Assessment Report:
Biological Impairment in the Burnt Mill Creek Watershed

Cape Fear River Basin
New Hanover County

February 2004

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Planning Branch

Collaborative Assessment of Watersheds and Streams (CAWS) Project
Funded by EPA 104(b)(3) Grant #CP984724-99

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Executive Summary

Introduction

This report presents the results of the Burnt Mill Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) and funded by the United States Environmental Protection Agency through its 104(b)(3) grant program. This project has been named 'Collaborative Assessment for Watersheds and Streams' (CAWS). It is modeled after DWQ's Watershed Assessment and Restoration Program (WARP); specifically, it follows the general approach laid out in the WARP projects, and borrows from the WARP reports (NCDWQ, 2003). This report, however, is uniquely composed of observations of, and data from, the Burnt Mill Creek watershed.

CAWS has sought to bring together numerous units from within DWQ to address biological impairments that appear on North Carolina's 303(d) list, a catalog of impaired streams. Biological impairments, as identified by assessment of the aquatic invertebrate communities, have the highest number of listings of any impairment type on the 303(d) list. Through this project, we made an effort to assess the causes of such impairments. The development of this report was possible with contributions from many units within DWQ, including: the Biological Assessment Unit (benthic macroinvertebrate and fish community surveys); Intensive Survey Unit (initial watershed reconnaissance); Aquatic Toxicology Unit (bioassays); Laboratory Section (chemical analyses of water and sediment samples); and, DWQ's Special Watersheds Project Unit (developed template for this project through the Watershed Assessment and Restoration Project, WARP). Also, the North Carolina Ecosystem Enhancement Program (EEP), formerly the Wetlands Restoration Program, provided land use and channel network data from their Local Watershed Plan (NCEEP, 2002).

Burnt Mill Creek is considered impaired by DWQ because it is unable to support a balanced and diverse community of aquatic organisms. This means that the stream does not support its designated uses of maintenance of biological integrity and propagation of aquatic life. The goal of the assessment was to provide the foundation for future water quality restoration activities in the Burnt Mill Creek watershed by: 1) identifying the most likely causes of the impairment; 2) identifying the major watershed activities and pollution sources contributing to those causes; and 3) outlining a general watershed strategy that recommends restoration activities and best management practices (BMPs) to address the identified problems.

Study Area and Stream Description

Burnt Mill Creek is a tributary of Smith Creek, which drains to the Cape Fear River, and is located wholly within New Hanover County and the City of Wilmington, in DWQ subbasin 03-06-23. Burnt Mill Creek's watershed covers 7.16 square miles. Streams in the watershed are designated as 'class C waters', which signifies that, among other uses, the waters shall be suitable for aquatic life propagation and maintenance of biological integrity. Sources of water pollution that preclude this use on either a short-term or long-term basis shall be considered to be violating a water quality standard (NCDENR, 2003).

There are no permitted point sources of domestic or industrial wastewater in the study area. Approximately 64 percent of the study area has an impervious surface, through which water does not readily infiltrate. Development is extensive throughout the watershed.

North Carolina's 303(d) list designates Burnt Mill Creek's entire length as impaired. The study area stops at Princess Place, one mile from the stream's confluence with Smith Creek. The principal sites for monitoring were at Forest Hills Drive and Metts Avenue. DWQ chose these sites to be consistent with prior benthic macroinvertebrate monitoring, the basis of the impairment listing. Impairment has been apparent since 1998, when DWQ conducted its first survey of benthic macroinvertebrates. Instream habitat quality is variable, though DWQ frequently observed sedimentation.

Approach

The project team collected a wide range of data to evaluate potential causes and sources of impairment. Data collection activities included: benthic macroinvertebrate sampling; assessment of stream habitat, morphology, and riparian zone condition; water quality sampling to evaluate stream chemistry and toxicity; sediment quality sampling to evaluate sediment toxicity and provide a longer term record of the pollutants that the stream carries; and characterization of watershed land use, conditions and pollution sources. Data collected during the study are presented in Sections 4, 5, and 6 of this report.

Conclusions

Multiple stressors, associated mostly with development in the watershed, impact aquatic organisms in Burnt Mill Creek. The primary cause of impairment is toxic impacts, particularly from polycyclic aromatic hydrocarbons (PAHs). The secondary cause of impairment is habitat degradation due to sedimentation. Cumulative causes that contribute to the impairment are habitat degradation due to lack of microhabitat, and nutrient enrichment.

Management Strategies

The objective of efforts to improve stream integrity is to restore water quality and habitat conditions to support a more diverse and functional biological community in Burnt Mill Creek. Because of the widespread nature of biological degradation and the highly developed character of the watershed, bringing about substantial water quality improvement will be a tremendous challenge. While a return to the relatively unimpacted conditions that existed prior to urbanization is not possible, Burnt Mill Creek can support a healthier biological community than it does today.

The following actions are necessary to address current sources of impairment in Burnt Mill Creek, and to prevent further degradation. Actions one through five are important to restoring and sustaining aquatic communities in the watershed, with the first three recommendations being the most important.

1. **Feasible and cost-effective stormwater retrofit projects should be implemented throughout the watershed to mitigate the hydrologic effects of development** (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). This should be viewed as a long term process. Although there are many uncertainties, costs in the range of $1 million per square mile can probably be anticipated.
    a) Over the short term, currently feasible retrofit projects should be identified and implemented. The stormwater wetlands on Kerr Avenue and in Wallace Park, funded, coordinated and implemented by a partnership of EEP, and the City of Wilmington and Cape Fear River Watch, are good existing examples.
    b) In the longer term, additional retrofit opportunities should be implemented in conjunction with infrastructure improvements and redevelopment of existing developed areas.
    c) Priorities should include evaluating the retrofit potential of existing in-stream impoundments (the few that exist), and retrofitting areas draining directly to Burnt Mill Creek main stem.
    d) Grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund and EEP.
2. **A strategy to address toxic inputs should be developed and implemented, including a variety of source reduction and stormwater treatment methods.** As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:
    a) Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended above to improve aquatic habitat potential, these BMPs will also remove toxicants from the stormwater system.

    b) Development of a stormwater and dry weather sampling strategy in order to facilitate the targeting of pollutant removal and source reduction practices.
    c) Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations. See NCEEP, 2002.
    d) Development and implementation of a broad set of source reduction activities focused on: reducing nonstorm inputs of toxicants; reducing pollutants available for washoff during storms; and managing water to reduce storm runoff. Suggestions for potential source reduction practices are provided.
3. **Stream channel restoration activities should be implemented in target areas, in conjunction with stormwater retrofit BMPs, in order to improve aquatic habitat. I**t would probably be advantageous to implement retrofit BMPs before embarking on stream channel restoration, as restoration is probably best designed for flows exemplifying reduced stormwater runoff. Costs of approximately $1 million per mile of channel should be anticipated. Again, grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund and the Ecosystem Enhancement Program.
4. Actions recommended above (e.g. stormwater quantity and quality retrofit BMPs) are likely to reduce nutrient/organic loading and its impacts to some extent. Other recommended activities to address this loading include the identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilizer use; street sweeping; catch basin clean-out practices; and the installation of additional BMPs targeting BOD and nutrient removal at appropriate sites.
5. Prevention of further channel erosion and habitat degradation will require effective post construction stormwater management for all new development in the study area. Also, reestablishment of woody riparian vegetation in areas where it is absent would improve habitat and runoff filtering.
6. Effective enforcement of sediment and erosion control regulations on the part of Wilmington and New Hanover County will be essential to the prevention of additional sediment inputs from construction activities. Development of improved erosion and sediment control practices may be beneficial.
7. Watershed education programs should be continued by the City of Wilmington and their collaborators (EEP, WECO, NCSU, UNC-W) with the goal of reducing current stream damage and prevent future degradation. At a minimum, the program should include elements to address the following issues:
    a) redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters;
    b) protecting existing woody riparian areas on ephemeral streams;
    c) replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent; and
    d) reducing and properly managing pesticide and fertilizer use.

Section 1
Introduction

This report presents the results of the Burnt Mill Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) and funded by the United States Environmental Protection Agency through its 104(b)(3) grant program. This program has been named the Collaborative Assessment for Watersheds and Streams (CAWS) project. It is modeled after DWQ's Watershed Assessment and Restoration Program (WARP); specifically, it follows the general approach laid out in the WARP projects, and borrows from the WARP reports (NCDWQ, 2003). This report, however, is uniquely composed of observations of, and data from, the Burnt Mill Creek watershed.

CAWS has sought to bring together numerous units from within DWQ to address biological impairments that appear on North Carolina's 303(d) list, a catalog of impaired streams. Biological impairments (impaired aquatic insect communities) have the highest number of listings of any impairment type on the 303(d) list. Through this project, we made an effort to address the causes of such impairments. The development of this report was possible with contributions from many units within DWQ, including: the Biological Assessment Unit (benthic macroinvertebrate and fish community surveys); Intensive Survey Unit (initial watershed reconnaissance); Aquatic Toxicology Unit (bioassays); Laboratory Section (chemical analyses of water and sediment samples); and, DWQ's Special Watersheds Project Unit (developed template for this project through the Watershed Assessment and Restoration Project, WARP). Also, the North Carolina Ecosystem Enhancement Program (EEP), formerly the Wetlands Restoration Program, provided land use and channel network data from their Local Watershed Plan (NCEEP, 2002).

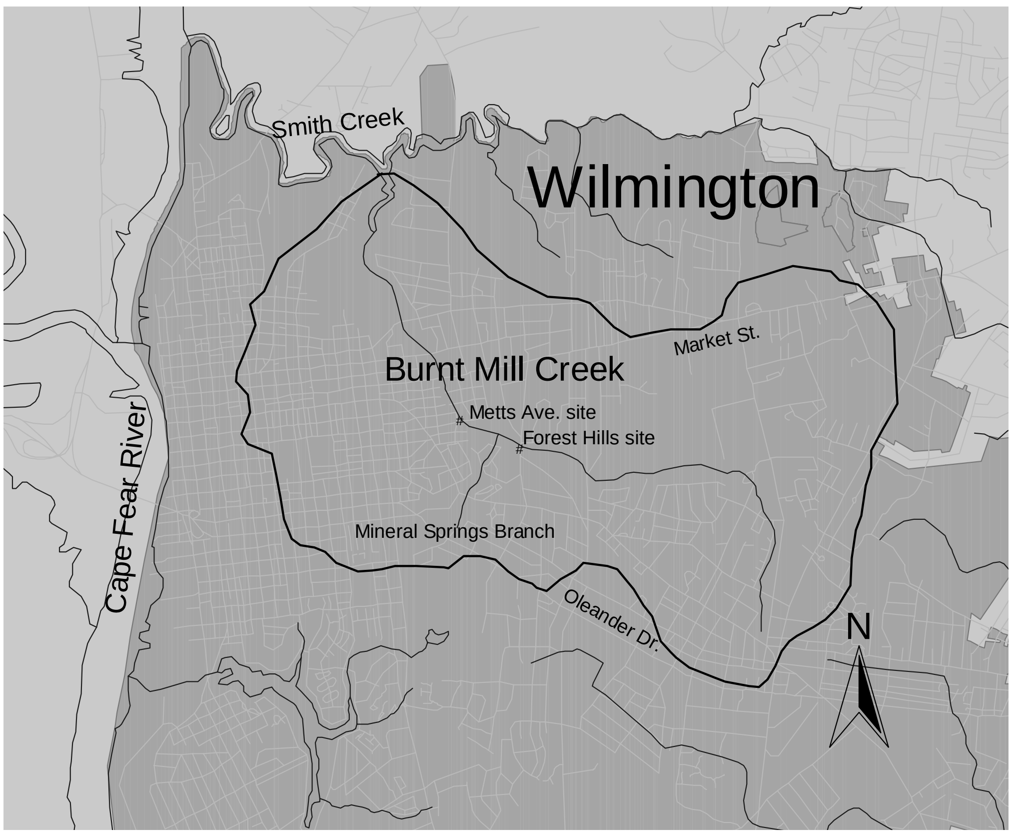
Burnt Mill Creek is considered impaired by DWQ because it is unable to support a balanced and diverse community of aquatic organisms. The reasons for this condition have been previously unknown, inhibiting efforts to improve stream integrity in this watershed.

Part of a larger effort to assess impaired streams across North Carolina, this study was intended to evaluate the causes of biological impairment and to suggest appropriate actions to improve stream conditions. DWQ is committed to encouraging local initiatives to protect streams and to restore degraded waters. There are numerous funding sources (e.g., EPA 319 grants, North Carolina Clean Water Management Trust Fund, North Carolina Ecosystems Enhancement Program) that local initiatives may tap to implement management strategies. It is clear that local cooperation and participation are essential to achieving a lasting attainment of the stream's designated use.

1.1 Study Area Description

Burnt Mill Creek is located in New Hanover County, in the Cape Fear River basin (Figures 1.1 and 1.2). The creek flows southeast for approximately 4.5 miles before emptying into Smith Creek. The stream's watershed is entirely within the city limits of Wilmington. The entire watershed is 7.2 square miles, but only about 6.5 square miles are included in this study; the study area stops at Princess Place Dr. to be consistent with prior benthic macroinvertebrate monitoring, the basis for the impairment listing. The study area contains no permitted point sources of domestic and industrial wastewater. Approximately 64 percent of the study area is covered by impervious surface, through which water does not readily infiltrate.

Figure 1.1 Burnt Mill Creek Watershed – Cape Fear River Basin



1.2 Study Purpose

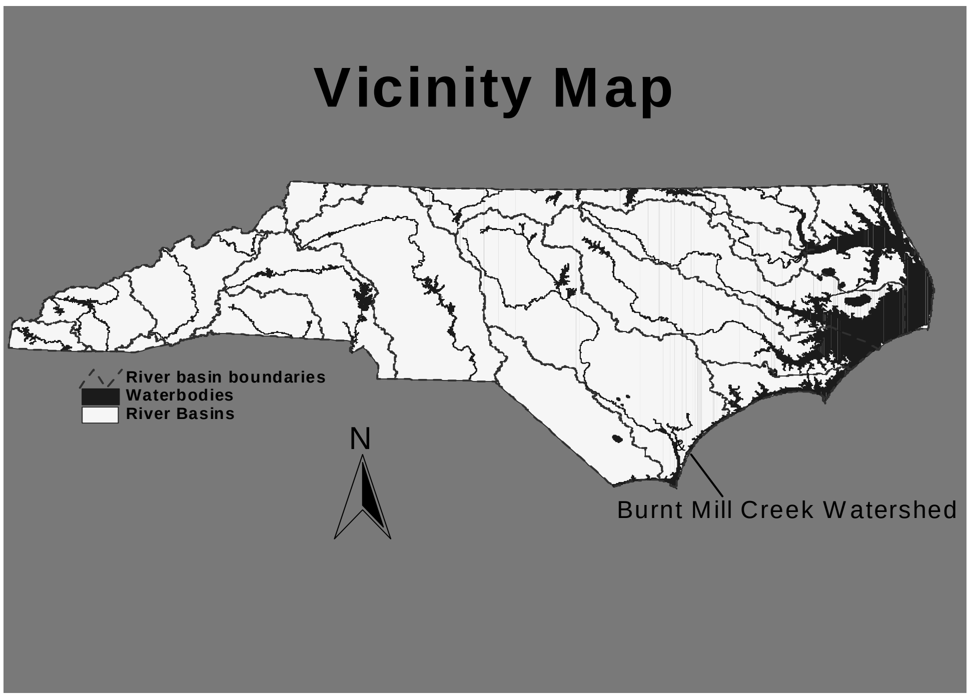
The Burnt Mill Creek assessment is part of the Collaborative Assessment of Watersheds and Streams (CAWS) project, a study of 4 watersheds across the state being conducted by DWQ between 2001 and 2003. The other three watersheds are Corpening Creek in the Catawba Basin, Clayroot Swamp in the Neuse Basin, and West Fork French Broad River in the French Broad River Basin. The goal of the project is to provide the foundation for future water quality restoration activities in each watershed by:

1. Identifying the most likely **causes** of biological impairment. Examples of such causes include degraded habitat or specific pollutants;

2. Identifying the major watershed activities and **sources** of pollution contributing to those causes. Examples of sources include streambank erosion or stormwater runoff from a particular location;

3. Outlining a watershed **strategy** that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

Figure 1.2



This process yields the probable primary and secondary causes of impairment. Based on these results, in Section 8, we recommend general management strategies for curbing the impacts associated with a particular stressor.

