the differences in pollutant removal percentages presented in Tables 6.2 & 6.3). Individual site and watershed characteristics, design of the BMP, and seasonality are just a few of the factors that can affect the performance of a given BMP. NC's lower coastal plain is a unique geographic environment, very different from other regions of NC. Therefore, long-term monitoring of structural BMPs will provide the most accurate picture of the actual water quality benefits realized. Researchers at UNC-W have identified BMP performance monitoring as an important field of future study within the tidal creek watersheds of New Hanover County.[19]

Table 6.2 Pollutant removal efficiencies (%) for various stormwater treatment practices.[20]

BMP Group	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Bacteria
Ponds	80	51	33	70
Wetlands	76	49	30	78 [b]
Filters [a]	86	59	38	37 [b]
Infiltration	95 [b]	70	51	N/A
Open Channels [c]	81	34 [b, d]	84 [b]	-25 [b]

[a] *Excludes vertical sand filters and filter strips*
[b] *Estimate based on fewer than five data points*
[c] *Highest removal rates for dry swales*
[d] *No data available for grass channels*

[19] Dr. Michael Mallin. April 2002. Personal communication.
[20] Table adopted from *Stormwater Treatment* CD, Vol 4. Center for Watershed Protection. Ellicott City, MD

Table 6.3 provides additional information on the advantages and disadvantages of various structural BMPs.

Table 6.3 Summary of BMPs commonly used in NC.[21]

BMP	Advantages	Disadvantages	Pollutant Removal
Wet Ponds	Traditional. Can double as recreational facility.	Relatively land intensive. Safety issues	Suspended particles (TSS) – very high (70%) Nitrate-nitrogen moderate (20%)
Stormwater Wetlands	Highest pollutant removal option. Good educational site.	Most land intensive. Public opinion can be negative.	Suspended particles (TSS) – very high (80%) Nitrate-N – high (40-45%)
Infiltration Trenches/Wells	Relatively low design and construction cost. Introduces surface to ground water.	Limited application (sandy soils). High potential for clogging.	Limited data suggests that removal of suspended particles is initially high – but this causes infiltration practices to fail. Very little nitrate-N is removed by this practice.
Sand Filters	Can fit in high land cost situations. Removes pollutants found in parking areas.	Most expensive per square foot of devise. Maintenance can be cumbersome.	Suspended particles (TSS) – very high (75-80%), but operators must maintain to keep high efficiency. Nitrate-N leaker (negative removal). High metal removal.
Bioretention / Rain Gardens	Aesthetically pleasing. Can double to meet landscape and water quality objectives.	Very new practice with little data to prove effectiveness. Plants must be removed if soil clogs or becomes polluted.	Suspended particles (TSS)— initially high but will result in clogging. Total nitrogen appears high, but nitrate-N may be negative.
Level Spreaders / Riparian Buffers	Construction cost very low. Effective pollutant removal. Aesthetically pleasing.	Land-intensive. Effectiveness of level spreader relatively untested.	Note: data from agricultural research Suspended particles (TSS)— very high (80%) Nitrate-N — moderate (20%)
"Reinforced" Grassy Swales	Can carry higher flow than traditional grassy swales. More aesthetic and cheaper to construct than rip-rap alternative.	Construction and maintenance costs higher than for traditional grassy swales. Relatively new device with limited long-term testing.	Highly variable removal efficiencies. Suspended particles (TSS)— moderate (median of 40%) Nitrate-N–low (10-15%)

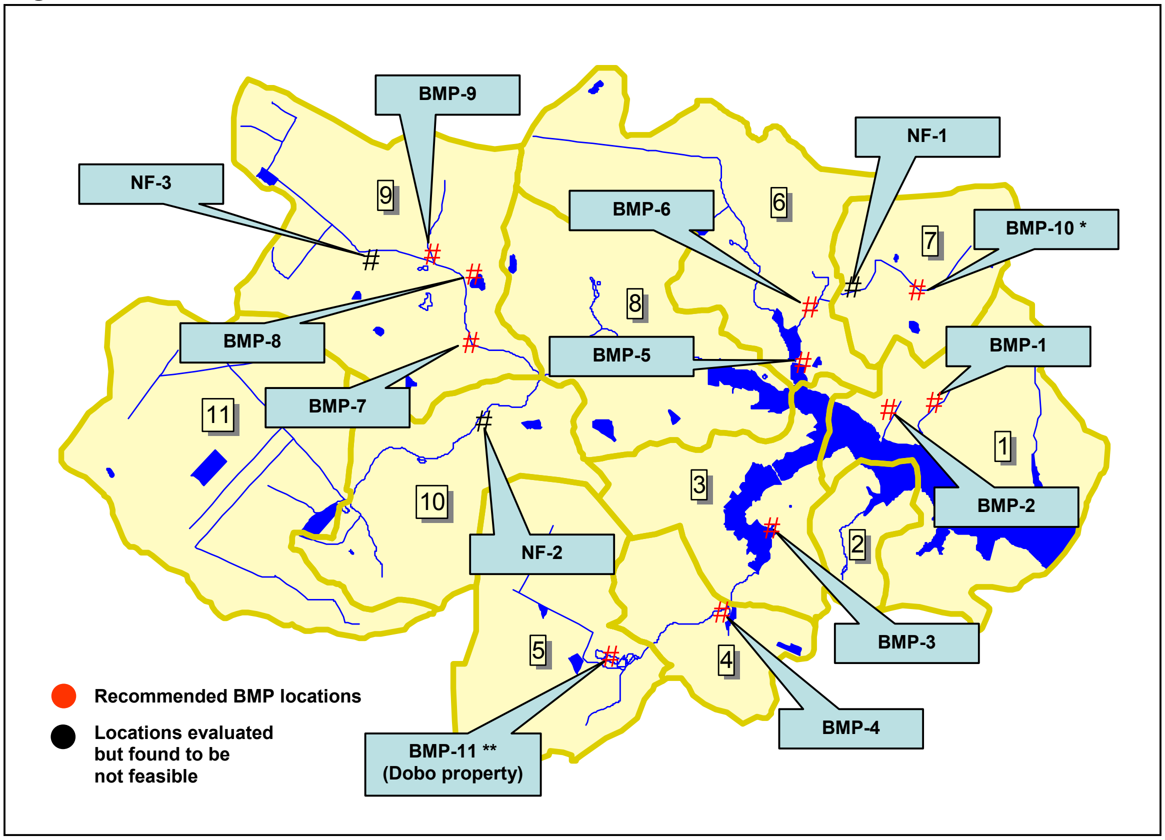
[21] The information in this table was adopted directly from AG-588 Urban Waterways / Urban Stormwater Structural Best Management Practices (BMPs). 1999. William F. Hunt, III. NC Cooperative Extension Service.

Recommended Structural BMPs

The structural BMPs outlined in this section are intended to treat stormwater runoff already contaminated with fecal coliform bacteria. Most of the BMPs fall into the category of stormwater retrofits. Retrofit BMPs treat runoff from existing development typically not already served by a stormwater BMP. Due to the limited availability of undeveloped land in an urban environment, retrofit BMPs are often undersized compared to the optimal size for maximum treatment.

It is important to keep in mind that no structural BMP in common use today can consistently achieve the high levels of removal efficiency typically required to achieve bacteria water quality standards (with the possible exception of well performing infiltration systems). Therefore, managers should emphasize both structural and non-structural BMP "chains" along overland flow pathways to reduce the level of fecal coliform contamination in urban runoff.

Figure 6.1 Recommended structural BMP locations in the Hewletts Creek watershed.



* See Volume I, Section 4.2.2. Wet detention pond near Ruxton Way and Weeping Willow Drive in problem area 9.

** See Appendices B1&B2. Dobo Property BMP Feasibility Analysis and Recommendations.

BMP-1

BMP CHOICE: Wet Detention Pond or Constructed Wetland
LOCATION: Parcel near Greenville Loop Rd. and Darby St.

Intended Treatment: Treatment Volume is first flush (1" of runoff over entire drainage area).

The contributing drainage area is approximately 55.7 acres of residential development. The area is nearly 100% developed except for two parcels, one of which contains the proposed BMP location. Approximately 1.2 acres are available for the BMP in the wooded area along the rear of the parcel. More area may be available depending on negotiations with the property owner. Topographic contours in this area suggest a BMP depth of four feet is available.

The existing channel is along the parcel line, so the design may allow for an off-line BMP with the existing channel serving as a bypass for high flows.

BMP SELECTION

WET DETENTION POND: A wet detention pond with an average depth of three feet would require a permanent pool of 0.95 acres, based on a conservative estimate of 40%

impervious area. In addition, approximately 0.2 acres of forebay would be required as per DENR stormwater BMP guide lines.[22]

Cost: $207,000 (NC Cooperative Extension Service[23]); $75,000 - $149,000 (Rouge River BMP Cost Estimating Guidelines[24]).

CONSTRUCTED WETLAND: A wetland with an average depth of two feet requires a permanent pool that is 0.41 acres in plan, with an additional 0.41 acres of high and low marsh area. Energy dissipation, such as riprap or a grassed swale, would be needed at the inlet.

Description	Quantity	Unit	Unit Cost	Cost
Earthwork*	4,700	cy	$10.00	$47,000.00
Clearing and Grubbing	1.5	ac	$4,000.00	$6,000
Riser Barrel Spillway	1	ls	$8,000.00	$8,000
Overflow Spillway	1	ls	$20,000.00	$20,000
Temporary Sediment and Erosion Control	1	ls	$25,000.00	$25,000
Seeding and Mulching	4,000	sy	$0.50	$2,000
Inlet Structure	1	ls	$8,000.00	$8,000
Plants	5,000	unit	$6.00	$30,000
Subtotal				$146,000
Contingencies (30%)				$43,800
Total				**$189,800**

*Earthwork estimated as: (1) 200 cubic yards to fill existing channel with top width of 8 feet and depth of 3 feet; (2) 711 cubic yards to build a two foot tall, two foot wide (at top) perimeter berm with 1:1 side slopes; and (3) 3,776 cubic yards for 0.08 acres with an average of four feet of fill, 0.38 acres with an average of two feet of fill, and 0.63 acres with an average of two feet of excavation. Quantities were rounded up to the nearest hundredth as appropriate for estimating cost.

SELECTION CRITERIA

BMP selection is limited by the size of the drainage area. BMPs such as bio-retention areas and swales are limited by the limits of appropriate contributing drainage area, while extended detention basis are limited by the area available for the BMP location. Wet detention ponds and constructed wetlands can both treat the site's drainage area within the proposed BMP location. Acquisition of a larger portion of the parcel may make other BMP options feasible.

[22] NCDENR Stormwater Management Practices, April 1999.
[23] NC Cooperative Extension Service – Stormwater BMP Academy Course Manual, June 2002.
[24] Cost Estimating Guidelines – Best Management Practices and Engineered Controls. July 1997. Rouge River National Wet Weather Demonstration Project.

BMP-2
BMP CHOICE: Extended Detention Stormwater Wetland
LOCATION: Open parcel near Greenville Loop Rd. and Cedar Landing Rd.