1.3 Approach to Management Recommendations

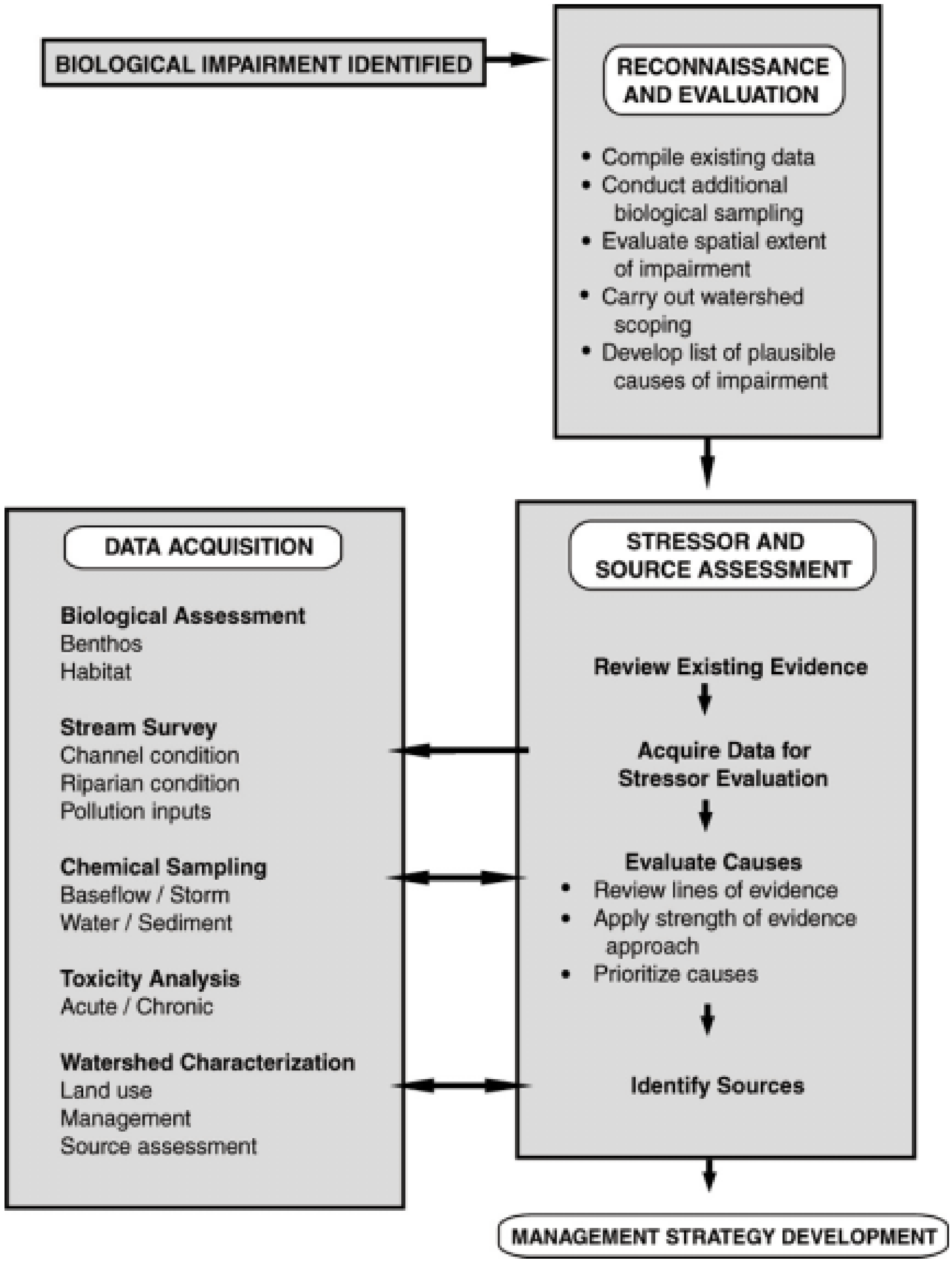
The recommended management strategies are suggested for others, including local watershed stakeholders, to implement with the intention of restoring the stream's designated use. Where problems are complex and perhaps have occurred for a long time, any set of management strategies may be inadequate in the near term to restore the stream's biological integrity. In such instances an iterative process of adaptive implementation (Reckhow, 1997; USEPA, 2001) is warranted. This process involves an initial round of management actions based on this preliminary study, then continued observation to determine the effects of the initial strategy, followed by consideration of what additional measures are needed.

Protection of the drainage network from additional harm due to future development, or other activities, in the watershed is a critical consideration. Without such protection, efforts to restore water quality by mitigating existing impacts may be ineffective, or have only a temporary effect.

Management recommendations included in this document are not intended to be specifically prescriptive. Rather, they are offered to describe the types of actions that need to occur to restore Burnt Mill Creek. It is DWQ's hope that local governments and other stakeholders in Burnt Mill Creek watershed will work cooperatively with each other and with state agencies to implement these measures in cost-effective ways. Presently, there are many opportunities to obtain grant funds to implement management strategies that will address impaired streams. DWQ could offer technical assistance on such proposals.

This study did not develop TMDLs (total maximum daily loads), nor establish pollutant loading targets. This task cannot be completed until a problem pollutant has been identified. Also, for many types of problems, including habitat degradation, TMDLs may not be a suitable mechanism for initiating water quality improvement. Where specific pollutants are identified as causes of impairment, TMDLs will need to be developed. Management strategies need not wait for TMDLs, however. If any organization or individual is able to address obvious problems/sources, this should be done.

Figure 1.3 Overview of Study Activities



Background Note: Identifying Causes of Impairment (Taken from DWQ's Watershed Assessment and Restoration Project; NCDWQ, 2003).

Degradation and Impairment are not synonymous. Many streams and other waterbodies exhibit some degree of degradation, that is, a decline from unimpacted conditions. Streams that are no longer pristine may still support good water quality conditions and function reasonably well ecologically. When monitoring indicates that degradation has become severe enough to interfere significantly with one of a waterbody's designated uses (such as aquatic life propagation or water supply), the Division of Water Quality formally designates that stream segment as impaired. It is then included on the State's 303(d) list, the list of impaired waters in North Carolina.

Many impaired streams, including those that are the subject of this study, are so rated because they do not support a healthy population of benthic macroinvertebrates (aquatic insects visible to the naked eye). While standard biological sampling can determine whether a stream is supporting aquatic life or is impaired, the cause of impairment can only be determined with additional investigation. In some cases a potential cause of impairment is noted when a stream is placed on the 303(d) list, using the best information available at the time. These noted potential causes are generally uncertain, especially when nonpoint source pollution issues are involved.

A cause of impairment can be viewed most simply as a stressor or agent that actually impairs aquatic life. These causes may fall into one of two broad classes: 1) chemical or physical pollutants (e.g., toxic chemicals, nutrient enrichment, oxygen-consuming wastes); and 2) habitat degradation (e.g., loss of in-stream structure such as riffles and pools due to sedimentation; loss of bank and root mass habitat due to channel erosion or incision). Sources of impairment are the origins of such stressors. Examples include urban and agricultural runoff.

The US Environmental Protection Agency defines causes of impairment more specifically as "those pollutants and other stressors that contribute to the impairment of designated uses in a waterbody" (USEPA, 1997, pp. 1-10). When a stream or other waterbody is unable to support an adequate population of macroinvertebrates or fish, identification of the causes of impairment thus involves a determination of the factors most likely leading to the unacceptable biological conditions.

All conditions that impose stress on aquatic communities may not be causes of impairment. Some stressors may occur at a frequency, duration and intensity that are not severe enough to result in significant degradation of biological or water quality conditions to result in impairment. In some cases a single factor may have such a substantial impact that it is the only cause of impairment, or clearly predominates over the other causes. In other situations, several major causes of impairment may be present, each with a clearly significant effect. In many cases, individual factors with predominant impacts on aquatic life may not be identifiable and the impairment may be due to the cumulative impact of multiple stressors, none of which is severe enough to cause impairment on its own.

Background Note, *continued*

The difficulty of developing linkages between cause and effect in water quality assessments is widely recognized (Fox, 1991; USEPA, 2000). Identifying the magnitude of a particular stressor is often complex. Storm-driven pollutant inputs, for instance, are both episodic and highly variable, depending upon precipitation timing and intensity, seasonal factors and specific watershed activities. It is even more challenging to distinguish between those stressors which are present, but not of primary importance, and those which appear to be the underlying causes of impairment. Following are examples of issues which must often be addressed:

- Layered impacts (Yoder and Rankin, 1995) may occur, with the severity of one agent masking other problems that cannot be identified until the first one is addressed.
- Cumulative impacts, which are increasingly likely as the variety and intensity of human activity increase in a watershed, are widely acknowledged to be very difficult to evaluate given the current state of scientific knowledge (Burton and Pitt, 2001; Foran and Ferenc, 1999).
- In addition to imposing specific stresses on aquatic communities, watershed activities can also inhibit the recovery mechanisms normally used by organisms to "bounce back" from disturbances.

For further information on use support and stream impairment issues see: the website of DWQ's Basinwide Planning Program at http://h2o.enr.state.nc.us/basinwide/; *A Citizen's Guide to Water Quality Management in North Carolina* (NCDWQ, 2000); *EPA's Stressor Identification Guidance Document* (USEPA, 2000).

1.4 Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not enough to fully address the causes of the impairment. Extensive data collection was needed to develop a sufficient base of information. The types of data collected during this study included:

1. Macroinvertebrate sampling;
2. Assessment of stream habitat, morphology, and riparian zone condition;
3. Stream surveys that entailed walking the stream channels to identify potential pollution inputs and obtain a broad scale perspective on channel condition;
4. Chemical sampling of stream water quality;
5. Chemical analyses of stream sediment;
6. Bioassays to assess water column toxicity, and, to a lesser degree, sediment toxicity; and
7. Watershed characterization that included evaluation of hydrologic conditions, land use, land management activities, and potential pollution sources.

Section 2
Description of the Burnt Mill Creek Watershed

2.1 Introduction

The 2002 303(d) list designates Burnt Mill Creek as impaired for its entire length. Streams in the watershed are designated as 'class C waters', which signifies that, among other uses, the waters shall be suitable for aquatic life propagation and maintenance of biological integrity. Sources of water pollution which preclude this use on either a short-term or long-term basis shall be considered to be violating a water quality standard (NCDENR, 2003).

This section summarizes watershed hydrography and topography, describes current land use, and discusses potential pollutant sources.

2.2 Streams and Hydrology

Burnt Mill Creek is a tidally influenced coastal stream in the lower Cape Fear River basin that flows northwest through the northern section of the City of Wilmington. The stream's length is 4.5 miles, and, typical of a coastal plain drainage it has a low gradient, from 42 feet above mean sea level (m.s.l.) in its headwaters to about 5 feet above m.s.l. at its confluence with Smith Creek.

A tide gate is located near the mouth of Burnt Mill Creek (at the railroad tracks below old McCumber's ditch). According to Dave Mayes, the City of Wilmington's stormwater engineer, this gate effectively prevents the tide from moving upstream past this point. Tides should still have the effect of minimizing the stream gradient, thus lessening stream flushing and increasing hydraulic residence time at high tide.

The only named tributary of Burnt Mill Creek is Mineral Springs Branch, which drains a small area (<1 square mile) in the south central part of the watershed. Mineral Spring Branch's watershed includes neighborhoods between Oleander Dr., Wrightsville Ave. and Metts Ave.

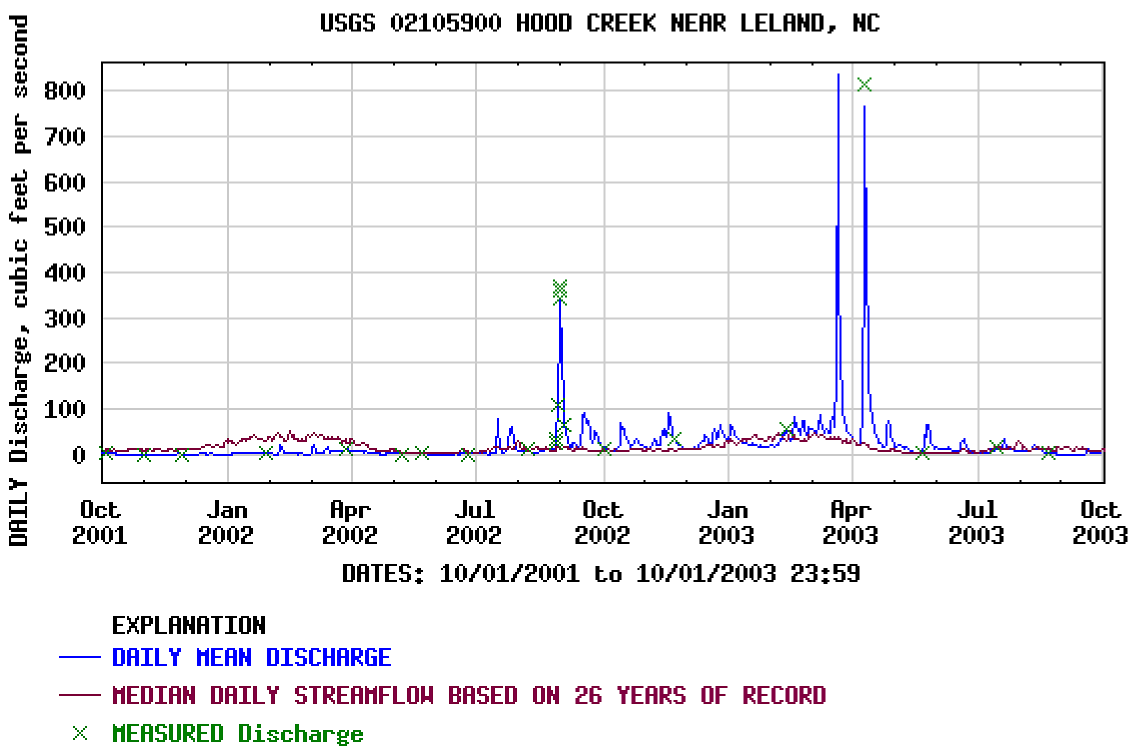
The stream network has spotty riparian buffers for the most part; some are excellent, while they are absent in other locations. This pattern seems to hold in the upper and lower regions of the watershed, and has mostly to do with whether local development has occurred or not, and the type of development practices employed.

The major dam in the watershed is for Ann McCrary Pond, a stormwater detention pond between Kerr and Mercer/Independence Avenues. The pond was built in the late 1980s. It covers 28.8 acres and serves to regulate streamflow in Burnt Mill Creek (Mallin et al., 2003).

Annual precipitation in Wilmington has averaged 54.2 inches over the past 30 years (Intellicast, 2003). A drought occurred beginning in the fall of 2001 and continued through 2002. The drought extended to years prior to the study, as well. 2003 has been a wetter than normal year.

No USGS streamflow gage exists on Burnt Mill Creek. The closest one is on Hood Creek near Leland, NC. This is about fifteen miles west-northwest from downtown Wilmington, so Burnt Mill Creek may follow a similar pattern. The biggest unknown in this estimation is the influence of tides from the Cape Fear River. Those are more likely to affect Burnt Mill Creek than Hood Creek, since Burnt Mill Creek is closer to the mouth of the Cape Fear River; however the Hood Creek gage is only 12 feet above m.s.l. As shown in Figure 2.1, from October 2001 to October 2003 Hood Creek experienced a period of below average flow until September 2002. After this time, more rain fell and the flows tended to be above average until July 2003. This is fortuitous for this study because it allows us to observe the stream during a range of conditions, when different causes and sources may be more prevalent.

Figure 2.1 Hydrologic Record of Hood Creek



Note on Figure 2.1: For readers without a color printout, the median daily streamflow based on 22 years of record is the less dynamic line.