Intended Treatment: Treatment Volume is first flush (1" of runoff over entire drainage area).

The BMP location provides adequate area and depth for first flush treatment by a wet detention pond or constructed wetland. Note the parcel to the north side of Greenville Loop Road has been recently developed.

The contributing drainage area is approximately 38 acres of residential development. The area is approaching 100% development with higher density on the eastern side of the drainage area. There are several large parcels on the western side of the drainage area that could become more densely developed in the future. Approximately 1.8 acres are available for the BMP in the wooded area along the eastern parcel line. More area may be available depending on negotiations with the property owner. The topographic contours in this area indicate six feet of relief across the proposed BMP location.

BMP SELECTION
Extend Detention Stormwater Wetland:

CONSTRUCTED WETLAND: A wetland with an average depth of two feet requires a permanent pool that is 0.51 acres in plan, with an additional 0.51 acres of high and low marsh area required (Table 1.1 NCDENR Stormwater Management Practices, April 1999 assuming 30% impervious cover). 1.6 acres would be need to capture and store the 1" of runoff on the watershed area.

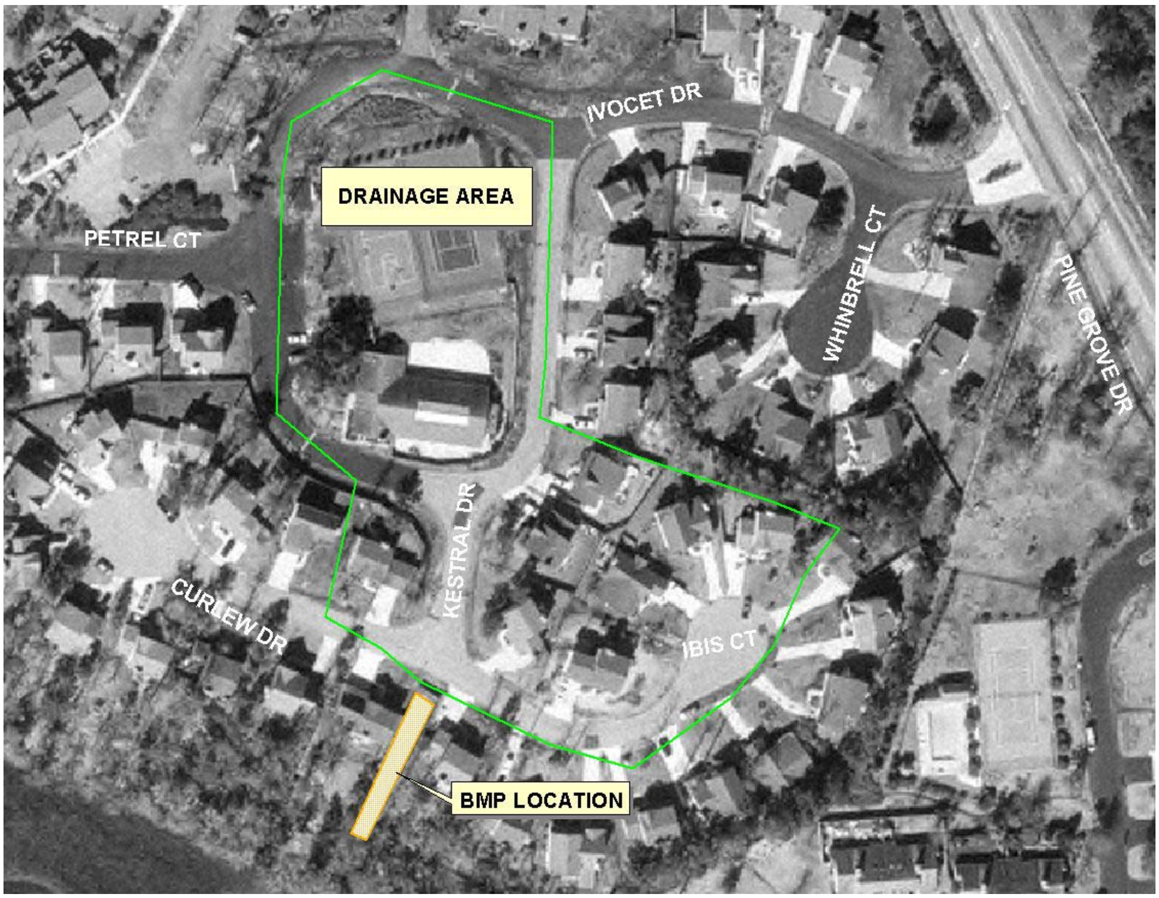
Description	Quantity	Unit	Unit Cost	Cost
Earthwork *	6,900	cy	$10.00	$69,000.00
Clearing and Grubbing	2	ac	$4,000.00	$8,000
Riser Barrel Spillway	1	ls	$8,000.00	$8,000
Overflow Spillway	1	ls	$20,000.00	$20,000
Temporary Sediment and Erosion Control	1	ls	$25,000.00	$25,000
Seeding and Mulching	6,300	sy	$0.50	$3,150
Inlet Structure	1	ls	$8,000.00	$8,000
Plants	8,000	unit	$6.00	$48,000
Subtotal				$189,150
Contingencies (~30%)				$57,750
Total				**$246,900**

* Earthwork estimated as: (1) 370 cubic yards to fill existing channel with top width of 20 feet and depth of 1.5 feet; (2) 1,200 cubic yards to build a two foot tall, two foot wide (at top) perimeter berm with 1:1 side slopes; and (3) 5,614 cubic yards for 0.28 acres with an average of two feet of fill and 1.46 acres with an average of two feet of excavation.

SELECTION CRITERIA
The site is located on a 10 acre parcel and the BMP location has at least six feet of relief. A wet detention pond or constructed wetland can treat the first inch of runoff with the available acreage on the site. An extended detention stormwater wetland should provide a higher level of pollutant removal and can be designed to be similar in appearance to the adjacent march.

BMP-3

BMP CHOICE: Bioretention area or check dams/level spreaders
LOCATION: Residential subdivision off Ivocet and Kestral Drives
NOTE: Concentrated flow draining directly into the estuary from residential areas can be identified using the GIS stormwater inventory database. Below is an example of one such occurrence. In cases where a good riparian buffer exists down gradient of the outfall then level spreaders offer a relatively inexpensive treatment option for smaller drainage areas < 5 ac.[25] In situations where the buffer is not very deep bioretention areas may be a suitable alternative. Community acceptance could be the primary factor influencing the selection of a BMP particularly in residential areas.



Intended Treatment: Enhance the existing swale and pipe system with a series of check dam/level spreaders.

The BMP location is along the parcel line between two private properties. Removing the downstream pipe and extending the existing swale will lengthen the BMP to approximately 125 feet. The limited area available limits the treatment options at this site.

[25] Small drainage areas and low slopes help to prevent level spreaders from being overwhelmed during heavier rain events.

BMP SELECTION

Level Spreaders: The small area available for enhancement all but eliminates all BMP alternatives. Level spreaders will improve treatment without additional land requirements or large expense.

Cost: $4,000. Cost is for four check dam/level spreaders one foot in height and 20 feet long (existing top of bank width is 10 feet) spaced every 30 feet (from NC Cooperative Extension Service[26]).

Grassed swale concentrating runoff into the riparian buffer from a residential area in the vicinity of Kestral Dr. Estuary pictured in background.

As an alternative to level spreaders at sites with limited existing riparian buffer areas, the swale could be reconstructed to maximize infiltration. An underdrain line approximately one foot below the swale could be installed and backfilled with porous soil media. Check dams would be installed to encourage ponding and infiltration as well as reduce the velocity of flow encountering the level spreader. Higher flows would pass over the check dam without treatment.

SELECTION CRITERIA

The site is located between two private parcels and less than 1,000 square feet may be available. The contributing drainage area is approximately three acres through primarily Group C & D soils, making capture and infiltration of runoff from a 1" storm impractical via a bioretention area designed for a 9" temporary pool depth.

[26] NC Cooperative Extension Service – Stormwater BMP Academy Course Manual, June 2002.

BMP-4

BMP CHOICE: Wet Detention Pond (expansion of existing detention pond)

LOCATION: Existing wet detention pond near Chelon Ave. and Beasley Rd.

Existing detention pond. Wooded property to the left of the pond is owned by a home owners association.

Intended Treatment: Treatment Volume is first flush (1" of runoff over entire drainage area).

The contributing drainage area is approximately 112 acres dominated by residential development. The drainage area in nearly 100% developed and the last large undeveloped parcel depicted on 1998 orthophotography has recently been developed into a school. There is an existing wet pond with riser outfall at the proposed location. This pond and dam could be expanded or replaced based on final design requirements.

BMP SELECTION

Wet Detention Pond: To capture 1" of runoff from the 112 acres of drainage, a four foot deep wet detention pond would require approximately 2.5 acres in surface area. More area may be available at the proposed location depending on design and property acquisition. Runoff will need to be redirected from the existing outfall at Chelon Avenue, down along Chelon Avenue to the new pond. One driveway will be impacted.

Cost: Assumes earthwork is limited to construction of five foot tall berm with four foot top width and one to one side slopes along 1,000 feet of the perimeter of the pond, plus an equal volume of excavation to remove the existing berm on the west edge of the pond and miscellaneous excavation to achieve required depth. This estimate is preliminary and based on limited topographic information. The pipe has not been sized and is an estimate for cost purposes only.

Description	Quantity	Unit	Unit Cost	Cost
Earthwork	50,000	cy	$10.00	$500,000
Clearing and Grubbing	2	ac	$4,000.00	$8,000
Riser Barrel Spillway	1	ls	$8,000.00	$8,000
Overflow Spillway	1	ls	$20,000.00	$20,000
Temporary Sediment and Erosion Control	1	ls	$25,000.00	$25,000
Seeding and Mulching	2,500	sy	$0.50	$1,250
60" RCP	500	lf	$163.00	$81,500
Driveway Replacement	1	unit	$1,000.00	$1,000
Subtotal				$644,750
Contingencies (~30%)				$193,450
Total				**$838,200**

SELECTION CRITERIA

Although the parcel targeted for this BMP is approximately 15 acres, the western half of the parcel can not be used because of the existing club house and tennis courts, and the channel with a large contributing drainage area that flows through the western side of the parcel. The available acreage limits the BMP selection to a wet detention pond.

The combination of this site and the proposed Dobo project will treat the runoff from roughly 70% of the drainage area upstream of the Tyndall Homeowners Association parcel.

Note: Since Chelon Ave borders the east side of the existing pond expansion would have to occur primarily on the west side. Currently the west side of the pond is maintained in a natural state and is heavily vegetated with trees and dense undergrowth. Approximately 2 acres would need to be cleared for construction which may reduce the overall environmental benefit realized from this project.

BMP-5

BMP CHOICE: Constructed Wetland

LOCATION: City property at the corner of Clearbrook and Greenville Loop Roads

Intended Treatment: Treatment Volume is first flush (1") of road side drainage.

Approximately 0.3 acres are available on the City of Wilmington parcel. This area is adequate to treat the drainage from Greenville Loop Road and adjacent right-of-way. To treat stormwater that drains to the opposite side of Greenville Loop, the existing infrastructure will need to be rerouted to outfall at the BMP location.

The total drainage area is approximately 31 acres, which would require a larger BMP area. Additional acreage could potentially be available from the large adjacent CP&L parcel. To treat the first 1" on the total drainage area, the City of Wilmington parcel and an additional acre would be needed.

BMP SELECTION

Constructed Wetland: Enhancement of existing wetland system to treat approximately 6 acres of Greenville Loop Road roadway runoff and runoff from adjacent right-of-way.

Cost: $36,400. The total cost includes (1) $8,900 for wetland construction (from NC Cooperative Extension Service[27]); (2) $23,700 for earthwork for a perimeter berm around 500 feet of the parcel sized 2 foot high, 2' wide at top with 1:1 side slopes at $10/cubic yard; and $3,500 for culvert installation (40' long 24" concrete culvert at $54/foot and 27 yards of asphalt replacement at $10/square yard).

SELECTION CRITERIA

The existing wetland likely provides some water quality treatment. However, redesigning the wetland in order to increase the flow pathway and provide some additional exposure to UV radiation from the sun should improve the treatment capability with respect to fecal coliform.

PERMITTING ISSUES

This project will require a 404 permit from the US Army Corps of Engineers. Preliminary discussions with the Corps suggest that the project will likely require an Individual permit as none of the General permits specifically cover this type of activity. A section 401 Water Quality Certification from the NC Division of Water Quality (DWQ) will also be required in response to the need for a federal permit. CAMA may also have involvement in the project depending in part on if the tidal estuary has any influence on the wetland, which is yet to be determined.

It is recommended that the City have a pre-application consultation with representatives of the Corps, DWQ, and CAMA concurrently. During this consultation meeting the parties can work towards determining the types of permits needed and which agency has primary jurisdiction over the project. Preliminary indications are that this is a permittable project given that it is specifically designed to improve water quality and will result in little to no loss of wetland area. Angie Pennock with the Corps' Wilmington District office can be contacted for more information (910) 251-4611.

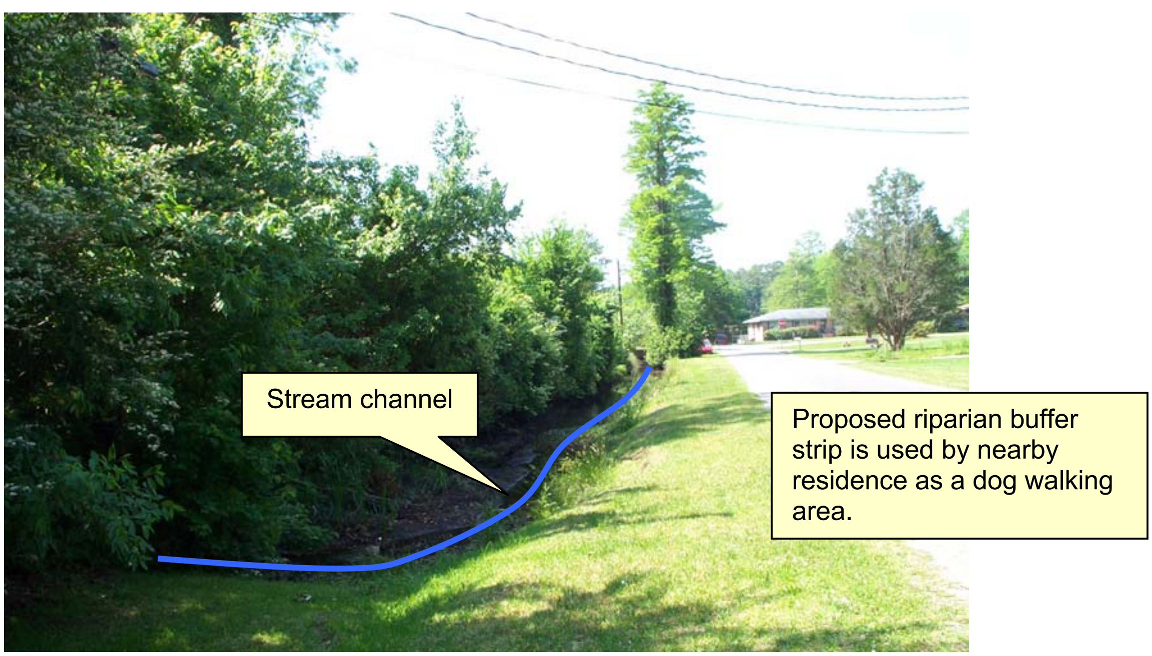
[27] NC Cooperative Extension Service – Stormwater BMP Academy Course Manual, June 2002.

BMP-6

BMP CHOICE: Establishment of riparian buffer
(A wet detention pond or constructed wetland was determined to be not feasible)

LOCATION: New Hanover County owned parcel near Sharon St. and Patricia St.

NOTE:



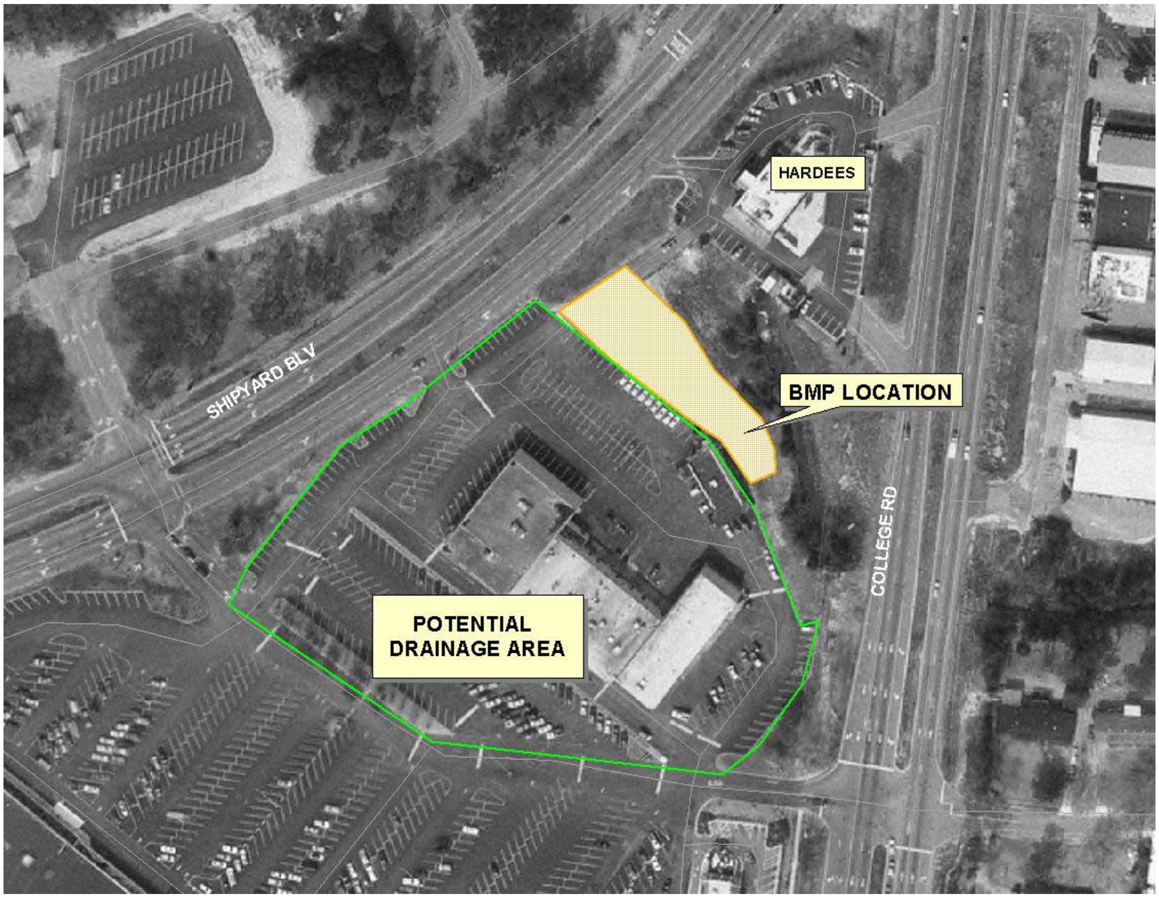
The contributing drainage is in excess of 339 acres and only 0.75 acres are available in this location. Treatment of 1” of runoff from the contributing area would require a larger BMP area than is available at the site.

The cost of establishing a riparian buffer could range from $0 if implementation simply involves the discontinuation of mowing activities along the stream channel bank to approximately $2,000 for landscape plantings and mulching.

The photograph below illustrates one of many parcels (private property) were establishment of a riparian buffer would enhance water quality.

The photograph above is presented as one example of many back yard residential areas along the estuary which could serve to improve water quality if converted into a naturally vegetated riparian buffer. While the picture does depict a 30’ foot buffer (maintained lawn) in compliance with CAMA regulations, the buffer allows sources such as dogs very close access to shellfishing waters. The proposed pet waste management program should target residential areas such as this one adjacent to the estuary.

BMP-7
BMP CHOICE: Bioretention area
LOCATION: Long Leaf Mall



Intended Treatment: Treatment of first flush from the rear portion of the mall parking lot.

The contributing drainage area is nearly 100% impervious area and has an unknown area (inventory of stormwater conveyance system not available). Approximately 1.2 acres are available for the BMP in the open/wooded area along the rear of the parcel.

BMP SELECTION

Bioretention Area: Approximately 0.45 acres are available for a proposed BMP. A storage depth of one foot would allow for 4.5 acres of the Long Leaf Mall parking lot to be treated.

Cost: $24,000 - $51,000 (from Rouge River BMP Cost Estimating Guidelines for dry detention requiring 25,000 – 75,000 cubic feet of storage[28]).

Enhancement: Including components of a bio-retention area will increase nutrient fixing and help prevent pollutant re-suspension. Planting soil and organic mulch enhance adsorption of heavy metals and biodegradation of petroleum products. Planting shrubs and ground cover will provide nutrient uptake and improve the aesthetic appeal of the BMP.

SELECTION CRITERIA

Runoff from the Long Leaf Mall parking lot does not currently receive any treatment. The actual drainage patterns off the parking lot are unknown at this time. Therefore, a relatively low cost BMP (bioretention area) has been recommended until further study of the contributing drainage area can occur.