The 7Q10 streamflow (lowest average 7-day flow occurring every 10 years) for Burnt Mill Creek may be estimated from USGS predictions for low flow per square mile in this part of North Carolina. The low flow per square mile in this part of state is 0.00 cubic feet per second per square mile (cfs/sq. mi.). In fact, USGS estimates that a drainage area of at least 35 square miles is needed to have a low flow statistic above zero (USGS, 1993). It may be, however, that even at very low flow conditions, Burnt Mill Creek still holds water in its channel, at least in its lowest reaches. Ann McCrary Pond and the tide gate should both contribute to higher baseflow.

2.3 Topography and Geology

Situated in the lower coastal plain, the Burnt Mill Creek watershed has very little topographic relief. The stream loses approximately 37 feet in elevation from its origin to its mouth, a distance of 4.5 miles. There are local pockets of hilly terrain.

The soils in the Burnt Mill Creek watershed are part of three series: the Dorovan-Johnston, the Kureb-Baymeade-Rimini and the Murville-Seagate-Leon. The Dorovan-Johnston soils cover a very small portion of the watershed, in its lowest areas near the confluence with Smith Creek. These soils are very poorly drained, and consist of a muck, loam or sandy loam surface layer, and a muck or sand underlying layer. This area is regularly flooded by tides. Just upstream, beginning around Princess Place, are the Kureb-Baymeade-Rimini soils. They are excessively drained and well drained upland soils that have a sand and fine sand surface layer, and a sand, fine sandy loam, and loamy fine sand subsoil. Further upstream, around Forest Hills School, the soil group changes to the Murville-Seagate-Leon series. These soils cover the headwater portion of the Burnt Mill Creek watershed and are very poorly drained to somewhat poorly drained. The surface layer is composed of fine sand and sand, while the subsoil has fine sand, sand, sandy loam and clay loam.

The soil make-up of the Burnt Mill Creek watershed suggests that the upper and lower reaches will have greater runoff tendency, due to their poor drainage characteristics, than that of the middle reach, where the drainage is good. This is something to keep in mind when deciding on which best management practices are suited for a given area in the watershed.

2.4 Land Cover in the Watershed

The study watershed is, for the most part, highly developed. It is contained entirely within the municipal boundary of the City of Wilmington. The developed areas consist of residential and commercial properties, plus some light industry. There are some areas with forest cover, primarily in the lower portion of the watershed below Princess Place. Also, there are parks and buffers where development has not occurred, or where buffers were left in place by development.

The land use/land cover (LU/LC) used in this project was developed by KCI Consultants to fulfill part of their contract with the North Carolina Wetlands Restoration Program, now the Ecosystem Enhancement Program (KCI, 2002a). The LU/LC data provided were manually interpreted from 1998 color infrared USGS digital orthophoto quarter-quadrangles (DOQQs). KCI used the Anderson Level I and II classification scheme (Anderson et al., 1976). The Level I classification includes urban land, agricultural land, rangeland, forest land, water, wetlands and barren land. Level II divides the Level I categories into finer components, such as low density and high density urban land.

KCI reports that the Burnt Mill Creek watershed is comprised of 75% urban land uses, and has approximately 64% impervious cover, through which water does not readily infiltrate. This is a very urban system, and impacts from such a developed watershed are expected to be high.

Figure 2.2 Watershed Land Use

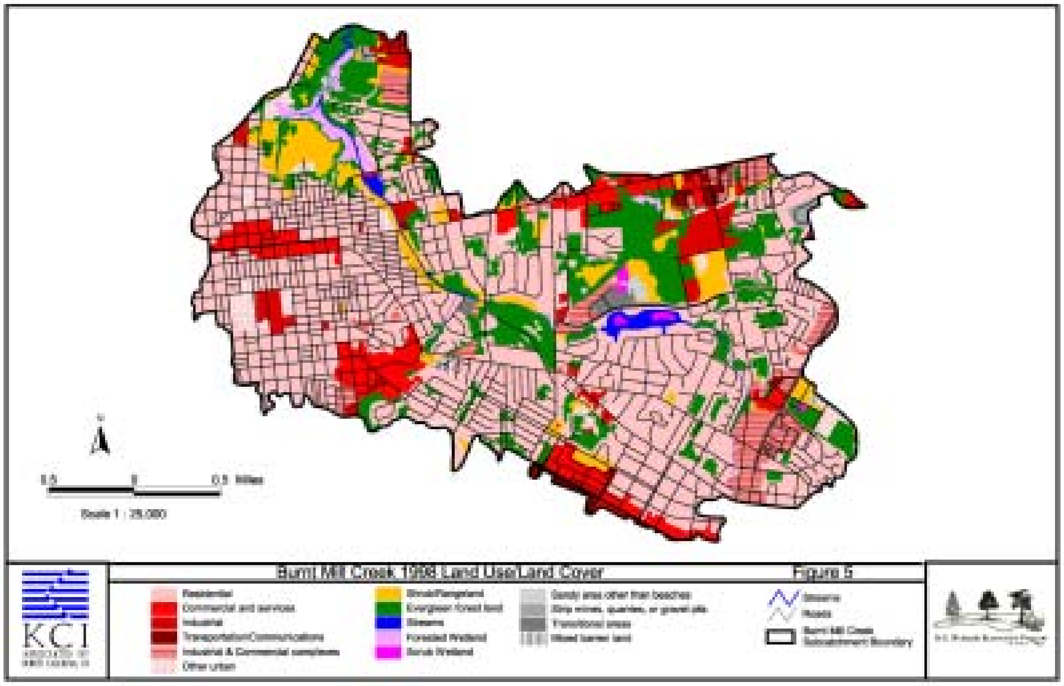


Table 2.1 Land Use in Burnt Mill Creek Watershed

Land Use	Total Acres	Percent of Total
Residential	2344	54.85
Commercial & Services	316	7.39
Industrial	145	3.40
Trans., Comm., & Utilities	45	1.04
Ind. & Commercial Complexes	242	5.65
Other Urban Land	99	2.32
Forest Land	635	14.85
Rangeland	253	5.92
Barren Land	91	2.11
Wetlands	58	1.35
Water	46	1.09
TOTAL	4273	100

2.5 Sources of Pollution

2.5.1 Permitted Discharges

Currently, there are no NPDES permitted discharges to Burnt Mill Creek or its tributaries. International Paper (NPDES permit NC0081507) had a permit until 2001, when it was rescinded at the permittee's request. The permit had always been inactive and a facility was never constructed. Instead of a direct discharge, International Paper elected to use a groundwater remediation strategy. This should not impact the Metts Avenue area of Burnt Mill Creek, where the impaired benthic community exists, since Metts Avenue is two miles upstream.

2.5.2 Nonpoint Source Inputs

A wide range of urban activities and pollution sources are of potential concern, including: roads, parking lots, rooftops, lawns, vegetable gardens, industrial areas, construction sites, etc. The list of pollutants which have been documented to increase with urbanization includes oils, antifreeze, tars, soaps, fertilizers, pesticides, solvents and salts (Bales et al., 1999; Burton and Pitt, 2001). Potential sources of pollution in the study area are discussed below.

a. Existing Developed Area.

Much of the lower watershed has older, high density residential land use. The upper watershed has been more recently developed in commercial, light industrial and residential uses. There are numerous large apartment complexes in the upper watershed.

Most of the Burnt Mill Creek watershed has been developed; there are some pockets of property, mostly around Ann McCrary Pond, that remain undeveloped, though this is likely to change.

<u>Residential Development</u>. The neighborhoods in the middle and lower portions of the Burnt Mill Creek watershed have probably been in existence for nearly a century. They have storm sewers (typically curb and gutter) and are generally of higher density (estimated one house per quarter acre on average). This is the area that will need to be most actively managed, as the impairment at Forest Hills Dr. and Metts Ave. occurs within these neighborhoods. Ann McCrary Pond mitigates some of the impact from the upper watershed, so focus downstream the pond appears to be warranted.

The upper watershed has been more recently developed, perhaps in the last 20-30 years. Apartment complexes are prevalent in the eastern and southeastern part of the watershed, as the UNC-Wilmington campus is close by. There is a mixture of curb and gutter, and swale drainage. Also, the main channel draining this neighborhood has been moved into a culvert.

Commercial and industrial development. Commercial activity within the City of Wilmington is considerable. Industrial activity is limited, though there is some such use. The commercial areas in Burnt Mill Creek are concentrated along certain roads. Market St., Kerr Ave., Oleander Dr., Wrightsville Ave. and Independence Dr. are the main commercial thoroughfares. Market St. and Oleander Dr. roughly delimit the north and south perimeters of the watershed, respectively.

The industry in the watershed primarily consists of small businesses that do screen printing, offset printing and commercial typesetting, exterior and interior signs, furniture finishing, disposable medical products, and concrete blocks and bricks. There are at least two larger operations in the watershed; International Paper, described above in Section 2.5.1, develops folding paper cartons, and there is a sheet metal fabrication company.

Roads and parking areas. Roads, driveways and parking lots are an integral part of an urban environment. One recent study (Cappiella and Brown, 2001) found that such “car habitat” accounted for a substantial portion of impervious cover in developed areas. Car habitat exceeded building footprints in all urban land use categories, accounting for between 55% and 75% of total impervious area.

Storm runoff from streets, highways and parking areas has been recognized as an important contributor of metals and organic chemicals to urban streams from sources such as tire and brake pad wear, vehicle exhaust, oil and gas leaks, pavement wear, among others (Davis et al., 2001; Bannerman et al., 1993; Young et al., 1996; Lopes and Dionne, 1998; van Metre et al., 2000).

Paved areas have increased in the Burnt Mill Creek watershed in recent decades. Vehicular traffic has increased due to both an increase in watershed population (33% increase in New Hanover Co. population between 1990 and 2000) and an increase in traffic (see Table 2.3).

Table 2.2 Annual Average Daily Traffic Counts at Selected Locations in Burnt Mill Creek Watershed, 2001.

Road name	Year		
	1979	**1990**	**2001**
Princess Place	10,200	12,800	18,000
Market	18,700	22,500	31,000
Oleander	13,600	17,400	19,000
Kerr	13,900	21,300	22,000
Highway 132	24,800	31,500	48,000

Source: NC Department of Transportation

b. Construction.

Most of Burnt Mill Creek watershed has already been developed. A few pockets of undeveloped commercial land remain, though those are likely to be developed over the next decade.

c. Sanitary sewer leaks.

Wilmington's sewage system serves the vast majority of the study area. Sanitary sewer lines run near the Burnt Mill Creek mainstem to the treatment plant, which discharges to the Cape Fear River.

From October 1997 through August 2003, 53 spills of untreated sewage reached surface waters of the study watershed, as reported to DWQ by Wilmington (Table 2.3). Of note is the sharp decline in SSOs starting in December 2001, and again in June 2002. The City of Wilmington has done a good job of addressing problem spots in their sanitary sewer system. This is certainly a positive for the stream's restoration potential. Continued maintenance of the system will be important.

Table 2.3 Spills of Sewage to Burnt Mill Creek and Tributaries August 1997 through July 2003

Date	Location	Estimated Volume to SW	Receiving Stream
10/2/1997	512 Mill Creek Apts.	100	Burnt Mill Cr.
2/17/1998	2618 Columbia Ave.	500	Burnt Mill Cr.
2/17/1998	2002 Princess Place Dr.	500	Burnt Mill Cr.
8/20/1998	742 McMillian Ave.	3,600	Burnt Mill Cr.
8/27/1998	495 N. 21st	1,500	Burnt Mill Cr.
10/5/1998	So. 19th & Lingo St.	120	Burnt Mill Cr.
10/7/1998	So. 19th & Queen St.	90	Burnt Mill Cr.
10/19/1998	3805 Cherry Ave.	100	Burnt Mill Cr.
11/12/98	S. 21st St.	100	Burnt Mill Cr.
12/1/98	1936 Church St.	125	Burnt Mill Cr.
12/22/1998	Wrightsville Ave. & Nun St.	6,000	Burnt Mill Cr.
2/19/1999	4110 Randall Parkway	100	Burnt Mill Cr.
9/21/1999	510 Mill Creek Apts.	NA	Burnt Mill Cr.
9/26/1999	Burnt Mill Cr. outfall line	1,500	Burnt Mill Cr.
12/7/1999	Confederate & Alpine	500	Burnt Mill Cr.
1/24/2000	N. 29th St. & Princess Place Dr.	500	Burnt Mill Cr.
7/27/2000	600 block of No. 6th St.	500	Burnt Mill Cr.
8/24/2000	Rankin St. & McRea St.	500	Burnt Mill Cr.
10/15/2000	2007 Metts Ave.	25	Burnt Mill Cr.
10/17/2000	Loves Grove Park – Stanley St.	500	Burnt Mill Cr.
10/20/2000	200 Block Fowler St.	500	Burnt Mill Cr.
10/24/2000	13th and Ann St.	500	Burnt Mill Cr.
11/05/2000	29th & Princess Place Dr.	500	Burnt Mill Cr.
11/30/2000	2819 Princess Place Dr.	500	Burnt Mill Cr.
12/5/2000	Confederate Dr. & Alpine Dr.	500	Burnt Mill Cr.
12/11/2000	1922 Market St.	500	Burnt Mill Cr.
12/12/2000	927 Bonham Ave.	500	Burnt Mill Cr.
12/19/2000	4925 Centre Dr.	500	Burnt Mill Cr.
12/21/2000	3115 Wrightsville Ave.	500	Burnt Mill Cr.
12/21/2000	807 Colonial Dr.	2,000	Burnt Mill Cr.
12/31/2000	3314 Winston Blvd.	500	Burnt Mill Cr.
1/10/2001	710 S. 14th St.	500	Burnt Mill Cr.

Table 2.3 Spills of Sewage to Burnt Mill Creek and Tributaries August 1997 through July 2003 - *Continued*

Date	Location	Estimated Volume to SW	Receiving Stream
2/1/2001	217 Keaton Ave.	500	Burnt Mill Cr.
2/5/2001	Covil Ave. and Randall Parkway	500	Burnt Mill Cr.
2/13/2001	11th & Dock St.	500	Burnt Mill Cr.
2/19/2001	900 block Bonham Ave.	500	Burnt Mill Cr.
2/21/2001	3805 Cherry St.	20	Burnt Mill Cr.
2/25/2001	413 Colonial Dr.	500	Burnt Mill Cr.
3/11/2001	413 Colonial Dr.	500	Burnt Mill Cr.
4/3/2001	Hoggard & Plum, near Lane	43,000	Burnt Mill Cr.
5/3/2001	1115 41st St.	20	Burnt Mill Cr.
6/11/2001	504 Evans St. to 31st & Princess Pl. Dr.	500	Burnt Mill Cr.
6/19/2001	Covil Ave. & Broad St.	100	Burnt Mill Cr.
8/16/2001	Liverpool and Wynswood St.	200	Burnt Mill Cr.
10/4/2001	Textilease	500	Burnt Mill Cr.
12/1/2001	Alpine/2500 block of Battery Pl.	500	Burnt Mill Cr.
1/18/2002	22nd & Gibson	500	Burnt Mill Cr.
3/12/2002	Colonial & Forest	500	Burnt Mill Cr.
3/25/2002	200 block Clay St.	500	Burnt Mill Cr.
6/14/2002	N. 13th St. & Rankin	500	Burnt Mill Cr.
6/19/2002	N. 13th St. & Rankin	500	Burnt Mill Cr.
2/2/2003	2000 block of Chestnut	500	Burnt Mill Cr.
8/5/2003	11th & Grace	500	Burnt Mill Cr.

d. Spills

DWQ found records of one spill that caused a fish kill in the watershed. In November 1996, Polo Citrus, a maker of household cleansers, spilled an organic detergent into the storm drain. The spill reached Burnt Mill Creek and was responsible for more than 13,000 dead fish. Toxicity tests showed a 1 hour LC50 of <3.125%, and MBAS (methyl blue active substance, a surfactant) results were notably high. Polo Citrus no longer operates in the watershed.

Another fish kill occurred in March 1999. A possible one-time toxicant discharge was suspected to be the cause, but could not be confirmed.

2.6 Trends in Land Use and Development

The population of Wilmington, the county seat, in the 2000 census was 75,838. New Hanover County had 160,307 residents in 2000, a 33.3% increase from the 1990 census.

The City of Wilmington has been developed for some time. Much of the lower watershed has older residential land use. Apparently, wastewater from these areas was discharged through the storm sewers (combined sewers) before the 1970s, when wastewater treatment became the standard (Mayes, 2003). At this time the wastewater pipes were disconnected from the storm sewers and rerouted to a wastewater treatment plant.

The upper watershed has been more recently developed in commercial, light industrial and residential uses. Much of this land drains to Ann McCrary pond, a regional stormwater detention pond that provides some pollutant removal (Mallin et al., 2002).

Most of the Burnt Mill Creek watershed has been developed; there are some pockets of property, mostly around Ann McCrary Pond, that remain undeveloped, though this is likely to change.

2.7 Regulatory Issues and Local Water Quality Activities

Recently, the City of Wilmington has been proactive about managing stormwater in the Burnt Mill Creek watershed. Some of these activities took place many years ago, while others are more recent.

Recent efforts have been made by the city in collaboration with the North Carolina EEP and Cape Fear River Watch (NCEEP, 2002). Two such projects are stormwater wetlands along Kerr Avenue and in Wallace Park. The Kerr Avenue stormwater wetland treats runoff from a commercial area above Ann McCrary Pond. The Wallace Park stormwater wetland is near Market St. and will treat 25 acres of primarily high density, residential land upon completion.

Many of the other activities have focused on the upper watershed, particularly around Ann McCrary Pond. The pond itself is a regional detention basin that was constructed in the mid-1980s and treats 1785 acres. The pond has three sediment basins that must be cleaned out every year or two. Marston's Branch drains into the southwest corner of the pond and Wilmington is preparing to stabilize its channel, which is incised and eroding. The upper end of the pond has a stormwater demonstration park that includes features such as a pervious concrete parking lot, rain barrels, and bioretention areas. Also, this site has an education component, as Wilmington conducts public outreach sessions at the site to inform the public of the utility of stormwater management.

Future plans for managing Burnt Mill Creek's water quality include public education, installation of additional BMPs and other restoration projects by the North Carolina Ecosystem Enhancement Program (formerly WRP) and the Watershed Education for Communities and Officials (WECO) program. Specifically, EEP is targeting stream restoration and enhancement for Mineral Springs Branch. They have obtained conservation easements, and contracted the design and execution of the plans.

Wilmington has a zoning ordinance and a stormwater ordinance. The former has little effect on protecting water quality since so much of the land has been developed. Wilmington has a stormwater utility, which provides revenue for stormwater management. Several municipalities in North Carolina have made strides in improving water quality through such a program. Also, Wilmington is included in the NPDES MS4 permitting program for stormwater. This places additional requirements for stormwater BMPs and monitoring on the city.

Section 3
Potential Causes of Biological Impairment

The study identified those factors that were plausible causes of biological impairment in the Burnt Mill Creek watershed using both biological assessment and watershed-based approaches. An evaluation of the aquatic macroinvertebrate community data, and data on stream and sediment chemistry, as well as habitat and land use activities, can point to the general types of impacts to the stream's biological integrity. These stressors were flagged for further investigation, which DWQ conducted in this study.

3.1 Key Stressors Evaluated in the Burnt Mill Creek Watershed

1. *Toxicity*. Sizeable portions of the watershed are highly developed, both in residential and commercial uses. There is a significant potential for a wide variety of toxicants to enter the streams during rain events or site specific mishaps. These include metals, pesticides and a range of organic chemicals. Because of the wide range of potential toxicants and source activities in this watershed, toxicity merits further evaluation as a potential cause of impairment.

2. *Habitat degradation—sedimentation*. Sedimentation impacts habitat through loss of pools, burial or embedding of riffles, and high levels of substrate instability.

3. *Habitat degradation—lack of key microhabitat*. Preliminary watershed investigations indicated that while habitat conditions are quite variable in Burnt Mill Creek and its tributaries, important microhabitats for benthic macroinvertebrates -such as woody debris, leaf packs and root mats- may be present in only limited amounts in some areas. The degree of, or reason for, and biological implications of habitat degradation needed further evaluation.

4. *Hydromodification—scour due to stormflows*. Highly developed watersheds, such as Burnt Mill Creek, often experience rapid changes in streamflows during storms. Increased levels of impervious cover increase the volume and energy of streamflows, which can dislodge aquatic macroinvertebrates and some microhabitats from the stream. Two results of scouring stormflow are incised stream channels, and streambank habitat lost through erosion.

5. *Nutrient/organic enrichment*. Organic enrichment can affect stream biota in several ways. First, it can deplete dissolved oxygen to harmful levels. Second, it can favor pollution tolerant species that filter their food from the water column.

   Organic matter in the form of leaves, sticks, and other materials provides a food source for aquatic microbes and serves as the base of the food web for many small streams. When microbes feed on organic matter, they consume oxygen in the process and make nutrients available to primary producers, especially periphyton.

Macroinvertebrates feed on the microbial community and are, in turn, consumed by fish.

These processes are natural and essential to the health of small streams. However, excessive amounts of organic matter (oxygen-consuming wastes and nutrients) from human or animal waste can increase the microbial activity to levels that significantly reduce the amount of oxygen in a stream. Adequate dissolved oxygen is essential to aquatic communities; only certain aquatic invertebrates are able to tolerate low oxygen levels.

Excess organic levels can also cause a distinct shift in community composition due to changes in food sources. Essentially, higher particulate matter, associated with organic enrichment, can favor dominance by filter feeders, some of which are in the pollution tolerant class of macroinvertebrates.

Section 4
Biological Conditions and Stream Habitat

Biological assessment (bioassessment) involves the collection of stream organisms and the evaluation of community composition and diversity to assess water quality and ecological conditions. Evaluation of habitat conditions at sampling locations is an important component of bioassessment.

Prior to this study, DWQ's Biological Assessment Unit conducted two benthic macroinvertebrate surveys at Metts Avenue in the Burnt Mill Creek watershed in 1998. DWQ did not give the stream a bioclassification in the February (first) survey as they suspected Burnt Mill Creek was a swamp system (DWQ protocol states that swamp streams have constant streamflow only in winter). Had DWQ given the February sample a bioclassification, it would have been 'Poor'. DWQ returned to sample in July 1998 and found ample streamflow, ruling out Burnt Mill Creek as a swamp system. This survey yielded a 'Poor' bioclassification.

An additional survey of the benthic community was conducted during this study for several reasons: to account for changes in biological conditions since the watershed was last sampled in 1998, and to collect additional information to support identification or likely stressors affecting the benthic community.

This section describes the results of the benthic macroinvertebrate survey completed for this project. A more detailed analysis of the condition of the aquatic macroinvertebrate communities in the Burnt Mill Creek watershed may be found in Appendix A.

4.1 Approach to Biological and Habitat Assessment

During this study, DWQ's Biological Assessment Unit collected benthic macroinvertebrate samples at one site in the watershed: Forest Hills Drive, which is approximately one-quarter mile upstream from Metts Avenue, the site of the benthic survey in 1998. Sampling at Forest Hills Drive took place in March 2001.

4.1.1 Benthic Community Sampling and Rating Methods

When surveying the benthic community, DWQ followed its general procedures outlined in the standard operating procedures (NCDWQ, 2001b). Reaches approximately 100 meters long were targeted, although the actual reach length sampled varied with site conditions. DWQ used standard qualitative sampling for most sites. This method included ten samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leaf pack sample and visual collections from large rocks and logs.

Two primary indicators or metrics are derived from macroinvertebrate community data: the diversity of a more sensitive subset of the invertebrates is evaluated using EPT taxa richness counts; while the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an acronym for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), which are insect groups that generally do not tolerate much or many kinds of pollution. A *higher* EPT number represents a healthier benthic macroinvertebrate community. A *lower* BI score represents a more balanced and diverse benthic community.

Biotic index ratings and EPT taxa richness rating are combined to produce a final bioclassification, such as Excellent, Good, Good-Fair, Fair or Poor. These final bioclassifications are used to determine if a stream is impaired. The cutoff for this decision is between Good-Fair and Fair, with Fair and Poor considered to be impaired. Under current DWQ policy, streams with a drainage area of less than three square miles are generally not formally rated, but are evaluated based on professional judgment. Small streams sampled using the Qual 5 method that have scores consistent with a Good-Fair or better rating are labeled as 'not impaired'.

4.1.2 Habitat Assessment Methods

When DWQ conducted benthic community sampling stream habitat and riparian area conditions were evaluated for each reach using DWQ's standard habitat assessment protocol for coastal streams (NCDWQ, 2001b). This subjective protocol rates the aquatic habitat of the sampled reach by adding the scores of a suite of local (reach scale) habitat factors relevant to fish and/or macroinvertebrates. Total scores range from zero (worst) to 100 (best). Individual factors include (maximum factor score in parenthesis):

- in-stream habitat variety and area available for colonization (20);
- channel modification (15);
- bottom substrate type and embeddedness (15);
- pool variety and frequency (10);
- bank stability and vegetation (20);
- light penetration/canopy coverage (10); and
- riparian zone width and integrity (10).

4.2 Findings and Discussion

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 4.1, which also includes information on historical sampling. See Table 4.1 and Appendix A for additional details. Figure 5.1 also shows the location of the various sites.

<u>Burnt Mill Creek</u>:

Burnt Mill Creek at Metts Ave. This site is located in the middle of the watershed, between Market St. and Forest Hills Drive. Downstream from Metts Avenue is a park that extends approximately 25 yards from the east bank and 75 yards from the west bank.

People regularly visit this park and children are known to fish the creek here. They report good catches of largemouth bass, bluegill, and carp. The creek has been channelized and straightened in this reach.

DWQ's Biological Assessment Unit conducted two macroinvertebrate surveys at this site. The first was in February 1998, and the second was in July 1998. Both surveys yielded 'Poor' Bioclassifications using coastal plain EPT criteria. The surveys found very few EPT taxa and the biotic indices were high, indicating a very pollution tolerant community.

The benthic habitat in this reach is also poor. Despite several types of instream habitat, including macrophytes, root mats, sticks and leafpacks, only 10% or so of the reach was favorable for colonization (decent variety, small quantity of microhabitat). Above Metts Ave., the reach has one stable bank, but receives poor marks in all other categories. The southwest bank is stable, but unnatural; it is covered by fabraform (concrete lining) over much of its area and otherwise has a thin grass covering. The opposite bank has erosion over perhaps 20% of its length, but also has a good vegetative cover and riparian zone. Below Metts Ave. there are some trees, but the riparian zone is composed mostly of grass. Aggradation of fine sediment (sand and silt) is common in the reach and limits habitat area. It also causes a high degree of embeddedness (covers some microhabitat) and substrate instability, meaning the sediment depth changes frequently.

Since this was once a swamp system, it isn't clear whether riffles should be present after humans channelized and straightened the stream. Nonetheless, riffles are clearly infrequent now.

Numerous stormwater outfalls draining surrounding neighborhoods connect to the creek in this area. This stormwater is likely to carry a significant amount of pollutants that originate from impervious surfaces that are used by automobiles and residences. These outfalls tend to be sediment sources in two ways: first, the stormwater carries sediment from the roads; and secondly, erosion is evident around the outfalls themselves.

Burnt Mill Creek at Forest Hills Drive. This site is located in the middle of the watershed next to a school, between Mercer Avenue (extension of Independence Dr.) and Metts Avenue. Forest Hills Drive turns into Colonial Drive in the vicinity of this site. This reach is also channelized and straightened.

DWQ's Biological Assessment Unit conducted one macroinvertebrate survey of this site in March 2001. They found very similar results to those at the Metts Avenue site. It received a 'Poor' Bioclassification with dominant intolerant taxa that included *Caenis*, a low flow indicator.

Once again, the habitat for this reach is sub-par, though perhaps not as bad as the habitat at Metts Avenue. The Forest Hills Drive habitat had some riffles, somewhat less embeddedness, better shading, and a riparian zone with trees and shrubs on the northeast bank. There were a good variety of instream habitat types, including sticks, macrophytes, leafpacks, and root mats. However, only 10-30% of the reach had these materials and was suitable for colonization. The root mats come at the cost of greater streambank erosion on both sides.

There are some larger stormwater pipes in the reach and scour is evident below their outfalls.

Burnt Mill Creek at Independence Drive. This site is below the first road intersection downstream of Ann McCrary Pond. DWQ conducted only one habitat survey here, in August 2003. This site's habitat, like most of the habitat in Burnt Mill Creek, is marginal. To its credit, the instream habitat variety is augmented by some coarser clasts (gravel and cobbles) and deeper pools, and the downstream, southwest bank has a mostly forested riparian buffer. It is downgraded by limited shade (no riparian vegetation whatsoever on northeast bank), channel modification and a lack of variable stream depth.

Burnt Mill Creek at Princess Place Road. This is furthest downstream site in the watershed, below Market St. DWQ surveyed the habitat here in August 2003. It received a higher score, owed largely to the reach's very good riparian buffers. On the other hand, it has a lack of depth diversity (certainly no riffles) and the channel has been straightened considerably, so it still has marginal habitat.

Mineral Springs Branch:

Mineral Springs Branch at Wrightsville Road. This is the lone tributary to Burnt Mill Creek. It drains a less than one square mile area in the southwestern section of the watershed. Above Wrightsville Road, the stream has a concrete channel and no riparian buffer. However, below Wrightsville Road, the habitat, as evaluated in August 2003, is average. In fact, it received the highest score of any site in the watershed. To the good, it has some riffle areas, a good mixture of sand and gravel, and good shade and riparian buffers on both banks. There are few pools, however, and embeddedness is significant in this reach.

All in all, the site has the best habitat and may be useful as a colonization site where downstream drift could provide Burnt Mill Creek with intolerant (desirable) benthos. There are some problems with this, though, as it drains an area with a high percentage of impervious cover. Consequently, without treatment, its water quality is not likely to support a balanced and diverse aquatic insect community.

4.3 Summary of Conditions and Nature of Impairment

The benthic macroinvertebrate community data collected by DWQ indicate that Burnt Mill Creek is impaired over its entire length. The stream has been impaired since its first sampling in 1998. Unfortunately, DWQ did not find a reference site (nearby location where benthic community is not impaired) to which conditions in Burnt Mill Creek might be compared.

Pollution tolerant taxa are common to both survey sites. Reach habitat tends to vary by substrate composition, degree of aggradation, and buffer width and vegetation. Common to nearly all sites is an accumulation of silt and sand, and the general paucity of instream organic debris (microhabitat).

KCI produced a Stream Inventory Report (KCI, 2002) on behalf of the North Carolina Ecosystem Enhancement Program that provides further information on habitat quality at additional sites in the watershed. In general, their observations agree with DWQ's assessment of Burnt Mill Creek habitat quality.

The stream has been channelized and straightened over much of its length. This was done some time ago to remove the swampy nature of the watershed in order to promote development. It may be possible to improve the hydrology so that the stream does not flood, while simultaneously improving water quality.

Table 4.1 Selected Benthic Community and Habitat Characteristics, Corpening Creek Watershed Study Sites.

	Burnt Mill Creek							Mineral Springs Br.
Location	Metts Avenue			Forest Hills Drive		Independence Dr.	Princess Place Rd.	Wrightsville Rd.
Date	Feb-98	Jul-98	Aug-03	Mar-01	Aug-01	Aug-03	Aug-03	Aug-03
Stream Width (m)	6	5	6	5	5	4	12	2
Substrate: %sand and silt	95	95	85	100	100	80	95	95
Habitat Score (max of 100)	35	48	37	36	44	46	52	56
In-stream Structure Score (max of 20)	5	8	9	10	11	11	10	13
Embeddedness (max of 15) Higher score = less embedded	7	7	5	7	8	8	7	9
EPT Taxa Richness	5	4	-	2	-	-	-	-
EPT Biotic Index	6.69	5.00	-	6.49	-	-	-	-
Biotic Index	7.99	7.36	-	7.84	-	-	-	-
Bioclassification	Poor	Poor	-	Poor	-	-	-	-

Figure 4.1 Burnt Mill Creek At Independence Dr.