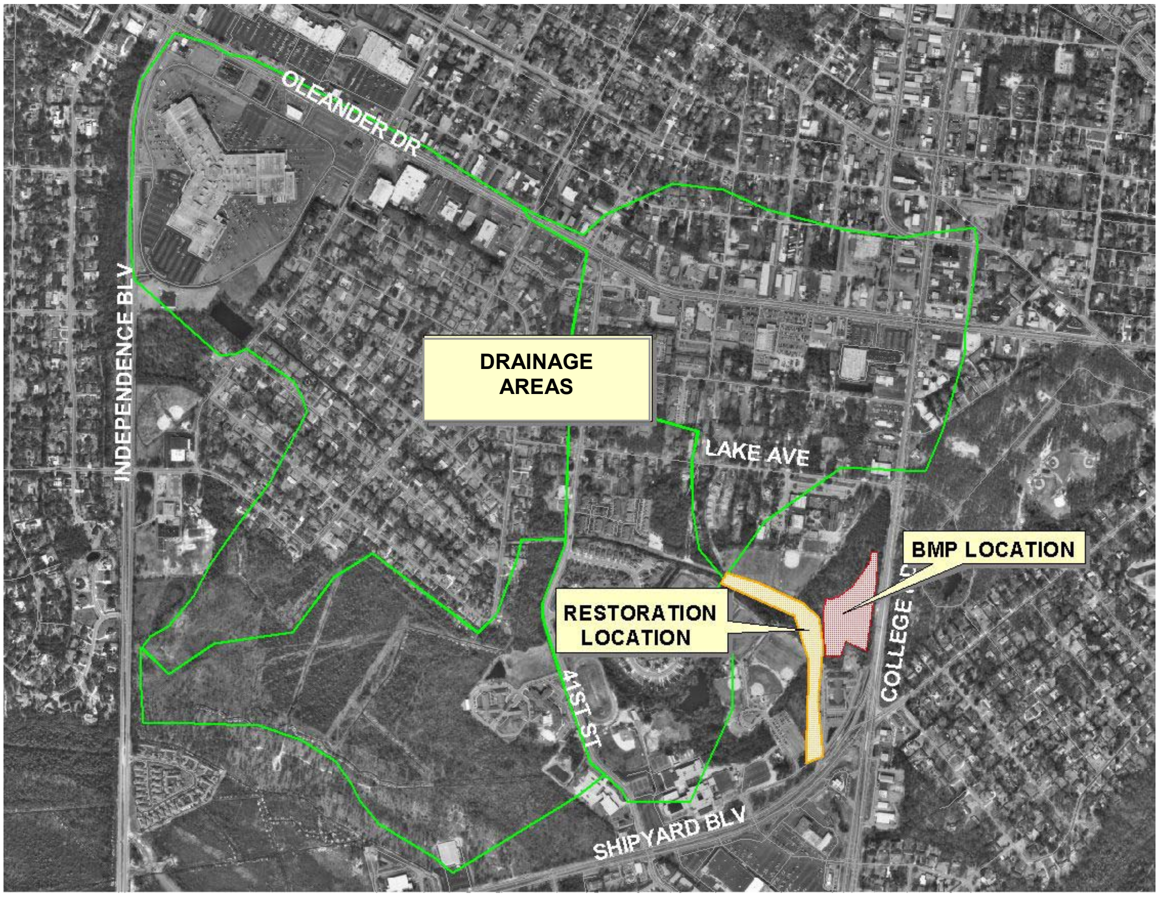
A berm may be required to prevent high flows from the stream from entering the BMP. Depending on the porosity of the native soil underdrains may be required to promote infiltration.

[28] Cost Estimating Guidelines – Best Management Practices and Engineered Controls. July 1997. Rouge River National Wet Weather Demonstration Project.

BMP-8

BMP CHOICE: Wet Detention Pond (expansion of existing pond)
Stream Restoration

LOCATION: New Hanover County Park adjacent to South College Rd. (Wet Pond)
Stream reach near Hoggard High School (Restoration)



This picture of the proposed restoration site was taken at the bend in the stream which can be seen in the orthophoto on the previous page. The New Hanover County park property border is to the right of the dirt road.

Intended Treatment (pond): Treatment Volume is first flush (1" of runoff over entire drainage area).

BMP SELECTION
Expansion of existing pond
Stream Restoration

SELECTION CRITERIA
This location has a drainage area in excess of 660 acres. A wet detention pond in this location would need to be approximately seven acres to store 1" of runoff with average depth of eight feet. Although the BMP location appears to have adequate relief for a pond with eight feet of storage, the pond would require a significant portion of the existing park. The existing pond occurs in a natural low area so a geotechnical investigation should explore impacts of groundwater to the required pond volume and the normal pool design elevation.

Cost: $867,100 (7 acre BMP). Cost does not include raising the existing private road or additional earthwork, if needed, for construction of a dam.

Description	Quantity	Unit	Unit Cost	Cost
Earthwork*	56,000	cy	$10.00	$560,000
Clearing and Grubbing	7	ac	$4,000.00	$28,000
Riser Barrel Spillway	1	ls	$8,000.00	$8,000
Overflow Spillway	1	ls	$20,000.00	$20,000
Temporary Sediment and Erosion Control	1	ls	$25,000.00	$25,000
Seeding and Mulching**	36,000	sy	$0.50	$18,000
Inlet Structure	1	ls	$8,000.00	$8,000
Subtotal				$667,000
Contingencies (30%)				$200,100
Total				**$867,100**

*Earthwork estimated as: (1) 4,000 cubic yards to build a two foot tall, four foot wide (at top) perimeter berm with 1:1 side slopes; and (3) 34,526 cubic yards for 5.3 acres with an average of six feet of excavation.
**Seeding and mulching for approximately 2,250 feet of berm.

A wet detention pond treating the first 1/2" of runoff would be approximately 3.5 acres with an average depth of eight feet. The existing pond is roughly 1.65 acres, so only two additional acres would be needed for the BMP. This option would reduce the number of trails and open area in the park, but would not require the majority of the parcel.

This site could be a candidate for a stream restoration project. Using NC Wetlands Restoration Program current total project costs, a restoration along this reach should be three to four hundred thousand dollars which includes design and construction. To justify the project beyond removal of the channelization, a bank erosion study and aquatic habitat studies could be performed on the existing major drainage channels upstream of the proposed location.

PERMITTING ISSUES

This project will likely require a 404 and 401 permit from the US Army Corps of Engineers and NC Division of Water Quality, respectively. If the stream restoration portion of the project is handled through the NC Wetlands Restoration Program then they will handle the permitting process for the restoration. Regardless, a pre-application consultation meeting with the Corps is recommended, especially with respect to the pond expansion as there may be impacts to surrounding wetlands.

Selected BMP Sites Investigated But Determined To Be Not feasible

NF-1

BMP CHOICE: None Selected

LOCATION: Low lying forested parcel at the corner of Shuney and Brittain Streets.

Intended Treatment: No treatment selected, however available land would mandate treatment of the first 1” of runoff only.

SELECTION CRITERIA

This location would be limited to 87,000 cubic feet of storage with a four foot average depth. A channel with a significant drainage, approximately 300 acres, flows through the site. The treatment volume limitation of the site would limit the contributing drainage area to approximately 20 acres. Two existing catchments to the north along Willow Woods Drive are approximately 20 acres in size. These drainage areas would have to be redirected to the parcel which would necessitate a road crossing. Due to its large drainage area the stream channel traversing the parcel would have to bypass the treatment area.

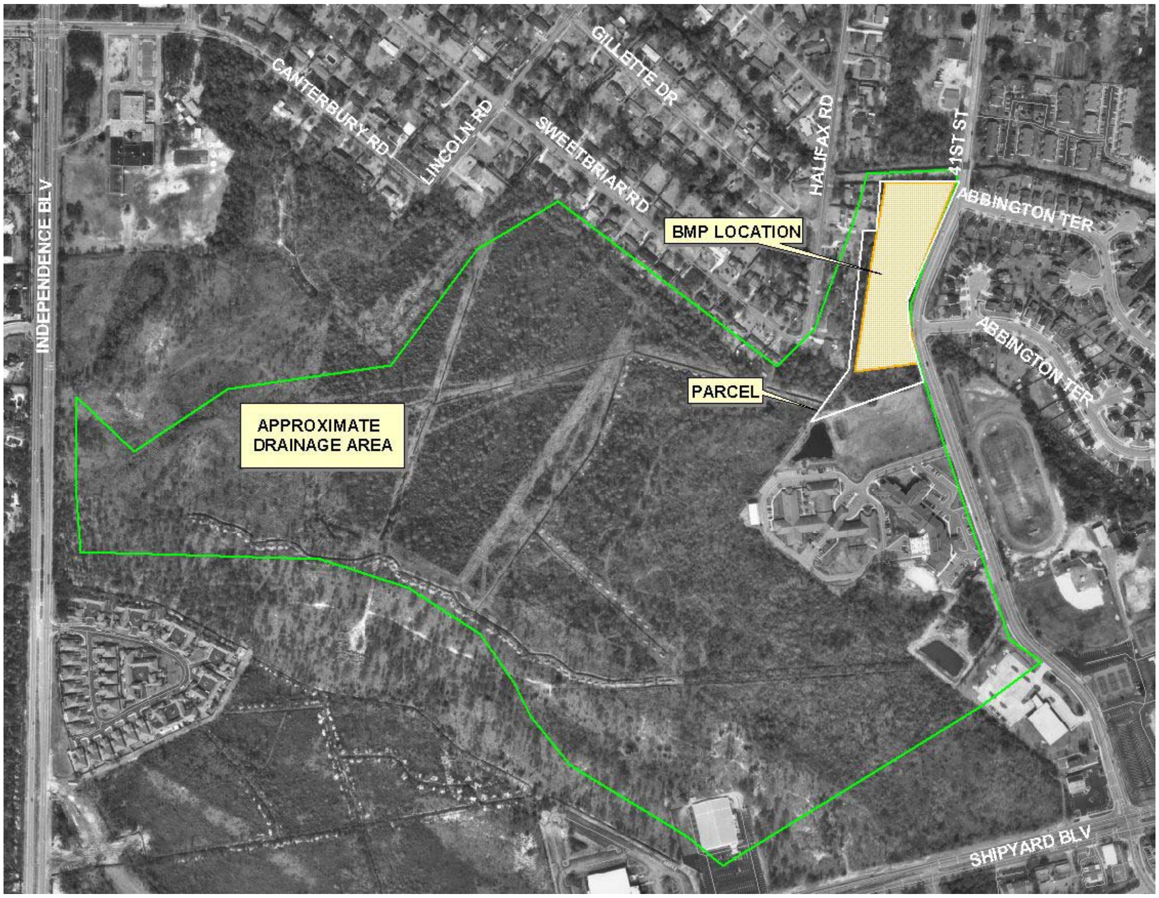
NF-2
BMP CHOICE: No BMP Selected
LOCATION: Undeveloped parcel at the corner of South College and Holly Tree Roads

The drainage area for the targeted parcel area is well in excess of 1,000 acres. A BMP to treat this drainage area is not feasible, even if the total site area, approximately 12 acres, was available. Portions of the site have been recently developed (not shown on aerial photograph).

NF-3

BMP CHOICE: None Selected

LOCATION: Forested parcel near intersection of 41st St. and Abbington Terrace.



Photograph of main channel bounding the north side of the parcel. The bottom of the stream channel is approximately 15' below the surface of the parcel. The land surface on the north side (left) of the channel is somewhat closer to the channel bottom.

Intended Treatment: The drainage area of the main channel which borders the northern side of the parcel is approximately 284 ac (not delineated in the above orthophoto). The drainage area actually flowing into the parcel is approximately 121 ac (delineated by a green line in the above orthophoto). Note that the 121 ac delineation is approximate as a variety of ditches criss-cross the area.

While the site is large enough to facilitate a wet detention pond treating the first 1" of runoff from the 121 ac drainage, there is not enough room for an inline regional facility to treat the first 1" off the 284 ac drainage.

Given the undeveloped nature of the 121 ac catchment and the uncertainty concerning drainage patterns in the area, a BMP recommendation at this site can not be made without further detailed investigation and analysis.

APPENDIX A

Existing Conditions Land Use/Land Cover

Table A1 is a summary of land use/land cover area by subwatershed.

Table A1 Existing conditions land use/land cover summary by subwatershed. All area values in acres.

Subwatershed	COMM	FOR	APT	HRES	LRES	MRES	ROW	VAC	WAT	INST	CEM	REC	GC	Totals
1	0.0	151.9	0.0	21.0	208.9	85.0	41.6	49.9	168.8	12.6	0.0	0.2	0.0	**740.1**
2	0.0	25.7	0.0	10.0	16.9	40.0	16.5	17.7	21.0	0.0	0.0	0.0	0.0	**147.9**
3	0.2	99.2	13.4	35.8	54.6	72.7	43.8	39.8	65.1	4.0	1.6	1.7	0.0	**431.9**
4	0.0	50.1	0.0	1.1	17.0	171.9	37.6	0.0	3.0	0.0	0.0	0.0	0.0	**280.7**
5	1.0	1.4	0.0	17.2	6.4	425.3	101.4	27.9	2.7	6.2	0.0	0.0	0.0	**589.6**
6	96.0	42.6	22.9	32.5	34.0	286.4	134.0	44.6	16.5	16.5	2.1	6.3	14.8	**749.1**
7	29.1	89.4	1.7	16.2	33.3	104.1	42.1	20.7	1.7	0.8	0.0	0.0	0.0	**339.1**
8	8.2	133.6	14.9	22.0	58.4	143.3	68.5	29.0	30.9	3.4	0.0	19.5	121.4	**653.1**
9	195.4	121.4	22.4	28.6	25.7	191.1	125.6	91.0	6.8	76.6	0.0	0.0	0.0	**884.6**
10	10.5	65.9	24.1	1.2	31.4	186.3	70.9	10.0	2.4	16.6	0.7	3.7	124.8	**548.6**
11	42.1	276.9	58.8	0.0	21.5	335.7	136.2	53.9	15.7	9.4	2.2	0.0	3.9	**956.3**
Totals	**382.5**	**1,058.3**	**158.1**	**185.6**	**508.2**	**2,041.6**	**818.3**	**384.7**	**334.4**	**146.3**	**6.7**	**31.4**	**264.9**	**6,321**

Future Conditions Land Use/Land Cover With Conservation

Table A2 is a summary of future conditions land use/land cover area by subwatershed. For this analysis existing undeveloped land cover within the New Hanover County Conservation land classification area remained as the same undeveloped land cover type under future conditions.

Table A2 Future conditions land use/land cover assuming conservation of undeveloped land with Conservation Areas.

Subwatershed	COMM	FOR	APT	HRES	LRES	MRES	ROW	VAC	WAT	INST	CEM	REC	GC	Totals
1	0.0	35.8	0.0	38.9	55.4	374.4	41.6	6.0	168.9	18.9	0.0	0.0	0.0	**740.0**
2	0.0	6.5	0.0	10.0	2.3	91.2	16.5	0.3	21.0	0.0	0.0	0.0	0.0	**147.9**
3	0.2	39.7	13.4	40.8	17.4	200.5	43.8	8.1	65.1	0.4	1.6	0.8	0.0	**431.9**
4	0.0	7.3	0.0	1.1	2.1	215.6	37.6	0.0	3.0	14.0	0.0	0.0	0.0	**280.7**
5	1.0	0.0	0.0	17.2	0.0	463.2	101.4	0.0	2.7	4.1	0.0	0.0	0.0	**589.6**
6	118.4	6.6	22.9	67.1	5.2	345.2	134.6	1.4	16.5	14.4	2.1	0.0	14.8	**749.1**
7	30.9	1.4	1.7	17.2	0.0	240.8	42.1	0.0	1.7	3.2	0.0	0.0	0.0	**339.1**
8	11.2	43.3	15.0	23.0	23.4	305.3	68.5	6.5	30.9	4.6	0.0	0.0	121.4	**653.1**
9	208.0	0.7	38.6	49.1	0.0	314.0	125.7	0.0	6.8	141.8	0.0	0.0	0.0	**884.6**
10	10.5	6.3	25.7	1.2	0.2	299.7	70.9	0.0	2.4	6.2	0.7	0.0	124.8	**548.6**
11	165.9	0.0	94.7	0.0	0.0	466.3	136.1	0.0	15.7	71.5	2.2	0.0	3.9	**956.3**
Totals	**546.0**	**147.6**	**211.9**	**265.7**	**106.2**	**3,316.3**	**818.9**	**22.2**	**334.6**	**279.1**	**6.7**	**0.8**	**264.9**	**6,321**

Future Conditions Land Use/Land Cover Without Conservation

Table A3 is a summary of future conditions land use/land cover area by subwatershed. For this analysis existing undeveloped land cover within the New Hanover County Conservation land classification area was assumed to develop to the maximum allowable level based on zoning.

Table A3 Future conditions land use/land cover assuming no conservation of undeveloped land with Conservation Areas.

Subwatershed	COMM	FOR	APT	HRES	LRES	MRES	ROW	VAC	WAT	INST	CEM	REC	GC	Totals
1	0.0	0.0	0.0	39.0	55.4	416.2	41.6	0.0	168.9	18.9	0.0	0.0	0.0	740.0
2	0.0	0.0	0.0	10.0	2.3	98.0	16.5	0.0	21.0	0.0	0.0	0.0	0.0	147.9
3	0.2	0.0	13.4	40.8	17.4	249.1	43.8	0.0	65.1	0.4	1.6	0.0	0.0	431.9
4	0.0	0.0	0.0	1.1	2.1	222.8	37.6	0.0	3.0	14.0	0.0	0.0	0.0	280.7
5	1.0	0.0	0.0	17.2	0.0	463.2	101.4	0.0	2.7	4.1	0.0	0.0	0.0	589.6
6	118.4	0.0	22.9	67.1	4.9	354.0	134.6	0.0	16.5	14.0	2.1	0.0	14.8	749.1
7	30.9	0.0	1.7	17.2	0.0	242.2	42.1	0.0	1.7	3.2	0.0	0.0	0.0	339.1
8	11.2	0.0	16.1	23.2	23.3	352.9	68.5	0.0	30.9	5.5	0.0	0.0	121.4	653.1
9	208.0	0.0	38.6	49.1	0.0	314.7	125.7	0.0	6.8	141.8	0.0	0.0	0.0	884.6
10	10.5	0.0	25.7	1.2	0.2	303.7	70.9	0.0	2.4	8.6	0.7	0.0	124.8	548.6
11	165.9	0.0	94.7	0.0	0.0	466.3	136.1	0.0	15.7	71.5	2.2	0.0	3.9	956.3
Totals	**546.0**	**0.0**	**213.1**	**266.0**	**105.7**	**3,483.1**	**818.9**	**0.0**	**334.6**	**282.0**	**6.7**	**0.0**	**264.9**	**6,321**

Methodology Used For Developing Existing and Future Land Use/Land Cover Data

Existing Land Use

Parcel data and 1998 digital orthophotos were used to create the existing land use coverage. Using the parcels as our "base layer" for classification, orthophotos were examined to determine general land use. Attribute data from the parcel coverage provided additional information for classification. Lot size was used to classify residential parcels according to density. Owner name was also examined to determine/support the designation of parcels as institutional, commercial, apartments, etc. The following classes were used:

- Apartment/Townhome
- High Residential (< 0.33 acre lots)
- Medium Residential (0.33 – 0.75 acre lots)
- Low Residential (> 0.75 acre lots)
- Commercial
- Industrial
- Institutional
- Water
- Marsh
- Forest
- Vacant
- Cemetery
- Golf Course
- Recreational
- Right-of-way

Future Land Use

Future land use is designed to illustrate the conditions that would exist if land parcels were developed in accordance with local zoning codes. To develop this coverage, the existing land use coverage was intersected with the zoning layer. The resulting coverage contained attributes specifying existing conditions and zoning codes.

The 1998 Wilmington - New Hanover County Land Use Plan outlines a land classification system, intended to provide guidance for future land use planning policies (page 1, online document www.co.new-hanover.nc.us/PLN/landclass.htm). Because the intentions of this document are to provide decision-making assistance for future development, it is important to include the classifications in analysis. On the other hand, because this plan does not regulate land use and only offers assistance to local government, it is equally important that we find the ultimate land use permitted by zoning code. Two future land use coverages were created to account for the two scenarios.

1. Future Land Use by Zoning Code (No Conservation)

Using the intersected zoning/existing land use coverage, a future land use was assigned by following the rules below:

a. All parcels for which existing land use was equivalent to zoning, future land use was given the existing land use value (majority of the cases).
b. Any parcel with existing land use of **WATER** or **MARSH** was given that value for future land use as well. It was assumed no development would occur. It was also assumed that existing **GOLF COURSES** and **CEMETERIES** would not be developed, thus future land use was assigned the existing value.
c. **FOREST, VACANT,** and **RECREATION** parcels were given future land use code equivalent to zoning, assuming total development (see Table A4 for zoning equivalents).
d. All **RESIDENTIAL (MRES, HRES, and LRES)** were assigned higher density land use code if zoning permitted. If zoning was lower density than existing land use, future land use was assigned the higher of the two. Any parcel zoned commercial, apartment, etc., received this code in future land use classification.
e. **COMMERCIAL** and **INSTITUTIONAL** parcels which were zoned as residential, were given future land use equal to existing land use. Using the general principle in which, parcels are usually developed more intensively over time, rather than less, we felt this would account for future land use more accurately.

***Parcels that did not fall into any of the above categories and required further investigation were analyzed individually and an assessment was made using zoning, existing land use coverages, and orthophotographs.**

Table A4 County zoning – land use equivalents.

County Zoning Code	County Description	Plan Equivalent
MF-H	36.3 units/acre	APT
MF-L	9.7 units/acre	APT
MF-M	17.4 units/acre	APT
CB	Community Business	COMM
CS	Commercial Services	COMM
PD	Mixed Use Development	COMM
RB	Regional Business	COMM
MHP	Manufactured Housing Park	HRES
R-10	10,000 sq. ft. min	HRES
R-5	5,000 sq. ft. min	HRES
R-7	7,000 sq. ft. min	HRES
O&I	Office	COMM
O&I	Institutional	INST
R-15	15,000 sq. ft. min	MRES
R-20	20,000 sq. ft. min	MRES
CEM	Cemetery	CEM

2. Future Land Use by Zoning Code (following Land Classification Guidelines)

The 1999 classification scheme and the coverage resulting from the intersection of existing land use and zoning were then intersected. Four land use classes are found within the Hewlett's Creek Watershed: Urban Transition, Transition, Conservation, and Resource Protection. Urban Transition and Transition permit intensive future urban development (page1). In Conservation and Resource Protection designated areas, limited development is recommended, with Conservation areas being the most sensitive of the two. The parcels within the Conservation designated class would be most likely affected by the land use plan.