Figure 4.2 Burnt Mill Creek looking downstream from Forest Hills Drive

Figure 4.3 Burnt Mill Creek looking downstream from Princess Place

Section 5
Chemical and Toxicological Conditions

Water quality monitoring provides a basis to assess whether chemical or physical conditions negatively affect benthic communities. Specifically, this monitoring is intended to characterize the water quality conditions in the watershed, and to collect a range of chemical, physical and toxicity data to help determine the specific causes of impairment, and to identify sources.

This section summarizes the sampling and data collection methods used, and discusses key monitoring results. See Appendix B for a more detailed discussion of methodology and a more comprehensive presentation of the results, detection levels and benchmarks.

DWQ does not maintain an ambient monitoring station in the Burnt Mill Creek watershed. DWQ data come from this study. UNC-Wilmington collected water quality data over the past several years and those will be summarized in this section. Funding for this has come from the City of Wilmington, and from EEP for 2000-2001 only. UNC-Wilmington does not have a site around Forest Hills Drive or Metts Avenue, where DWQ has surveyed the aquatic insect community.

5.1 Approach to Chemical, Physical and Toxicity Sampling

5.1.1 General Approach

General Water Quality Characterization. Two stations in the middle of the study area, Burnt Mill Creek at Forest Hills Drive and Metts Avenue, were sampled four times each. DWQ analyzed those samples for a full suite of parameters, similar to those reported at an ambient monitoring station. Grab samples were collected during baseflow and stormflow conditions. **We defined baseflow periods as those in which no measurable rain fell in the watershed during a 48-hour period preceding sampling**.

Stressor and Source Evaluation. Samples were collected at a few locations in order to identify major chemical/physical stressors to which aquatic biota are exposed, evaluate toxicity and assess major pollution sources. Station locations for stressor identification sampling were linked to areas that, through the surveys described in Section 4, showed an impairment in the benthic community. Most of the sampling occurred at two stations along the mainstem of Burnt Mill Creek: Forest Hills Drive and Metts Avenue. Samples were also collected at Independence Drive, Chestnut Avenue, Princess Place Drive and Wrightsville Road. DWQ collected sediment samples, and storm and baseflow water samples from August 2001 to August 2003.

Sampling focused primarily on those physical and chemical parameters that preliminary investigation indicated merited further study as causes of biological impairment. As discussed in Section 3, these were primarily toxicants, but also included nutrients and dissolved oxygen.

We looked at a wide variety of toxic pollutants in five sites in the watershed, including:

- Metals
- Semi-volatile organics (EPA Method 625)
- PAHs (polycyclic aromatic hydrocarbons; EPA Method 610)
- Phenols (EPA Method 604)
- MBAS (methyl blue active substances, an indicator of anionic surfactants)
- Chlorinated pesticides and PCBs
- Other pesticides

Much of the sampling for these parameters focused on sediment analyses, as sediment is a better long-term recorder of certain pollutants in the stream. Also, benthic macroinvertebrates are constantly exposed to sediment, in contrast to infrequent, potentially toxic **pulses** of stormwater. DWQ collected sediment samples at four locations in the watershed: three from the mainstem of Burnt Mill Creek and one from a ditch below Metts Avenue. These samples were collected as a composite at each reach by combining finer grained, more organic-rich material from several locations.

Ambient toxicity tests (bioassays) using *Ceriodaphnia dubia* were conducted on four occasions at Metts Avenue. Laboratory bioassays provide a method of assessing the presence of toxicity from multiple pollutants, and their cumulative effect on biota. DWQ ran three chronic tests and one acute test. The acute toxicity test used protocols defined in USEPA document EPA/600/4-90/027F (USEPA, 1993), which includes a 48-hour exposure and measures subject survival. The chronic toxicity test used the North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (NC Division of Water Quality, 1998), which measures subject survival and reproduction during a one-week exposure. DWQ collected a grab sample on two separate days for the chronic test, and once for the acute test. DWQ favored the chronic test as, to some degree, it better represents field conditions that the local benthic macroinvertebrates experience.

DWQ did not have the resources to conduct a forty-two day chronic toxicity sediment bioassay using *Hyallela azteca* as described in ASTM (2000) and USEPA (2000b). This test would be a useful addition to the project at a later date, as it measures longer-term exposure of organisms to a collection of pollutants that accumulated over time. This, of course, is more akin to actual field conditions.

DWQ was able to run one sediment toxicity test using Microtox®. This test uses bioluminescent marine bacteria, *Vibrio fischeri*, to detect sample toxic effects, which result in reduced light emissions by the bacteria. Serial dilutions of the sample are prepared in a sodium chloride solution, and mixed with the bacteria. The sample is exposed to the bacteria under tightly controlled conditions of temperature and time of contact. After exposure, the light intensity of the sample/bacterium mixture is measured and compared to simultaneously prepared non-toxic controls. The percent light intensity is plotted versus percent sample to determine an "EC50", the percent of sample causing a 50% reduction (50% "effect concentration) in light intensity, as compared to control organism light emission.

The identity of the material(s) causing toxicity cannot be identified, and relative effects on other organisms cannot be confirmed on the basis of Microtox® analysis. However, *Vibrio fischeri* have been shown to have sensitivities similar to other standardized toxicity organisms (Mort, 2003). As with any species, sensitivity is contaminant-class and species specific. Any impact on native species, or induced toxicity of the sample by salinity adjustment to accommodate the test species is not known.

Water and Sediment Benchmarks.

Measured water column concentrations were compared to a suite of benchmarks to help evaluate whether observed concentrations might have an impact on aquatic life. The benchmarks for water included:

- EPA's National Ambient Water Criteria (NAWQC) for freshwater (USEPA, 1999) and Tier II benchmarks (USEPA, 1995). Metals benchmarks were adjusted for hardness where possible (USEPA, 1999).
- DWQ's standards for protection of aquatic life – 15A NCAC 2B .0100 and .0200.

The sediment benchmarks were taken from EPA's "A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems" (EPA, 2002). These benchmarks may be divided into categories for threshold effect concentrations, below which harmful effects are unlikely, and for probable effect concentrations, above which harmful effects are likely.

The threshold effect sediment quality guidelines (SQGs) include:

- TEC = Threshold effect concentration (MacDonald et al., 2000)
- TEL = Threshold effect level; dry weight (Smith et al., 1996)
- LEL = Lowest effect level, dry weight (Persaud et al., 1993)
- MET = Minimum effect threshold; dry weight (EC & MENVIQ, 1992)
- ERL = Effects range low; dry weight (Long and Morgan, 1991)
- TEL-HA28 = Threshold effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)
- SQAL = Sediment quality advisory levels; dry weight at 1% OC (USEPA, 1997)

The probable effect sediment quality guidelines (SQGs) include:

- PEC = Probable effect concentration (MacDonald et al., 2000)
- PEL = Threshold effect level; dry weight (Smith et al., 1996)
- SEL = Severe effect level, dry weight (Persaud et al., 1993)
- TET = Toxic effect threshold; dry weight (EC & MENVIQ, 1992)
- ERM = Effects range median; dry weight (Long and Morgan, 1991)
- PEL-HA28 = Probable effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)

Specific sediment benchmark levels for metals and semi-volatile organics are further discussed in Section 5.3.2, and listed in Appendix B.

Two caveats for these SQGs should be noted. First, they should be normalized for total organic carbon (TOC), and DWQ's laboratory does not have the equipment to measure that constituent. Secondly, no total metals concentration benchmarks exist, which means we cannot account for cumulative metals effects.

We used benchmarks as part of a larger screening process. All lines of evidence available, including toxicity bioassays, benthic macroinvertebrate surveys, and water quality chemistry, were used to make a decision on the likelihood of pollutants to impact the benthos.

5.1.2 Site Selection

There were only two primary chemical and toxicological, or integrator, stations for this project.

- *Burnt Mill Creek at Metts Avenue.* This site is located roughly in the center of the watershed, about one mile downstream from Ann McCrary Pond. DWQ collected samples here for suspected stressor pollutants on numerous occasions. Additionally, four bioassays were performed using water collected at this site.

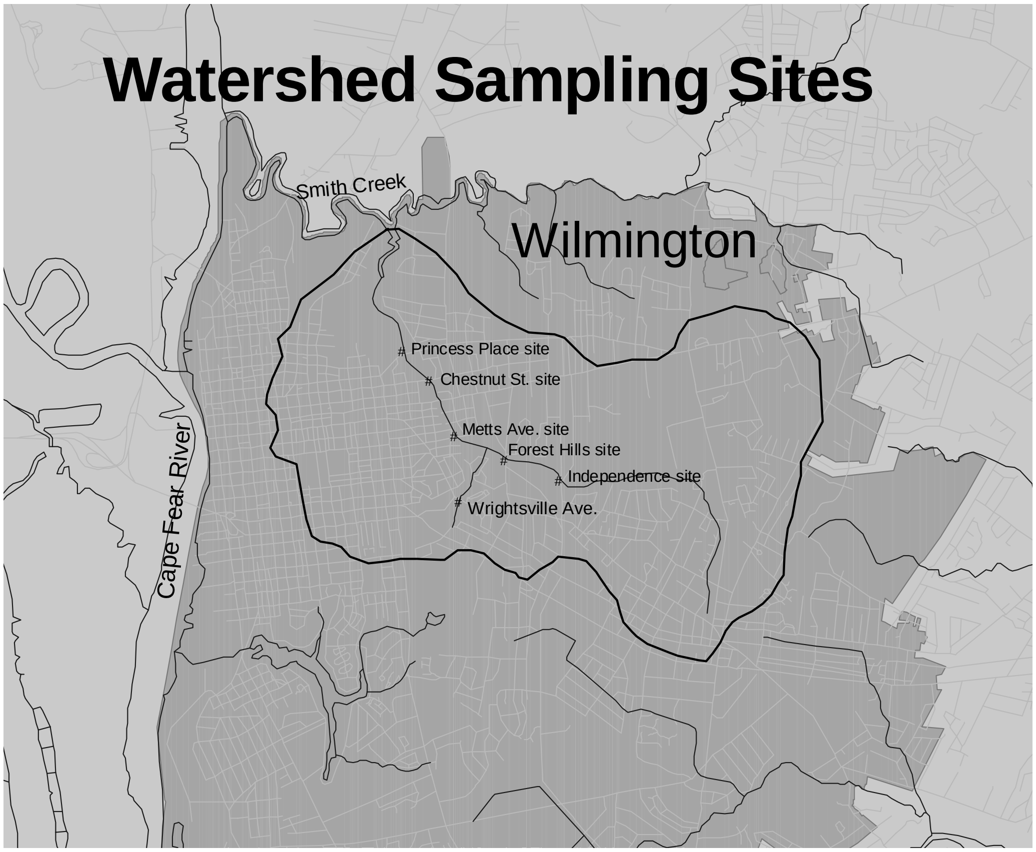
- *Burnt Mill Creek at Forest Hills Drive.* This site is also in the middle of the watershed, about one-quarter mile upstream from Metts Avenue. We treated this site as the integrator station for the first half of the project, but then switched to Metts Avenue to capture more of the watershed.

We sampled these two sites primarily to evaluate what has caused the benthic impairment.

Secondary sites, where DWQ collected at least one sample, include:

- *Burnt Mill Creek at Independence/Mercer*. DWQ analyzed one sediment sample from this site for metals, semi-volatile organics and pesticides. It should show what pollutants exit Ann McCrary Pond, or that originate from the very small area between the pond and this site.
- *Burnt Mill Creek at Princess Place.* DWQ analyzed one sediment sample from this site for metals, semi-volatile organics and pesticides. We also collected a semi-volatile water sample here, as there is a boom in place to trap less dense liquids that come from a stormwater outfall.
- *Mineral Springs Branch below Wrightsville Road.* DWQ analyzed one sediment sample from this site for metals, semi-volatile organics and pesticides.

Figure 5.1 Map with locations of chemical sampling stations



5.2 Water Quality Characterization

During the two years between August 2001 and August 2003, DWQ collected three baseflow and five storm samples at either Forest Hills Road or Metts Avenue – the integrator sites. DWQ collected the first four samples from the Forest Hills site, but then decided the Metts site was not affected by tidal influence and captured more of the watershed, so the next four samples were taken there. Results are shown in Table 5.2 and Appendix B.

Table 5.2 Means and Ranges of Selected Parameters at Forest Hills or Metts sites.

PARAMETER	Baseflow n	Baseflow mean	Baseflow range	Stormflow n	Stormflow mean	Stormflow range
DO (mg/L)	3	6.9	6.5 - 7.6	5	7.4	5.3 - 9.3
pH (standard units)	2	7.3	7.1 - 7.5	4	7.3	6.8 - 7.7
Specific conductance (uS/cm)	2	310	309- 310	5	266	254 - 278
Ammonia nitrogen (mg/L)	3	0.04	0.03 - 0.04	5	0.05	0.02 - 0.15
Total Kjedahl nitrogen (mg/L)	3	0.30	0.28 - 0.33	5	0.35	0.22 - 0.57
Nitrate+nitrite nitrogen (mg/L)	3	0.14	0.05 - 0.18	5	0.15	0.06 - 0.35
Total nitrogen (mg/L)	3	0.44	0.33 - 0.51	5	0.50	0.35 - 0.66
Total phosphorus (mg/L)	3	0.05	0.03 - 0.07	5	0.48	0.04 - 0.71

Dissolved oxygen levels were always above the state standard. We cannot rule out low dissolved oxygen, however, as it may occur during low streamflow in the early morning as part of diurnal fluctuation in photosynthesis/respiration by periphyton. Also, for the same reason, low dissolved oxygen could occur in the upper part of the substrate where benthic macroinvertebrates often reside.

Nitrogen concentrations were somewhat low while phosphorus concentrations were high compared to EPA's recommended nutrient criteria. For the North Carolina coastal region (ecoregion 63), total nitrogen and total phosphorus recommended levels are 0.71 mg/L and 0.03125 mg/L, respectively (USEPA, 2000). See Section 5.3.3 Organic Enrichment and Dissolved Oxygen for further discussion of nutrient levels.

UNC-Wilmington has monitored Burnt Mill Creek water quality since 1997. They do not have a site that overlaps well with either Forest Hills Drive or Metts Avenue, the location of DWQ's benthic macroinvertebrate surveys, however. Three of the UNC-Wilmington sites, Burnt Mill Creek at Princess Place (BMC-PP), Burnt Mill Creek below the outfall of Ann McCrary Pond (AP3), and Mineral Springs Branch near its confluence with Burnt Mill Creek (BMC-GS), provide useful information. Those data will be discussed in Section 5.3.3.

5.3 **Stressor and Source Identification**

A wide range of chemical stressors could potentially impact water quality in Burnt Mill Creek. Urban runoff constituents, particularly semi-volatile organics and metals, as well as pesticides and herbicides, could be present at levels that would stress or kill aquatic life. This possibility will be evaluated using different means in this section.

5.3.1 Water Column Toxicity

This section presents the results of bioassays performed on water samples, followed by a discussion of metals, semi-volatiles organics and other toxicants.

Bioassays.

DWQ performed one acute and three chronic bioassays using water collected from Burnt Mill Creek at Metts Avenue between September 2002 and August 2003. Generally, we tried to run acute bioassays using storm samples and chronic bioassays using baseflow samples, but weather and test scheduling prevented rigorous adherence to this protocol. In fact, many chronic samples were collected following periods of rain. In the end, we preferred the more sensitive chronic test because it is considered to be more representative of the pollutant exposure (longer duration and two samples) that local benthos experience. Clearly, it does not approach constant, in-situ exposure, but it is the more telling option.

Table 5.3 Chronic and Acute Bioassays – Water Column

Burnt Mill Cr at Mett Ave.	Test type & result	
Date	**acute**	**chronic**
9/10/2002	pass	-
1/21/2003 & 1/24/2003	-	pass
4/22/2003 & 4/25/2003	-	pass
8/5/2003 & 8/8/2003	-	pass

As shown in Table 5.3, all four water column bioassays conducted resulted in a 'Pass', indicating toxicity was not predicted to be present. Bear in mind that toxicity is likely to be very episodic, and DWQ may have missed toxic periods.

Metals in Water Samples.

Trace metals were commonly found at all sites. The most ubiquitous metals include aluminum, iron, magnesium and manganese. Table 5.4 shows metals concentrations at Forest Hill Road or Metts Avenue compared to hardness-adjusted aquatic life criteria. As discussed in Section 5.1.1, we used EPA NAWQC benchmarks, and applied the chronic benchmarks during baseflow and acute benchmarks during stormflow.
The only benchmark that is regularly exceeded is aluminum at chronic levels.

Chronic aluminum benchmark exceedances occurred during an acute and two chronic bioassays (on 9/10/2002, and on 1/21/03 and 4/22/02, respectively). Technically, only the chronic bioassay on 4/22/03 applies, since the other samples were taken during stormflow when we applied the acute criterion. Nonetheless, all bioassays passed, indicating that observed concentrations of aluminum in the stream were likely not harmful on these occasions. However, with only eight sample dates, it is certainly possible that we did not capture the highest metals levels that occur in the stream, which may be representative of regularly occurring intermittent conditions.

Since total, rather than dissolved, concentrations were measured, metals bioavailability is difficult to determine. Adjusting benchmarks for hardness only partially addresses this issue. Metals such as aluminum, iron, manganese, copper and zinc are widespread in

North Carolina's waters. Potential effects on benthic macroinvertebrates are uncertain since organisms in a given reach may be adapted to local concentrations (NCDWQ, 2003).

<u>Organic Compounds in Water Samples</u>.

DWQ performed organic chemical analyses (semi-volatile organics, PCBs, PAHs, phenols, MBAS) on a number of water samples collected at Metts Avenue and Princess Place Drive. Sampling dates for Metts Avenue included 4/22/03 during 'dry' conditions, and 9/10/02 and 1/21/03 during 'storm' conditions. DWQ also analyzed a sample from 9/10/02 for volatile organics (VOAs). Finally, DWQ analyzed a 12/18/01 Princess Place sample for semi-volatile organics.

No organic compounds were detected in any of these analyses. See Appendix B for reported detection levels. Due to the episodic nature of stormwater pollutant loading and the limited number of sample events, DWQ does not interpret a lack of detected organics in water samples as evidence that these pollutants do not ever appear in stormwater runoff to Burnt Mill Creek. In fact, sediment chemistry analyses suggest that stormwater does carry these pollutants.

<u>Current- and Past-Use Pesticide Concentrations in Water Samples</u>.

DWQ sampled Burnt Mill Creek at Metts Avenue for pesticides on one occasion, 9/10/02, during 'storm' conditions. No pesticides were found above the DWQ laboratory detection limit.

For organochlorine pesticides, detection limit varies but is typically in the 0.015 to 0.025 or higher range (see Appendix B for reported detection levels). For organophosphate pesticides, detection limits are 0.40 ug/L or higher. For nitrogen pesticides, detection limits are usually 4.5 or 15 ug/L, depending on the target compound.

Table 5.4 Burnt Mill Creek at Forest Hills Road or Metts Avenue: Total Metals Concentrations and NAWQC Values.

	CHRONIC [1]	BASEFLOW			ACUTE [1]	STORMFLOW			
Metal (ug/L)		8/27/2001	4/16/2002	4/22/2003	12/18/2001	7/2/2002	9/10/2002	1/21/2003	8/5/2003
Aluminum	87	**130**	59	**110**	750	62	130	140	84
Arsenic	150	-	-	-	340	-	-	-	-
Cadmium	3.1	-	-	-	6.2	-			-
Chromium	11	-	-	-	16	-			-
Copper	11.9	-	-	2.3	18.3	2.2			2.6
Iron	1000	560	250	470	N/A	330	430	430	850
Lead	4.6	-	-	-	117.4	-			-
Manganese	120 [2]	35	27	26	2300 [2]	20	22	33	53
Mercury	0.77			-	1.4	-	-	-	-
Nickel	66	-	-	-	597	-			-
Silver	0.36 [2]	-	-	-	6.63	-	-	-	-
Zinc	153	23	26	-	153	-			-

[1] Benchmark values are adjusted according to average hardness except for aluminum, iron and manganese for which no conversions are available.

[2] Tier II benchmark value; NAWQC not available.

- Metal concentration was below detection limit. Detection limits are found in Appendix B.

See Section 5.1.1 for definitions of baseflow and stormflow conditions.

5.3.2 Bed Sediment Toxicity

This section presents the results of various analyses to assess bed sediment toxicity. These analyses include: chemical samples for semi-volatile organics, metals, herbicides and pesticides, and one bioassay.

Sediment Bioassay.

DWQ does not have the capability to run the standard bed sediment bioassay, which uses the organism *Hyallela azteca* (ASTM, 2000; USEPA, 2000b). This is something that would benefit DWQ's program as it stands to reason that bed sediment is an important media to test for toxicity, since, through adsorption, it holds pollutants delivered over time. Also, benthic organisms are almost constantly exposed to stream sediment.

DWQ does have the capability to assess bed sediment toxicity using Microtox®. We ran one test using this tool. With a composite sample of organic-rich, fine-grained sediment collected on August 5, 2003 from several locations at the Metts Avenue site, DWQ ran serial dilutions of sediment suspended in a sodium chloride solution. At 32,900 mg/kg (3.29%) sediment, dry weight, the test sediment showed toxic effects. This concentration is the EC50, or percent of sample that causes a 50% reduction in light intensity emitted by the test bacteria, as compared to the control organism light emission. See Section 5.1.1 for further explanation. **The test results indicate that the sediment may impact the receiving water ecosystem.**

This does not tell us, though, what constituent caused the apparent toxicity. Sediment chemistry analyses, detailed below, may provide clues in this regard.

Organic Compounds and Pesticides in Sediment.

DWQ sampled sediments at four locations: Burnt Mill at Metts Avenue (2 dates), Independence Drive (1 date), and Princess Place Drive (1 date), and drainage ditch near Metts Avenue (1 date). These samples were primarily analyzed for metals and semi-volatile organics, but we did analyze them for pesticides and herbicides, as well. Sediment benchmark levels for metals and semi-volatile organics are introduced in Section 5.1.1, and listed in Appendix B.

On 8/5/03, DWQ collected organic-rich, fine-grained sediment from all four sites, and had these analyzed for semi-volatile organics, metals, herbicides and pesticides. The results of all analyses are presented in the Tables 5.5 through 5.8. Polycyclic aromatic hydrocarbons (PAHs) were commonly found, some at probable toxic effect levels. The highest reported levels came from the lower end of the watershed at Metts Avenue and Princess Place Dr. Because PAHs are found at high (toxic) levels in Burnt Mill Creek sediment, it is very possible that water column concentrations at all sites in the watershed are, at times, high enough to harm the aquatic insect community. Meanwhile, we know the sediments are toxic to the aquatic insect community, since they exceeded numerous published benchmarks. PAH sources are discussed in Section 7.2.

Table 5.5 Burnt Mill Creek at Metts Ave.		Organic Pollutants Detected in Depositional Sediment		
Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
9/10/2002	phenanthrene	1600	**PEL, TET, ERM, PEL-HA28, PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	fluoranthene	3500	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	anthracene	180	**PEL-HA28**, ERL, TEL-HA28, TEC	N3
	pyrene	3000	**PEL, TET, ERM, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	benzo(a)anthracene	1400	**PEL, TET, ERM, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	chrysene	1900	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	benzo(a)pyrene	1500	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	dibenzo(a,h)anthracene	210	NA	N3
	benzo(k)fluoranthene	830	NA	
	benzo(b)fluoranthene	2400	NA	
	indeno(1,2,3-CD)pyrene	960	NA	
	benzo(g,h,l)perylene	820	NA	
	alkane	2600	NA	N1
	benzo fluorene C20.H12	1900	NA	N1
	tetramethyl phenanathrene C18.H18	1500	NA	N1
8/5/2003	phenanthrene	1400	**PEL, TET, ERM, PEL-HA28, PEC**, TEL, MET, ERL, TEL-HA28, TEC	
	fluoranthene	3500	**PEL, TET, PEL-HA28, PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	pyrene	2900	**PEL, TET, ERM, PEL-HA28, PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	benzo(a)anthracene	1200	**PEL, TET, PEL-HA28, PEC**, TEL, LEL, ERL, TEL-HA28, TEC	
	chrysene	1800	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	benzo(a)pyrene	1400	**PEL, TET, PEL-HA28**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	dibenzo(a,h)anthracene	230	NA	N3
	benzo(k)fluoranthene	790	NA	
	benzo(b)fluoranthene	2200	NA	
	indeno(1,2,3-CD)pyrene	1100	NA	
	benzo(g,h,l)perylene	910	NA	
	hexadecenoic acid C16.H30.O2	990-1800	NA	N1
	alkane	510-1400	NA	N1

See notes below following table (Table 5.6) – they apply to this table, as well.

Table 5.6 Organic Pollutants Detected in Depositional Sediment, Burnt Mill Creek at Princess Place Drive.

Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
8/5/2003	phenanthrene	1200	**PEL, TET, PEL-HA28,** TEL, LEL, MET, ERL, TEL-HA28, TEC	
	fluoranthene	3200	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	pyrene	3000	**PEL, TET, ERM, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	benzo(a)anthracene	1300	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	chrysene	2000	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	benzo(a)pyrene	1600	**PEL, TET, PEL-HA28**, **PEC**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	dibenzo(a,h)anthracene	290	NA	N3
	benzo(k)fluoranthene	880	NA	
	benzo(b)fluoranthene	1600	NA	
	indeno(1,2,3-CD)pyrene	1300	NA	
	benzo(g,h,l)perylene	1300	NA	
	alkane	940-3900	NA	
	hexadecenoic acid C16.H30.O2	1500	NA	N1
	hexadecenoic acid C16.H32.O2	1600	NA	N1

Analytes with benchmarks exceeded are all polycyclic aromatic hydrocarbons (PAHs).
Benchmarks in bold are for probable effects level; the others are for threshold effects level.
NA: Not applicable – no benchmark provided.
N3: estimated concentration less than the laboratory PQL limit and greater than the laboratory
N1: the component has been tentatively identified based on mass spectral library search and has an estimated value.

Table 5.7 Organic Pollutants Detected in Depositional Sediment, Burnt Mill Creek at Independence Drive

Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
8/5/2003	fluoranthene	220	TEL, TEL-HA28	N3
	pyrene	200	TEL, TEL-HA28, TEC	N3
	benzo(b)fluoranthene	210	NA	N3
	alkane	170-1300	NA	N1
	hexadecenoic acid C16.H30.O2	190-630	NA	N1
	hexadecenoic acid C16.H32.O2	850	NA	N1

Analytes with benchmarks exceeded are polycyclic aromatic hydrocarbons (PAHs)
Benchmarks in bold are for probable effects level; the others are for threshold effects level.
N3: estimated concentration less than the laboratory PQL limit and greater than the laboratory
N1: the component has been tentatively identified based on mass spectral library search and has an estimated value.
NA: Not applicable – no benchmark provided.

Table 5.8 Organic Pollutants Detected in Depositional Sediment, Drainage Ditch below Metts Avenue

Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
8/5/2003	hexadecenoic acid C16.H30.O2	1800	NA	N1, A
	hexadecenoic acid C16.H32.O2	2000	NA	N1, A

N1: the component has been tentatively identified based on mass spectral library search and has an estimated value.
A: value reported is the average of two or more determinations.
NA: Not applicable – no benchmark provided.

Table 5.9 Pesticides Detected in Depositional Sediment, Burnt Mill Creek at Metts Avenue

Date	Analyte	Level (ug/Kg)	Benchmarks Exceeded
9/10/2002	*chlorinated pesticides*	none identified	none
		>10 unidentified peaks detected	
		1 of 6 spike recoveries qualified J2, J3	
		multiply chlorinated pest. PQLs by 4	
	organophosphate pesticides	none identified	none
		1 unidentified peak detected	
	nitrogen pesticides	none detected	none
8/5/2003	*chlorinated pesticides*	none identified	none
		>10 unidentified peaks detected	
		surrogate and spike recoveries J2 & J3	
		(dilutions due to matrix interference)	
		multiply chlorinated pest. PQLs by 20	
	organophosphate pesticides	none identified	none
		5 unidentified peaks detected	
	nitrogen pesticides	none detected	none
	acid herbicides	none identified	none
		>10 unidentified peaks detected	
		multiply acid herb. PQLs by 5	

J2: estimated value, the reported value failed to meet the QC criteria for either precision or accuracy
J3: estimated value, the sample matrix interfered with the ability to make an accurate determination
PQLs are listed in Appendix B

Table 5.10 Pesticides Detected in Depositional Sediment, Burnt Mill Cr. at Indedendence Drive

Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
8/5/2003	*chlorinated pesticides*	none identified	none
		4 unidentified peaks detected	
		surrogate recoveries J2 (dilutions due to matrix interference)	
		multiply chlorinated pest. PQLs by 20	
	organophos-phate pesticides	none identified	none
		3 unidentified peaks detected	
	nitrogen pesticides	none detected	none
		1 unidentified peak detected	
	acid herbicides	none identified	none
		>10 unidentified peaks detected	
		multiply acid herb. PQLs by 5	

Table 5.11 Pesticides Detected in Depositional Sediment, Burnt Mill Creek at Princess Place Drive

Date	Analyte	Level (ug/Kg)	Benchmarks Exceeded
8/5/2003	*organochlorine pesticides*	>10 unidentified peaks detected	
		multiply chlorinated pest. PQLs by 20	
		surrogate recoveries J2 (dilutions due to matrix interference)	
	chlordane-gamma	32.2	no SQGs for this analyte
	dieldrin	56.4	**PEL, ERM**, TEL, LEL, MET, ERL, TEL-HA28, TEC
	trans-nonachlor	28.7	no SQGs for this analyte
	organophosphate pesticides	none identified	
		7 unidentified peaks detected	
	nitrogen pesticides	none identified	
		2 unidentified peaks detected	
	acid herbicides	none identified	
		>10 unidentified peaks detected	
		multiply acid herb. PQLs by 5	

Table 5.12 Pesticides Detected in Depositional Sediment, Drainage ditch below Metts Avenue

Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
8/5/2003	*chlorinated pesticides*	>10 unidentified peaks detected	
		multiply chlorinated pest. PQLs by 5	
		surrogate recoveries J2 (dilutions due to matrix interference)	
	chlordane-gamma	7.05	no SQGs for this analyte
	dieldrin	24.8	**PEL, ERM**, TEL, LEL, MET, ERL, TEL-HA28, TEC
	organophosphate pesticides	none identified	none
		3 unidentified peaks detected	
	nitrogen pesticides	none detected	none
	acid herbicides	none identified	none
		>10 unidentified peaks detected	
		multiply acid herb. PQLs by 5	

As shown in Tables 5.11 and 5.12 above, pesticides could not be individually identified, with few exceptions. One organochlorine pesticide, dieldrin, was found at probable effect levels in the sediment samples from Princess Place Dr. and drainage ditch below Metts Avenue.

Metals in Sediment.

DWQ found many types of metals in the sampled relatively fine-grained, organic-rich bed sediment of Burnt Mill Creek. Concentrations were usually below the benchmark levels described in Section 5.1.1; however, levels of lead exceeded probable effects levels, and zinc, copper and cadmium exceeded some threshold SQGs at Princess Place Drive.

Table 5.13 Metals Detected in Depositional Sediment, Burnt Mill Cr. at Metts Avenue

Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
8/5/2003	Cd	0.21	none
	Cr	3.5	none
	Cu	8.6	none
	Ni	1.6	none
	Pb	17	none
	Zn	51	none
	Al	1,100	NA
	Fe	2,000	NA
	Mg	180	NA
	arsenic	0.76	NA
	Hg	0.02 U	none

NA: Not applicable – no benchmark provided.
U: Below laboratory detection level.

Table 5.14 Metals Detected in Depositional Sediment, Burnt Mill Cr. at Indedendence Drive

Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
8/5/2003	Cd	0.2 U	none
	Cr	1.3	none
	Cu	2.4	none
	Ni	0.46	none
	Pb	4.2	none
	Zn	10	none
	Al	820	NA
	Fe	880	NA
	Mg	160	NA
	arsenic	0.27	NA
	Hg	0.02 U	none

NA: Not applicable – no benchmark provided.
U: Below laboratory detection level.