Adjacent to Hewletts Creek (and also within the 100-year floodplain), lies an area designated "Conservation" by this plan. Within this area, future land use is assumed to be the same as existing land use, i.e., no development is recommended.

Methodology Used For Developing Impervious Surface Estimates

Ideally, impervious surface percentages are estimated directly from GIS planimetric data. Because of certain limitations in the City of Wilmington/New Hanover County's planimetric data, another method had to be devised. Impervious surface was calculated using a sampling method and orthophotograph heads-up digitizing. Subsets of parcels were selected from each land use category for the process. Parcels that were representative of the land use class were chosen for the subset. For each subset, the impervious surface visible from orthophotographs, was digitized as polygons. The total impervious surface area divided by the total parcel area resulted in the average percent impervious for each land use class. See Table A5 for calculated percentages.

Table A5 Average percentage of impervious surface by land use type based on sampling.

Land Use	Imp Surface (%)
HRES	19.61
MRES	21.68
LRES	10.35
APT	54.24
COMM	69.09
INST	43.89
IND	89.13
REC	17.18
ROW	50

APPENDIX B1

DOBO PROPERTY BMP FEASIBILITY ANALYSIS AND RECOMMENDATIONS

PREPARED FOR THE

CITY OF WILMINGTON STORMWATER SERVICES

IN PARTNERSHIP WITH

NEW HANOVER COUNTY TIDAL CREEKS PROGRAM

PREPARED BY

DEWBERRY & DAVIS, INC
RALEIGH, NC

DECEMBER 2001

EXECUTIVE SUMMARY

The New Hanover County Tidal Creeks Program is considering the purchase of a 16.5 acre parcel located in the Hewletts Creek watershed. With support from the City of Wilmington's Stormwater Services a preliminary investigation was conducted to determine the feasibility of constructing a regional stormwater treatment facility to improve water quality and minimize nuisance flooding downstream.

A number of structural Best Management Practices (BMPs) were evaluated for the site. Ultimately, a combination wet detention pond/stormwater wetland was selected as the most effective practice to meet the project goals. Based on a planning level design, the pond/wetland system would cost approximately $2,006,000.

Due to the high ecological value of the downstream estuarine nursery and shellfish growing areas, BMP recommendations in this report were not restricted to the lowest cost option. However, lower cost options may be available depending on the priorities of the project partners.

The following analysis and cost estimate are for planning level purposes only. Calculations and cost estimates should be confirmed during final design.

PROJECT BACKGROUND

The New Hanover County Tidal Creeks Program is considering the purchase of a 16.5 acre parcel located in the Hewletts Creek watershed within the City of Wilmington's 1998 annexation area. In this report the parcel is referred to as the Dobo property. With support from Wilmington's Stormwater Services, the City and County are exploring various opportunities to use the property to enhance downstream water quality and provide flood attenuation. This effort is part of a larger program managed by the New Hanover County Tidal Creeks Program to protect and enhance water quality in the tidal creeks of New Hanover County.

Dewberry & Davis, Inc has been asked to identify Best Management Practices (BMPs) which may be applicable to the site and make preliminary recommendations. This analysis is being conducted as part of a broader comprehensive stormwater master plan for the Wilmington 1998 Annexation Area.

Water Quality Issues in the Hewletts Creek Watershed

In 1993 the New Hanover County Tidal Creeks Program initiated a chemical, physical, and biological sampling program of a number of tidally influenced creeks in the county, including Hewletts Creek. This program is managed by the UNC-Wilmington Center for Marine Science Research with support from a variety of local and state organizations. Based on seven years of sampling data UNCW researchers have repeatedly identified nutrient related water quality problems, e.g. algal blooms, as a potential issue of concern. Low dissolved oxygen concentrations and excessive turbidity have also been noted in annual reports as occasionally problematic.

Chemical sampling conducted by the NC Division of Water Quality (DWQ) has also lead to observations of elevated nutrient concentrations in Hewletts Creek. DWQ reports in its June 1999 Basinwide Assessment Report of the Cape Fear River basin that orthophosphate and nitrate+nitrite concentrations in the creek are among the highest in DWQ subbasin 03-06-24, which encompasses the tidal/estuarine region from Snow's Cut northeastward to near North Topsail Beach. DWQ benthic macroinvertibrate sampling in 1993 and 1998 yielded water quality bioclassification ratings of *Moderate[ly Impacted]*. The cumulative effects of rapid urbanization were noted in the report as a significant stressor on water quality.

The lower reaches of Hewletts Creek are posted closed to shellfish harvesting by the NC Division of Marine Fisheries due to persistent elevated fecal coliform bacteria concentrations. For this reason DWQ has listed approximately 66 acres of Hewletts Creek on its 2000 303(d) list of impaired waters. Per the federal Clean Water Act the DWQ is required to take some form of management action in an attempt to restore water quality standards and uses for 303(d) listed waterbodies. This management action may be in the form of a Total Maximum Daily Load (TMDL) analysis. However, with the publication of the 2000 303(d) list, DWQ began segregating out waters impaired due to shellfish harvesting restrictions (Part 6 of the list). This action strongly suggests that the State intends to take a management planning approach, as opposed to a complex modeling/TMDL approach, for addressing impaired shellfish waters. Wilmington's

Stormwater Services is taking proactive steps to gain a better understanding of the various sources of fecal coliform contamination and potential solutions to the problem. These efforts are being coordinated through the development of a shellfish waters restoration plan for the Hewletts Creek watershed. This plan is a subcomponent of a more comprehensive stormwater masterplan for the City's 1998 Annexation Area. Findings of this BMP analysis may be incorporated into these planning documents.

Water Quantity Related Issues in the Hewletts Creek Watershed

Before preparation of the Wilmington 1998 area stormwater masterplan City Stormwater Services conducted a public workshop to identify local flooding issues in the area. Through one-on-one conversations with citizens several flooding issues of varying severity were identified in the Hewletts Creek watershed, including problem areas up and downstream of the property being examined in this report. Most of the issues in the vicinity of the Dobo property are mainly street and yard flooding.

During Dewberry's site visit to the property indications of channel instability were noted in the main tributary bounding the southeast portion of the property. Channel sloughing, undercutting, and mid-channel sediment bars were observed. These characteristics of active channel widening can routinely be observed in urban watersheds with impervious areas over 10 - 20%.

PROJECT OBJECTIVES

Based on discussions with the City and County project partners, and a review of existing water quality and quantity information, the following five project objectives are proposed:

- **Water Quality:** improve water quality downstream of the Dobo property through the implementation of structural BMPs. Water quality parameters of particular concern include fecal coliform bacteria and nutrients. Hence, BMP selection and design should maximize removal of these pollutants.

- **Flood Control:** localized street and yard flooding have been reported downstream of the property. To the degree practical, the selected BMP should minimize nuisance flooding and aid in the protection of public safety and property.

- **Channel Protection:** channel erosion and instability is believed to be an issue downstream of the property due in part to increases in impervious surfaces in the watershed over time. To mitigate for increased peak flows and velocities during rainfall runoff events, the selected BMP should provide a degree of detention and slow release.

- **Environmental Education/Habitat Improvement:** to the extent practical the selected BMP and final site design should support ongoing environmental education efforts at the City and County level. If practical the final site design should provide a linkage to existing riparian buffer areas to enhance wildlife movement corridors and habitat.

- **Flexibility:** to the extent practical the upper northwest portion of the parcel should remain unaltered to allow the flexibility to extend Bethel Street or to remain vacant.

WATERSHED CHARACTERISTICS

Figure B1 illustrates the Dobo property and 2 contributing watersheds. The main watershed is approximately 515 acres and is dominated by residential landuses. The small 82 ac watershed was delineated separately from the main one to illustrate the drainage area which intersects the lowest portion of the Dobo property.

Figure B1 Landuses/cover in the watershed draining to the Dobo property.

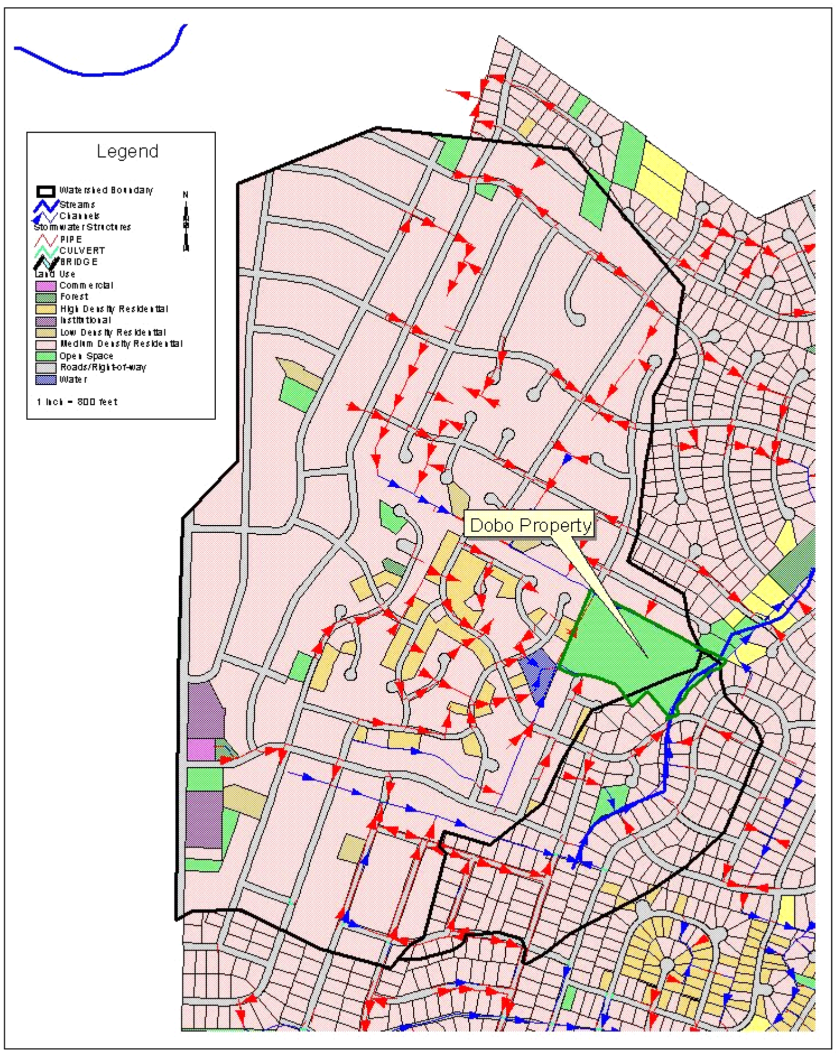


Table B1 outlines several key features of the watershed.

Table B1 Selected watershed characteristic.