Table 5.15 Metals Detected in Depositional Sediment, Burnt Mill Cr. at Princess Place Drive

Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
8/5/2003	Cd	1.2	TEL, LEL, MET, TEL-HA28, TEC
	Cr	19	none
	Cu	36	TEL, LEL, MET, TEL-HA28, TEC
	Ni	7	none
	Pb	250	**PEL, SEL, TET, ERM, PEL-HA28, PEC**, TEL, LEL, ERL, TEL-HA28, TEC
	Zn	250	TEL, LEL, MET, ERL, TEL-HA28, TEC
	Al	7,200	NA
	Fe	9,500	NA
	Mg	590	NA
	arsenic	4.7	NA
	Hg	0.21	none

Benchmarks in bold are for probable effects level; the others are for threshold effects level.
NA: Not applicable – no benchmark provided.

Table 5.16 Metals Detected in Depositional Sediment, Drainage ditch below Metts Avenue

Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
8/5/2003	Cd	0.62	TEL, LEL, TEL-HA28
	Cr	6.7	none
	Cu	4.7	none
	Ni	4.2	none
	Pb	20	none
	Zn	42	none
	Al	6,900	NA
	Fe	2,200	NA
	Mg	510	NA
	arsenic	1.10	NA
	Hg	0.02 U	none

NA: Not applicable – no benchmark provided.

Bed Sediment Toxicity Summary
We know from the Microtox sediment bioassay that sediment toxicity is evident at Metts Avenue. The most likely candidates for causing this toxicity, based on sediment chemistry analysis described above, are PAHs. PAHs are above numerous probable effects benchmarks **in the reach where DWQ surveyed the benthic macroinvertebrate community**. According to published sediment quality benchmarks, the particular PAHs of concern are phenanthrene, fluoranthene, chrysene, pyrene, benzo(a)anthracene and benzo(a)pyrene. DWQ also detected anthracene at very high levels in the September 2002 sample, but not in the August 2003 sample.

5.3.3 Organic Enrichment and Dissolved Oxygen

DWQ measured dissolved oxygen each time it collected a water or sediment sample at a given location in the Burnt Mill Creek watershed. This amounted to four measurements at each Forest Hills Drive and Metts Avenue. It also included measurements during the drought period of late 2001 to late 2002. DWQ never measured dissolved oxygen below the state standard of 5 mg/L. That does not mean dissolved oxygen sags do not occur, as we never measured DO at night, when it is likely to be lowest.

It appears that organic enrichment caused by excessive phosphorus loading is more of a problem. Observed water column nutrient levels are shown in Table 5.17. For the ecoregion where Burnt Mill Creek is located (ecoregion 63, coastal region spanning several states), total nitrogen and total phosphorus **recommended levels** are 0.71 mg/L and 0.03125 mg/L, respectively (USEPA, 2000). Note that these values are **not benchmarks indicating harmful levels**; rather, they are suggested levels that were purposely chosen to serve as a 'high bar' for states to consider for adoption. DWQ has plans to develop their own nutrient criteria, using just North Carolina water quality data (EPA's levels were based on data from several states). In the meantime, EPA's recommended levels will be used in this report as a loose measure by which to compare observed nutrient levels in Burnt Mill Creek.

These criteria are the median values for all seasons' 25th percentiles, based on data collected between 1990 and 1999 at 56 streams for nitrogen and 375 streams for phosphorus. EPA intended for these criteria to be compared to growing season average nutrient levels. Since only a limited number of samples are available for Burnt Mill Creek, DWQ calculated the median value of all samples. These equaled **0.455 mg/L** for total nitrogen and **0.055 mg/L** for total phosphorus.

Based on only eight samples, and compared with EPA's recommended nutrient criteria, Burnt Mill Creek's median nitrogen concentration was quite low, while the median phosphorus concentration was high. The reader should bear in mind, however, that the sample pool is small and may not provide good estimates of the true average nutrient concentrations. Also, two of five total phosphorus samples taken during storm flow were reported at 0.62 and 0.71 mg/L; these are very high levels and should be further investigated.

The impact of high nutrient levels on the biological community appears to relate more to the available food types and consequent community structure, than to low dissolved oxygen levels. Nutrients serve as food for two general types of algae: phytoplankton that float freely in the water column, and periphyton, which attaches to rocks. These algae then become the food for higher organisms on the food chain, such as benthic macroinvertebrates and fish. The types of macroinvertebrates and fish that prefer algae as their primary food source out-compete those that favor other food sources. Consequently, the assemblage of aquatic organisms in a phosphorus-rich stream like Burnt Mill Creek is not a balanced and diverse community, as shown by the community surveys conducted by DWQ's Biological Assessment Unit.

5.3.4 Other Monitoring

As mentioned in Section 5.2, UNC-Wilmington has monitored Burnt Mill Creek water quality since 1997. The parameters sampled include nutrients, chlorophyll, fecal coliform, turbidity, total suspended solids, and physical measures, such as dissolved oxygen and conductivity. Nutrient data are of particular interest to this study. UNC-W does not have a site, however, that overlaps well with either Forest Hills Drive or Metts Avenue, the location of DWQ's benthic macroinvertebrate surveys. Three of the UNC-Wilmington sites, Burnt Mill Creek at Princess Place (BMC-PP), Burnt Mill Creek below Ann McCrary Pond (AP3), and Mineral Springs Branch near its confluence with Burnt Mill Creek (BMC-GS), provide useful information.

Based on monthly samples between 1997 and 2002, BMC-PP had median total nitrogen and total phosphorus of 0.60 and 0.08 mg/l, respectively (Mallin et al., 2003). Perhaps as expected, since Princess Place is lower in the watershed than Metts Avenue and drains additional urban land cover, these nutrient levels are somewhat higher than the median concentrations from DWQ data. The data are rather close, however, and support the conclusions that total nitrogen levels appear to be acceptable, while total phosphorus levels are too high.

UNC-Wilmington monitored BMC-GS only from 2001 to 2002. Based on 12 samples, the median concentrations for total nitrogen and total phosphorus at this site were 0.615 and 0.115 mg/l, respectively. Again, the total nitrogen levels appear acceptable. Also, phosphorus is yet higher, indicating that the Mineral Springs Branch subwatershed may be considered a problem source area for phosphorus at Metts Avenue.

A third UNC-Wilmington site, AP3, is located 40 meters below the outfall of Ann McCrary Pond. Between 1997 and 2001, it had a median total nitrogen concentration of 0.42 mg/l, and median total phosphorus of 0.04 mg/l. This demonstrates that though there may be nutrient source areas in the headwaters, Ann McCrary pond effectively reduces nutrient levels, so that future nutrient management might focus below the pond.

Table 5.17 Nutrients Levels in Water Column, Burnt Mill Cr. at Forest Hills Drive and Metts Ave.

Parameter (mg/L)	BASEFLOW 8/27/2001	4/16/2002	4/22/2003		STORMFLOW 12/18/2001	7/2/2002	9/10/2002	1/21/2003	8/5/2003	50th percentile (all data)
Ammonia, NH_3	0.03	0.04	0.04		0.15	0.02	0.02	0.03	0.03	0.03
Total Kjedahl Nitrogen, TKN	0.29	0.28	0.33		0.29	0.22	0.37	0.31	0.57	0.3
Nitrite + Nitrate, NO_2 + NO_3	0.18	0.05	0.18		0.06	0.22	0.06	0.35	0.07	0.125
Total Nitrogen, TN	0.47	0.33	0.51		0.35	0.44	0.43	0.66	0.64	**0.455**
Total Phosphorus, TP	0.07	0.03	0.04		0.62	0.04	0.04	0.71	0.09	**0.055**

TKN = organic N + NH_3
TN = TKN + NO_2 + NO_3
See Section 5.1.1 for definitions of baseflow and stormflow.

Section 6
Channel and Riparian Conditions

The characterization of stream habitat and riparian condition at benthic macroinvertebrate sampling sites provides additional information to the assessment of conditions in the Burnt Mill Creek watershed. This section provides a more holistic look at the condition of the stream network beyond several sampling sites. This broader characterization is critical to an evaluation of the contribution of local and regional habitat conditions to stream impairment, and to the identification of source areas and activities.

Project staff walked about half of the 4.5-mile main stem of Burnt Mill Creek, mostly between Princess Place Dr. and tributary mouths to Ann McCrary Pond, and the upper portion of Mineral Springs Branch. DWQ also consulted KCI Associates' stream inventory data (cataloging of selected stream channels and adjacent riparian zones), which was part of their watershed assessment of Burnt Mill Creek for the North Carolina Ecosystem Enhancement Program (KCI, 2002b). This section summarizes channel and riparian conditions, and discusses likely future changes in stream channels.

6.1 Summary of Existing Conditions

6.1.1 Overall Channel and Riparian Condition

<u>Channel Conditions</u>. Burnt Mill Creek and its tributaries have been historically channelized and straightened. The purpose was to remove the swampy nature of the watershed, which was perhaps more prone to flooding and harbored nuisance fauna, such as mosquitos. Some sinuosity persists, though this is usually in the upper reaches or tributaries.

Despite this channelization, most of the stream network does not have pronounced incision. This is due, in part, to Wilmington's installation of a perforated cement covering, called 'fabraform', over numerous reaches of the channel network. Fabraform prevents vertical and lateral movement by the stream. Another Burnt Mill Creek channel control is riprap, or piled rocks for prevention of streambank erosion.

In some places, incision does exist, as the stream does not appear to have access to its floodplain. Examples of such locations are Mineral Springs Branch near Wrightsville Road, and Burnt Mill Creek between Forest Hills Drive and Metts Avenue.

It appears that presently the increased stream energy from continued development and consequent impervious surface additions is being directed towards streambank erosion, rather than channel deepening (incision). Other sediment sources include runoff from roadways, parking lots, construction sites and a myriad of spots without vegetative cover. The typically sandy soils in the watershed are easily eroded (see Section 2.3).

As a result, channel aggradation is widespread, with silt and fine sand accumulations up to one foot or more, in places. This produces unstable habitat for the benthic macroinvertebrate community. Sediment accumulation is evident throughout the watershed, but is most prevalent upstream from Princess Place Dr. Below this location, stream velocities slow, due to reduced gradient and tidal influence, and sediment transport capacity lessens.

Riparian Conditions. For the most part, riparian buffers only minimally protect the stream network of Burnt Mill Creek watershed. The most typical scenarios are either grass on both banks, or one bank with grass and the other with trees and shrubs. For the most part, only the lower watershed, below Princess Place Dr., has treed buffers on both banks.

Even the banks with good riparian buffer coverage have many places where stormwater pipes empty into the stream channel, thus negating the positive effects the buffer might have through filtering runoff from a broader area.

Aquatic Habitat. In most locations, in-stream habitat in the Burnt Mill Creek watershed is very suspect in terms of its suitability to support aquatic life. Historically, the watershed has been converted from a swamp system (e.g., slow moving) to a flowing system through channelization. The premise has been to move the water off site in the name of flood prevention. Coupled with thinning of the riparian buffers, this has served to remove much of the microhabitat from the stream and promote streambank erosion, which yields an accumulation of fine-grained sediment in the channels. Hence, even though Burnt Mill Creek is now more of a flowing system, it has very infrequent riffle zones due to sediment accumulation and a low stream gradient.

The streambank erosion does create root mat habitat for aquatic insects. Logs and snags are largely absent; this is likely the result of channel cleaning. Allowing some fallen trees and branches to remain in the channel would improve habitat conditions.

DWQ does not know the stream classification for Burnt Mill Creek. A geomorphic assessment should be conducted before any stream channel restoration is initiated (note: KCI's stream inventory for EEP provides useful information, but it is not the equivalent of a geomorphic assessment for assessing stream restoration needs and potential).

6.2 Future Changes

Burnt Mill Creek and its tributaries appear to be responding to the altered hydrologic conditions brought about by an increase in impervious cover in the watershed. The stream appears to be unable to transport its current sediment load, so perhaps further channel widening appears to be the most likely scenario. This widening may continue until the channel width is sufficient to allow for stabilization of eroded banks (Schumm et al., 1984; Simon, 1989; Simon and Darby, 1999). Baseflow water depths will become shallower, potentially resulting in increased water temperatures, and in more dynamic dissolved oxygen levels. With an expected increase in algal density due to greater sunlight penetration and temperature increases, dissolved oxygen levels may rise more in the day and fall more at night, following the pattern of photosynthesis.

6.3 Other Efforts

As part of their contract with the North Carolina Ecosystem Enhancement Program (EEP, formerly the Wetlands Restoration Program), KCI Consultants (2002b) conducted detailed channel and riparian area surveys over six distinct reaches in the watershed. They noted widespread channelization and straightening, and provide a good summary of conditions in each reach. Additionally, KCI (2002c) compiled an inventory of pipes, culverts and ditches, which provides additional information on potential pollutant sources. Finally, Eel's New Hanover Local Watershed Plan (NCEEP, 2002) may be viewed at http://h2o.enr.state.nc.us/wrp/plans/new_hanover_plan.htm. As part of this planning effort, EEP and the City of Wilmington convened a broad range of stakeholders to coordinate the watershed's restoration and enhancement. EEP details these measures in the plan.

Section 7
Analysis and Conclusions – Causes and Sources of Impairment

This section analyzes the likely causes of impairment in the Burnt Mill Creek watershed, drawing on the information presented earlier in this report. The sources or origin of these key stressors are also discussed.

Admittedly, the project focused more on causes than on sources. The goal is to move Burnt Mill Creek to the appropriate part of the 303(d) list, and then later, with more data on sources, develop a TMDL, or implement a management strategy.

7.1 Analyzing Causes of Impairment

The following analysis summarizes and evaluates the available information related to candidate causes of impairment in order to determine whether that information provides evidence that each particular stressor plays a substantial role in causing the observed biological impacts. A strength of evidence approach is used to assess the evidence for or against each stressor, and draw conclusions regarding the most likely causes of impairment. Causes of impairment may be single or multiple. All stressors present may not be significant contributors to impairment. [See the Background Note "Identifying Causes of Impairment", presented in Section 1, for additional discussion.] Acknowledgement for significant assistance on this section is owed to DWQ's Watershed Assessment and Restoration Project, which preceded this project and had the same objectives (NCDWQ, 2003).

7.1.1 A Framework for Causal Evaluation—the Strength of Evidence Approach

A 'strength of evidence' approach or 'lines of evidence' approach involves the logical evaluation of all available types (lines) of evidence to assess the strengths and weaknesses of that evidence in order to determine which of the options being assessed has the highest degree of support (USEPA, 1998; USEPA, 2000).

This section considers all lines of evidence developed during the course of the study using a logical process that incorporates existing scientific knowledge and best professional judgment in order to consider the strengths and limitations of each source of information. Lines of evidence considered include benthic macroinvertebrate community data, habitat and riparian area assessment, chemistry and toxicity data, and information on watershed history, current watershed activities and land uses and pollutant sources. The endpoint of this process is a decision regarding the most probable causes of the observed biological impairment and identification of those stressors that appear to be most important. Stressors are categorized as follows:

- **Primary cause of impairment.** A stressor that has an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing the impairment, the primary cause is the one that is most critical or limiting.

Impairment is likely to continue if the stressor is not addressed. All streams will not have a primary cause of impairment.

- **Secondary cause of impairment.** A stressor that is having an impact sufficient to cause biological impairment but that is not the most critical or limiting cause. Impairment is likely to continue if the stressor is not addressed.
- **Cumulative cause of impairment.** A stressor that is not sufficient to cause impairment acting singly, but that is one of several stressors that cumulatively cause impairment. A primary cause of impairment will generally not exist. Impairment is likely to continue if the various cumulative stressors are not addressed. Impairment may potentially be addressed by mitigating some but not all of the cumulative stressors. Since this cannot be determined in advance, addressing each of the stressors is recommended initially. The actual extent to which each cause should be mitigated must be determined in the course of an adaptive management process.
- **Contributing stressor.** A stressor that contributes to biological degradation and may exacerbate impairment but is not itself a cause of impairment. Mitigating contributing stressors is not necessary to address impairment, but should result in further improvements in aquatic communities if accomplished in conjunction with addressing causes of impairment.
- **Potential cause or contributor.** A stressor that has been documented to be present or is likely to be present, but for which existing information is inadequate to characterize its potential contribution to impairment.
- **Unlikely cause or contributor.** A stressor that is likely not present at a level sufficient to make a notable contribution to impairment. Such stressors are likely to impact stream biota in some fashion but are not important enough to be considered the causes of or contributors to impairment.