Watershed Size:	515 acres	
Topography:	Land surface elevations range from approx. 48' to 16' above sea level, with the highest area along S. College Rd (NC 132). [1]	
Soils:	Predominantly NRCS Types A, D, and A/D	
Landuses/cover	**Landuse/cover Type**	**Area-Acres (% of total area)**
	Commercial	1.0 (0.2%)
	Forest	1.0 (0.2%)
	High Density Residential	17.1 (3.3%)
	Medium Density Residential	368.4 (71.5%)
	Low Density Residential	5.2 (1.0%)
	Institutional	6.2 (1.2%)
	Right-of-way	92.3 (17.9%)
	Open Space	22.2 (4.3%)
	Water	2.0 (0.4%)
Percent Imperviousness:	~ 35%	

[1] Elevations based on 2 foot contour data.

Since the majority of the watershed is developed, drainage is facilitated predominately through a series of yard and curb inlets connected to pipes which discharge into linear, man-made ditches. Over 90% of the watershed is drained by a ditch which bounds the Dobo property on the northeast side.

The eastern portion of the Dobo property is bounded by a channel that drains an additional 82 acres. Due to the location of the channel with respect to the Dobo property, it might be difficult to treat the runoff from these 82 acres. Initial inspection suggests that flow from the channel might have to be conveyed upgrade for it to receive the full benefit of the BMP assuming treatment of the northern channel is the highest priority. Since the drainage area to the northern channel is significantly larger and erosion problems are more prevalent in this ditch, the BMP was designed to only treat the flow from the northern channel. The BMP could possibly be sized to accommodate the additional 82 acres of drainage pending more detailed survey during final design. Treating the additional 82 acres would increase the expected cost of the project.

Dobo Property Site Characteristics

There are several characterizes with make the Dobo property unique compared to other parcels in the contributing watershed. First is the size of the property. At approximately 16.5 acres, this parcel is considerably larger than the ¼ to ½ acre parcels which dominate the watershed. With the exception of a structure located near the northwest corner, the property is almost entirely undeveloped (< 1% impervious).

The property is ditched on its northern and southern sides. An unnamed tributary to Hewletts Creek bounds the property on its eastern side. Given the series of ditches and engineered stormwater conveyance structures, very little runoff from the watershed appears to traverse the property. Instead runoff is diverted around the property, with the majority of the flow being concentrated through the large main ditch on the northeast property boundary.

These unique characteristics of the property present both advantages and challenges for the use of the parcel for stormwater treatment.

Advantageous Site Characteristics:

- The relatively large size and undeveloped nature of the parcel potentially facilitates a greater range of BMP options than are typically available in urban watersheds.
- The central portion of the property is vegetated predominantly by grasses and small shrubs. The larger trees (mostly pine) tend to be located along the property margins which helps to minimize the amount of clearing needed during construction.
- The City's stormwater infrastructure inventory database indicates that the majority of the 515 acre watershed drains via a ditch along the northern property boundary, making the site potentially suitable as a regional treatment facility.

Limiting Site Characteristics:

- The topography and ditching diverts runoff around the property as opposed to through it. Therefore, alterations to the existing drainage network will be needed to conduct stormwater runoff into the property for treatment.
- During low flow conditions the distance between the top of bank and the water surface in the main ditch ranges from approximately 16 feet at the NW corner of the property to roughly 8 feet near the NE corner. The deeply incised nature of the main ditch presents the greatest challenge for diverting runoff into the property without pumping.
- An electrical transmission line running roughly in a north-south direction traverses the lower (elevation wise) third of the property. The siting and design of a BMP may be affected by the tower structures and maintenance right-of-way areas.

Despite these challenges the property does appear to be suitable as a regional stormwater treatment site. However, a significant amount of excavation on the property and/or alteration to the main drainage ditch will be required to divert flow into the site. This factor may significantly add to the cost of the selected BMP.

BMP EVALUATION

A wide variety of structural BMPs have been developed over the years to manage stormwater runoff. In order to determine which BMP(s) might best achieve our project objectives a four step evaluation process was employed:

1. Group structural BMPs into major types
2. Compare which BMP types are most effective at meeting our project goals based on first hand experience and literature reports.
3. From the list of BMP types selected as potential canidates, screen the list further considering known site characteristics of the Dobo property.
4. Select a BMP which appears to be the most promissing and conduct prelimenary sizing and cost analyses.

Seven major BMP types were screened for their relative ability to support the project objectives. Note that each BMP type can include several design alternatives based on the central theme of the BMP. For example, design variations on the Wet Detention BMP type include Pocket Ponds, Extended Detention Ponds, and Water Reuse Ponds. However, the central theme of each of these designs is to temporarily hold back stormwater and slowly release it as surface flow over time. The seven major BMP types considered for the Dobo property are outlined in Table B2.

Table B2 Major BMP types considered for the Dobo property.

BMP Type	Example/Comment
Wet Detention	Wet detention pond – retains a permanent pool of water.
Dry Detention	Dry detention basin – stormwater slowly drains out often leaving a dry basin between rainfall events.
Wetland	Stormwater wetland – planted primarily with herbaceous perennial vegetation.
Filters	Refers to sand filter type BMPs.
Infiltration	Includes infiltration basins and trenches – objective is to infiltrate as much stormwater into the ground as possible.
Swales/Open Channels	Includes grassed/vegetated swales. Open channels for this analysis refers to stream channels engineered using nature design principals (stream restoration).
Bioretention	Vegetated depressions which partially infiltrate stormwater runoff. Depression should dry-up between rainfall events.

The overall relative effectiveness of each BMP type was compared against the major project objectives of water quality improvement, flood control, and stream channel protection from erosive flows. For each objective a rating of either *most effective, moderately effective, or least effective* was assigned to each BMP type. The ratings are presented in Table B3.

Table B3 Evaluation of major BMP types for the Dobo property.

	Bacteria Die-off Nutrient Removal	*Flood Control and Channel Protection*	
BMP Type	**Water Quality**	**Flow Attenuation**	**Runoff Volume Reduction**
Wet Detention	◓	●	○
	○	●	○
	●	●	◓
Filters	◓	○	○
Infiltration	◓	◓	●
Swales/Open Channels	○	◓	○
Bioretention	●	◓	◓

Note that the effectiveness measures are intended to reflect the general ability of the BMPs falling within a BMP type to achieve the project objectives. It should be recognized that a given individual BMP may be more or less effective than the rating shown depending on watershed and design characteristics.

Key:
●- Most effective
◓- Moderately effective
○- Least effective

BMPs Selected for Closer Evaluation

Based on the initial screening **wet detention ponds, stormwater wetlands, and infiltration basins** were selected as potential candidate BMPs. Dry detention and open channels/swales were discounted because these types generally offer relatively few water quality benefits. Filters were also discounted as these are typically used as on-site BMPs for small drainage areas. While bioretention ranked relatively high overall, this class of BMP is typically used to treat small drainages (< 2 acres) such as parking lots. Bioretention areas are generally not recommended for treating large drainages due to the difficulty in maintaining a clog free infiltration area vegetated with both large and small plants.

Infiltration Basins – A Closer Look

Infiltration basins are vegetated (typically grassed) stormwater impoundment areas designed to capture runoff volume and infiltrate it into the ground over a period of days. A flow splitter or weir is typically used to direct runoff into the basin. Upon initial inspection the Dobo property appeared to be relatively flat with well drained sandy soils – conditions suitable for infiltration-type BMPs. In addition, the central portion of the property was relatively free of trees which would minimize clearing costs. These characteristics suggested that an infiltration basin might be suitable for the site.

Studies have indicated that infiltration basins suffer from a high failure rate due to clogging from sediment and debris. However, many of the clogging problems noted in these studies could be traced to a lack of maintenance and/or lack of a pretreatment pond to settle out sediment before runoff entered the basin.

In order to more closely evaluate whether or not an infiltration basin might be feasible sizing calculations were made to estimate the area needed to infiltrate runoff from a 1" storm. Focusing first on the water quality improvement objective only, Dewberry estimated that a 9-10 acre basin would be needed to retain and infiltrate runoff from the 1" storm. A basin of this size would be needed to ensure that the maximum water depth does not exceed two feet. Greater water depths can lead to excessive soil compaction thereby reducing infiltration performance. Additional storage for flood attenuation would require a significant amount of surface are beyond the 9-10 acres.

For infiltration basins a separation distance of 2'-4'between the bottom of the basin and the seasonal high water table is needed to ensure consistently good performance. The highly incised nature of the main ditch on the northern border of the property raises additional concerns over how to divert water into the site and still maintain the required separation distance for infiltration. Assuming a strategy of maintaining the bed of the ditch at its current elevation, a considerable amount of excavation will be needed to divert flows into the basin even at the low end of the property. The excavation could reduce the separation distance between the water table to a less than desirable amount.

Raising the water surface elevation in the ditch by installing a diversion structure would help to minimize the amount of excavation needed. However, upstream flooding could become problematic if the water surface is raised too high in order to facilitate diverting water onto the site. Detailed additional study is needed to ensure the protection of public safety and property before such a recommendation could be made. Given the constraints described above, infiltration basins were ultimately discounted as a suitable BMP for the Dobo property.

Wet Detention Ponds – A Closer Look

A wet detention pond is a constructed stormwater pond designed to maintain a permanent pool of water. Depending on the size, ponds can be designed to detain runoff for water quality treatment as well as peak flow control. The principal water quality treatment mechanism for pollutants, including nutrients, is sedimentation. In addition to settling, bacteria removal rates are increased by exposure to UV radiation from sunlight in the upper portion of the water column.

Wet detention ponds are a commonly prescribed regional BMP to attenuate flows from large drainage areas. Hence, a properly sized wet pond should be an asset towards meeting the flood control and channel protection objectives of this project. Proper landscaping along the margins of the pond is important to discourage non-migratory waterfowl, e.g. geese, from taking up residence and turning the pond into a source of fecal coliform as opposed to a solution.

Initial sizing calculations indicate that a 5 – 5.5 acre pond, averaging 6 feet deep, would be required to meet the project objectives based on NCDENR design guidance for 85% TSS (total suspended solids) removal. Depending on final design specifications approximately 2 additional acres would be needed for construction of a safety bench and littoral planting zones.

Stormwater Wetlands – A Closer Look

Stormwater wetlands are engineered wetland systems most frequently designed to maximize the removal of pollutants from runoff. Principal pollutant removal mechanisms include microbial breakdown of pollutants, plant uptake, settling and adsorption. Stormwater wetlands also offer some of the benefits of wet ponds in terms of peak flow attenuation. If properly planted with native species, stormwater wetlands can offer excellent wildlife habitat and provide unique environmental education opportunities.

Stormwater wetlands must intersect the water table or have a relatively large contributing drainage area (>10 acres) to ensure flow through the system during dry weather conditions. Wetlands should not be allowed to dry up as many obligate wetland plant species would be damaged or killed during dry weather. If infiltration rates are high at a given site then a geotextile liner may be required.

Soils on the Dobo property are classified as NRCS Type A/D meaning that under certain conditions they are well drained (less suitable for a wetland) and under wetter conditions they are poorly drained (more suitable for a wetland). Based on visual observations during the field visit it is reasonable to expect that the lower portion of the property (eastern side) has infiltration rates more frequently associated with poorly draining D soils, while the middle and upper portion of the property has characteristics closer to an A soil (well draining).

Regardless of the BMP type, a considerable amount of excavation will be required to divert water from the main ditch on the north side into the property. Hence, the NRCS soil type should not necessarily be relied upon as an accurate indicator of soil characteristics in this particular case.

Before a final determination can be made as to whether or not a stormwater wetland is suitable for the Dobo property, a water balance should be calculated which estimates inflows versus water losses. The idea behind estimating a water balance is to ensure that the wetland maintains an adequate pool of water even during dry weather to protect the plants. To be conservative the water balance should assume no surface water inflows, high evapotranspiration rates for the region, and no rainfall for a 30-40 day period. Given that a significant amount of excavation and alteration of the topography will be needed to divert water into the property, combined with a general lack of site specific soils and water table data, Dewberry elected not to base a recommendation on the outcome of a water balance calculation. Rather, the suitability of a stormwater wetland is based on the assumption that a geotextile liner would be used to minimize water loss from the wetland via infiltration.

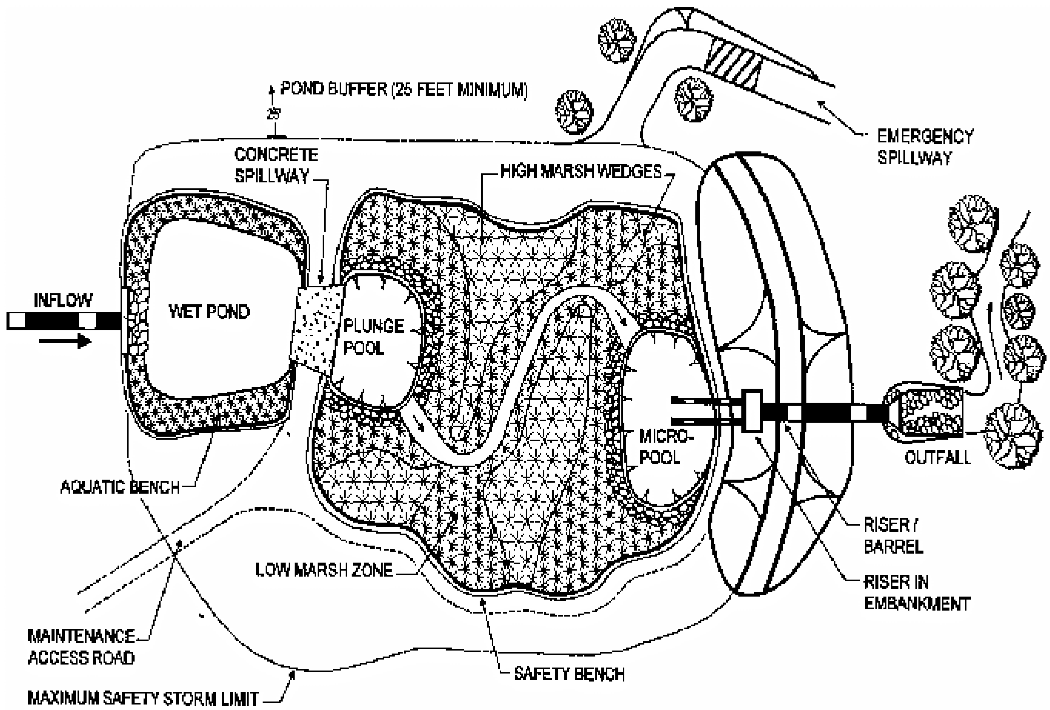
RECOMMENDATION

The location of the Dobo property offers a unique opportunity to construct a relatively large regional stormwater treatment facility within a fully developed watershed. Given the high ecological value of the downstream waters as estuarine nursery and shellfish growing areas, the preliminary recommendations are based on a combination of BMPs which are believed to most effectively achieve the project goals, but which are not necessarily the lowest cost option.

Combination Wet Detention Pond/Stormwater Wetland

The enhanced water quality treatment capabilities of a stormwater wetland, combined with the flow attenuation of a detention pond is recommended as the most effective means of achieving the project objectives on the Dobo property. Figure B2 (p. 104) illustrates an example of a combination pond/wetland system.

Figure B2 Example of a combination pond/wetland BMP.



Source: Center for Watershed Protection. Ellicott City, Maryland

Sizing of Pond/Wetland BMP

In lieu of regional BMP design performance data, the project size was based on a minimum required area equal to 1% of the contributing drainage area as per guidance published by Thomas Schueler and the Center for Watershed Protection. Therefore, the entire protect is estimated to require approximately 9 acres with 1.5 acres being required for maintenance accessibility. The remaining 7.5 acres is divided into 45% deep pool/pond, 30% high marsh (6”-18” water depth), and 25% low marsh (<6” water depth). The water depth of the deep pool will be 6’, roughly based on NCDENR guidelines for pond design. The water quality elevation based on a 1” rainfall event is estimated to increase the water surface of the project by 2.1’.

In addition to water quality benefits, this facility will provide peak flow rate attenuation and may alleviate flood conditions downstream. The amount of available storage can be determined during final design pending a detailed survey of the area. The wetland plants specified should be able to withstand periods of inundation, so that flood control objectives can be incorporated into the project.

Sizing Summary

Area of pond/wetland system	7.5 ac (1.46% of DA > 1% minimum assumed criteria)
Deep pool area	3.4 ac (45% area), 6' deep
High marsh	2.3 ac (30% area), 6"-18" deep
Low marsh	1.9 ac (25% area), < 6" deep
Deep pool volume	17.45 ac-ft
Marsh volume	3.25 ac-ft
Water quality volume	15.66 ac-ft
Total volume	36.36 ac-ft

Cost Estimate

For comparison purposes two different cost analyses were completed. The first is based on an EPA cost equation with volume as the only variable (cost = $18.5V^{0.7}$). Total volume was computed based on normal pool volume plus the water quality volume. Any additional flood control volume was not included in the estimate. A 3% inflation rate per year was assumed since the EPA study was from 1997. Including a 30% contingency/design factor the total cost estimate equaled approximately $722,000.

Due to the unique nature of the site in terms of the amount of excavation which might be needed, the EPA-based cost estimate probably underestimates the "real cost". Therefore, a second cost analysis was conducted using the best available unit costs and 2' contour elevation data. This estimate includes earthwork, clearing and grubbing, spillways, erosion and sediment control, seeding and mulching, pond/wetland liner, wetland plants, and contingencies.

Since the invert of the channel is estimated to be 15', the invert of the pond will be 9' (assuming a 6' pond depth). The water surface of the channel and the pond should be roughly the same. The invert of the marsh is 14'. Due to differences in depth, the amount of excavation required for a wetland is generally less than the amount required for a pond. The amount of excavation required was calculated by finding the volume difference between the ground elevation and the invert of the structure. The ground elevation was estimated using the best available topographic data. The amount of earthwork required may change during final design. If the inflow channel is raised earthwork may be decreased. The cost of the earthwork may decrease depending on the need for fill on the project site or offsite.

The entire pond/wetland was fitted with a liner to control infiltration during dry conditions. Spacing for wetland plants was assumed to be 3' off center throughout the high and low marsh.

Cost Summary

Description	Quantity	Unit	Unit Cost	Cost	Source
Earthwork	122,888	cubic yard	$10.00	$1,228,880	a
Clearing and Grubbing	9	acre	$4,000.00	$36,000	a
Riser Barrel Spillway	1	lump sum	$8,000.00	$8,000	a
Overflow Spillway	1	lump sum	$20,000.00	$20,000	a
Temporary Sediment and Erosion Control	1	lump sum	$25,000.00	$25,000	a
Seeding and Mulching	7,260	sq. yard	$0.50	$3,630	a
Pond/wetland liner (optional)	1	lump sum	$100,000.00	$100,000	b
Plants	20,328	each	$6.00	$121,968	a
Subtotal				$1,543,478	
Contingencies/Design (30%)				$463,043	
Total				**$2,006,521**	

Source key: a – Dewberry past project experience; b – Vendor quote from In-Line Plastics Inc. (Houston TX)
Note: Liner may not be required after detailed geotechnical investigation/analysis.

Dewberry & Davis, Inc.
A Dewberry Company

APPENDIX B2

ADDENDUM

Date: March 4, 2002

Report: Dobo Property BMP Feasibility Analysis and Recommendations, December 2001

Topic: Effect of Past Land Uses on the Report Recommendations

Project background

The City of Wilmington's Storm Water Services has contracted with Dewberry & Davis, Inc. to develop a stormwater masterplan for the 1998 Annexation Area portion of the city. As a subcomponent of this project Dewberry was directed to conduct a site visit of the Dobo property and render a written opinion as to whether a structural stormwater treatment facility designed to improve downstream water quality and manage flooding might be suitable for the site. The scope of work included selecting potential BMPs and conducting preliminary sizing and cost estimates for a single recommended BMP. The scope of the project did not include the collection of new data such as field survey, geotechnical investigations, or researching past land uses on the site.

Past land uses of the Dobo property

Dewberry staff has become aware that a wastewater treatment facility ("package plant") used to be located on the Dobo property. The facility, formally known as Millbrook WWTP (NC0031631), was permitted by the NC Division of Water Quality (DWQ) to discharge 0.1 MGD of treated 100% domestic wastewater into an unnamed tributary to Hewletts Creek. The facility received wastewater from surrounding residential customers and was not permitted to treat industrial or commercial process wastewater. The primary treatment processes at the Millbrook WWTP consisted of a series of lagoons. The permitee, Mr. R.R. Dobo, requested a rescission of his permit which was granted by the DWQ on October 21, 1988. Presently, the lagoons have been filled in, native vegetation is growing over the former treatment facilities, and there is little to no visual evidence that a wastewater treatment facility used to exist on the site.

Impact of the former WWTP on the potential use of the property for a regional stormwater treatment facility

Dewberry & Davis, Inc. currently does not have any information about the former WWTP which would change our recommendations concerning the potential use of the property as a regional stormwater treatment facility. Note however that neither research nor sampling was conducted to determine the type of fill material covering the former lagoons, or whether or not a layer of bio-residuals (sludge) exists below the fill. This type of information will need to be gathered to determine if excavated material would be suitable for use in construction of the recommended pond/wetland stormwater treatment system, and what type of bio-residuals, if any, might be exposed during construction. The presence of bio-residuals or unsuitable fill material could affect the cost of construction.

Typically, the DWQ does not require permit limits or effluent monitoring for heavy metals in Minor 100% domestic NPDES wastewater permits. Dewberry has not reviewed a copy of the Millbrook WWTP's former waste load allocation. However, the fact that the facility was considered by DWQ as a 100% domestic plant suggests that there is a reduced risk that heavy metals contaminate any remaining bio-residual layer to a degree which would make the property unusable for the desired purpose.

Given the uncertainties over the fill material used and the possible presence of a bio-residual layer still remaining under the fill, Dewberry recommends that soil core physical and chemical sampling be conducted to gather additional information about the soil material on the site before the project partners purchase the property.