7.1.2 Candidate Stressors

As outlined in Section 3, the primary stressors evaluated were:

- Habitat degradation—sedimentation;
- Habitat degradation—lack of microhabitat;
- Scour due to hydromodification;
- Toxicity due to nonpoint source impacts;
- Nutrient enrichment.

7.1.3 Review of Evidence

Burnt Mill Creek is impaired for its entire length in the study area, a condition that has been evident since 1998. It is not known when the last time the creek was unimpaired (had a balanced aquatic community).

Habitat degradation—sedimentation. Sedimentation is evident over much of the course of Burnt Mill Creek. Relevant lines of evidence include benthic macroinvertebrate community data, habitat and geomorphic evaluations, and watershed characteristics.

Stream surveys and habitat assessments indicate that sedimentation is occurring, but has probably not yet reached a point where it can be considered a primary cause of impairment. As is typical of coastal plain streams, not many riffle sections are evident. This is likely a reflection of the stream's low gradient, but it may be exacerbated by sedimentation. Either way, sedimentation is definitely extensive in Burnt Mill Creek. Every reach has considerable amounts of fine-grained (e.g., sand and smaller) sediment. In fact, fine- grained sediment comprises always more than 80 percent, and often 95 or 100 percent, of the substrate in the sampled locations (see Table 4.1).

Sedimentation in Burnt Mill Creek causes unstable habitat for the benthic macroinvertebrate community. Since it is so extensive, **this probably means that sedimentation is a secondary or cumulative cause of impairment**. Since pockets with less sediment accumulation exist, some habitat remains, so DWQ does not believe sedimentation is a primary cause of impairment.

Habitat degradation—lack of microhabitat. Habitat degradation's role in the benthic impairment was further evaluated because preliminary assessments revealed variable microhabitat habitat quality in Burnt Mill Creek, with unfavorable conditions in some areas. Relevant lines of evidence include benthic macroinvertebrate community data, habitat surveys, and watershed characteristics.

As part of the habitat surveys, the in-stream structure score (see Table 4.1) reflects, in large part, microhabitat variety and quantity. These scores are low throughout the watershed. Also, they are lower at Metts Avenue (5 – 9 range out of 20) than they are at Forest Hills Drive (10 – 11 range). Both sites have macrophytes, leaf packs, and root mats; however, the Forest Hills site has these microhabitats over more of the reach area. Specifically, DWQ's Biological Assessment Unit rated 10-30% of the Forest Hills reach and <10% of the Metts reach available for colonization.

Logs and snags appear to have been removed from the stream as there are very few of each present. Leaving future fallen logs and branches would help to increase and diversify microhabitat.

Despite this difference in microhabitat quantity, the two sites received 'Poor' bioclassica-tions. At first glance, this leads one to suspect that the habitat differences are inconse-quential. This may be the case, but it is also possible that other factors, such as toxicity, account for the difference. In this case it is difficult to determine without a reference stream or different measured toxicity levels, neither of which are available for this study.

In sum, **lack of microhabitat appears to be more of a cumulative stressor, or perhaps a secondary cause of impairment**.

Scour due to hydromodification. Scour is closely related to habitat degradation, because it relates to elevated streamflow, which also causes sedimentation and removes microhabitat. Scour will be defined as streamflow that washes aquatic insects downstream, away from their original habitat.

There is indication that scour occurs in Burnt Mill Creek. Channelized stream reaches are common, though incision is usually not more than one or two meters below the streambanks. Aggradation seems to be more common than channel incision.

Burnt Mill Creek has a highly impervious watershed, which raises the potential for scour to occur. On the other hand, it has a low gradient that may prevent streamflow velocities from reaching levels that wash away the benthos or their microhabitat.

It is difficult to say if this scour is sufficient to severely impact the benthos. Since some microhabitat remains in the stream, the elevated flows appear to not affect the whole channel, otherwise leafpacks might be washed away. If this were the case, the limited microhabitat would leave some locations for aquatic insects to cling during high flow events.

Ann McCrary Pond, located in the upper reaches of the watershed, serves as a mitigating factor for high stormwater flows. This regional detention pond greatly reduces the stormwater runoff that reaches the benthic sites at Forest Hills Drive and Metts Avenue. It drains, and hence treats, 1785 acres of land (Mallin, 2003).

DWQ believes that scour is a less important stressor, perhaps a potential cause of the impairment.

Toxicity due to nonpoint source impacts. DWQ evaluated toxicity as a cause of impairment because the initial benthic community survey for Burnt Mill Creek indicated toxic impacts were evident (e.g., community composition). That the watershed is highly developed also raised some concern, since this translates to a wide variety of potential toxicants. Six lines of evidence are relevant: water and sediment chemistry data, water bioassays, one sediment bioassay, watershed characteristics and benthic community data.

All the benthic macroinvertebrate surveys conducted in the Burnt Mill Creek watershed exhibit high Biotic Index or EPT Biotic Index values (see Table 4.1), indicating the prevalence of organisms tolerant of a variety of stressors.

Watershed characteristics, such as a high level of development and high traffic volumes, suggest the potential for higher loading levels of many pollutants. The entire watershed is within the City of Wilmington.

DWQ conducted three chronic and one acute water column bioassays. All of the water bioassays passed. Consideration of other factors is warranted when discussing the water bioassays. For instance, the number of water column samples was limited, and it is likely that higher concentrations occur periodically. So, it cannot be ruled out that toxicity due to infrequent incidents did not occur outside of sampling events.

Another consideration is how laboratory bioassay results apply to in-stream conditions. Or probably more to the point, how can in-stream conditions be represented in bioassays? Though laboratory bioassays are useful for integrating the impacts of multiple pollutants (accounting for cumulative effects), laboratory conditions often will not reflect actual in-stream exposures or account for the full range of biological responses (Burton and Pitt, 2001; Herricks, 2002). For example, stream organisms may experience multiple stresses over an extended period (such as repeated pulses of various pollutants), a situation difficult to duplicate in lab bioassays. While difficult to assess, the long-term cumulative effects of frequent exposures is likely important (Burton and Pitt, 2001). Also, volatile toxicants can escape a sample and result in bioassay conditions that are not representative of in-stream toxicant levels.

Water column chemical analyses included samples for toxic constituents such as metals, organics, MBAS and pesticides. In the metals category, aluminum was the only parameter above NAWQC benchmarks (all chronic, no acute exceedances). North Carolina metals standards and action levels were never exceeded. North Carolina does not have an action level or standard for aluminum. DWQ's laboratory did not detect any semi-volatile organics from four samples on separate days at Metts Avenue (3 samples) and Princess Place Drive (1 sample). Also, lab analyses found no organochlorine, organophosphate or nitrogen pesticides above detection limits on one samples date at Metts Avenue. **In sum, with the possible exception of aluminum, DWQ found little evidence of toxicity in water column samples**.

Sediment chemistry analyses for metals, organics and pesticides were done on samples from Burnt Mill Creek at Metts Avenue, Independence Drive, Princess Place Drive and a drainage ditch below Metts Avenue. Samples exceeded **many probable effects** semi-volatile sediment benchmarks -particularly polycyclic aromatic hydrocarbons, PAHs- at Metts Avenue and Princess Place Dr. Lead exceeded a number of probable effects benchmarks at Princess Place Drive, while cadmium, copper and zinc exceeded threshold effects levels at this site. Elsewhere sediment metal levels did not appear to be a problem. One organochlorine pesticide, dieldrin, exceeded two probable effects benchmarks and many threshold effects benchmarks below Princess Place Drive and in the drainage ditch below Metts Avenue.

To summarize, sediment chemistry showed toxicity according to published benchmarks for PAHs, lead, zinc, copper, cadmium and dieldrin. Toxicant levels were definitely highest, and most likely to cause impairment, at Princess Place Drive. **At Metts Avenue, the integrator site and location of regular benthic macroinvertebrate surveys, PAH levels really stood out, as seven different analytes were present at probable effects levels**.

DWQ conducted one sediment bioassay at Metts Avenue using Microtox®. This test uses bioluminescent marine bacteria, *Vibrio fischeri*. It showed toxic effects were evident. A long-term bioassay using *Hyallela azteca* would be preferable, but, due to resource constraints, could not be performed.

The evidence for toxicity is diverse and complicated; nevertheless, benthic community composition, one failed sediment bioassay, and numerous PAH benchmark exceedances by sediment samples suggest that toxic conditions contribute to the Burnt Mill Creek benthic impairment. The specific pollutants responsible for this toxicity cannot be determined with certainty and may be variable. Leading candidates include PAHs, such as phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene and benzo(a)pyrene.

Unfortunately, DWQ does not have reference stream that might allow us to compare the effects of degraded habitat and toxicity on the benthic communities. **Nevertheless, given the evidence presented, DWQ believes that toxicity is a primary cause of the impaired benthic macroinvertebrate community**.

Organic/nutrient enrichment. DWQ considered organic enrichment as a cause of impairment because the initial benthic community surveys reported potential impacts from organic loading. The two relevant lines of evidence in this case are habitat surveys, benthic community data and water quality monitoring data.

Recent benthic community surveys included organic enrichment indicator species. Abundant macrophyte growth supports this assertion.

The nature of the organic enrichment seen in Burnt Mill Creek does not seem to extend to low dissolved oxygen (DO), as that parameter was never measured below 5.0 mg/L at any of the sites. This may not be the whole story, however, as DWQ did not take DO measurements at night, or during the early morning, when the diurnal cycle of photosynthesis would produce the lowest levels of DO. Also, it may be possible that low dissolved oxygen occurs in organic-rich, periphyton-covered sediment.

Another impact of high nutrients and subsequent algal growth is the advantage gained by aquatic insects that prefer organic particles or algae as their food sources. These organisms tend to be placed in the pollution tolerant class of insects.

Phosphorus levels were elevated, while nitrogen levels appeared to be below average for the region. However, in free-flowing streams, biological response to high nutrient loading is difficult to characterize, and depends on shading, stream velocity, fate of the nutrients, and other factors. The prevalence of macrophytes (aquatic plants) indicates that at least some of the nutrients are absorbed locally.

The strength of evidence regarding organic/nutrient enrichment points to this as a cumulative cause of impairment.

7.1.4 Conclusion

Multiple stressors impact aquatic organisms in Burnt Mill Creek. The watershed is highly developed, and characteristic of such urbanizing area, multiple stressors are evident. The leading stressors, in decreasing order of impact, are:

- Toxicity. Primary cause of impairment.
- Habitat degradation--sedimentation. Secondary or cumulative cause of impairment.
- Nutrient enrichment. Cumulative cause of impairment.
- Habitat degradation--lack of microhabitat. Cumulative cause of impairment.
- Scour due to hydromodification. Potential cause of impairment.

Other than toxicity and scour, the relative contribution of each of these stressors is difficult to differentiate based on this study.

7.2 Sources of Impairment

The primary pollutants deemed to cause the biological impairment in Burnt Mill Creek are toxicants, sediment and nutrients. DWQ provides a brief discussion below on potential sources of these pollutants.

Toxicants. Based on water column and sediment chemistry data, we know that the following potentially toxic pollutants occur at elevated levels: PAHs, dieldrin (an organochlorine pesticide), lead, aluminum, copper, and zinc. There may be other toxicants that have not been identified through this study. The observed toxicants are common to highly developed watersheds and may originate in residential, commercial and industrial areas, and vehicles. Contaminants are probably transported via a variety of pathways, including stormwater runoff, seepage from groundwater, periodic spills, unpermitted discharges to the storm sewer system and atmospheric deposition.

More specific information on potential sources of PAHs, copper, zinc and lead is provided below. Less specific source characterization is provided for pesticides.

Polycyclic Aromatic Hydrocarbons (PAHs). DWQ used a publication by Van Metre et al. (2000) as the primary source of information on PAHs. PAHs come from burning of fossil fuels, including petroleum, oil, coal and wood. Automobiles, heating and power plants, industrial processes, and refuse and open burning are considered to be the principal sources. The PAHs observed in Burnt Mill Creek are mainly the type that come from combustion; these include flouranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene. Nationally, over the past few decades there have been improvements in sediment quality caused by changes in power generation and home heating technology. These advances have been offset by increases in other stormwater PAH sources, primarily vehicle use. Specific automobile sources of PAHs are especially car emissions and crankcase oil, but also tire and roadway wear.

Two observations from the monitoring data are worth noting. First, PAHs are not high everywhere. The sample sites at Independence Drive and the drainage ditch below Metts Avenue had significantly lower PAH levels than other sites. This supports the notion that background atmospheric deposition of PAHs is not the primary issue; there must be a local source or sources (probably vehicle emissions or crankcase oil) that cause Bunt Mill Creek sediment to contain PAHs. Also, lower PAHs at Independence Drive suggest that either PAH source areas in the upper realm of the watershed are negligible (unlikely given high traffic volumes on some of the roads in that area) or that Ann McCrary Pond removes PAHs. This should be confirmed by re-sampling the Independence Drive site. Finally, higher PAHs in the sediment at Metts Avenue and Princess Place Drive indicate that the larger sources are in these catchments.

About 80 percent of the semi-volatile organic compounds (SVOCs) in runoff are attached to suspended solids (Lopes and Dionne, 1998). Thus, controlling sediment loading is likely to be a good strategy for reducing PAH and SVOC loading.

Copper. Copper originates from various urban sources. The primary source of copper in urban stormwater is deposition of abraded automobile brake linings (brake emissions) on roads (Davis et al., 2001; Malmqvist, 1983; Hewitt and Rashed, 1990). Davis et al. (2001) estimated that copper from brake wear composed at least 50% of copper in stormwater; this was from an analysis of a low density residential area that assumed residents account for all vehicle traffic, or where all travel outside the area is matched by non-resident travel inside. The Burnt Mill Creek watershed is entirely within downtown Wilmington, and several major roads, all of which have high traffic volumes, dissect the watershed. Secondary sources include building siding (possibly from wood preservative) and roofs (especially commercial buildings), and wet and dry atmospheric deposition (Davis et al., 2001).

Copper exceeded several threshold benchmarks in a Princess Place sediment sample, while the Metts Avenue sample had much lower copper amounts. At these levels it may not be a problem for the benthic community.

Also, given what we know about the sources of copper, it is likely that no one area is the origin of copper; major copper sources are likely to be found at crowded road intersections.

Zinc. According to Davis et al. (2001), the primary nonpoint sources of zinc are building siding (58%, particularly brick, then concrete and painted wood), and tire wear (25%).

Zinc levels in Burnt Mill Creek sediment are somewhat high at Princess Place. This may have as much to do with the organic content of the sediment as proximity to zinc sources, since it appears that there is more organic material in Princess Place sediment than other locations (note: DWQ does not have the capability to measure sediment organic content). If true, this would also increase the likelihood of having higher toxicant levels, somewhat irrespective of sources in the vicinity.

Lead. According to Davis et al. (2001), the primary sources of lead in urban stormwater are dry deposition (42%), wet deposition (33%), building siding (12%, brick and painted wood are highest, by far), and then lesser amounts from tire wear, brake wear and roofs (total from all three is 13%).

High lead levels exist only at the Princess Place site. Thus, the source(s) of lead may be somewhere below Metts Avenue. This is surprising as the sources listed above suggest that lead primarily comes from the atmosphere. Perhaps there are buildings in the lower catchments that have high levels of lead in their siding. Higher sediment organic content at Princess Place Drive (see copper sources, above) may be another explanation.

Organochlorine pesticides. Pesticides were found at problematic levels in the stream sediment at Princess Place Drive and in the ditch below Metts Avenue. The latter is situated among commercial, and medium to high-density residential areas; the former has similar land use nearby. The source of the pesticides is likely to be homeowners in these neighborhoods from some time ago, as organochlorines have largely been phased out of use. It is possible that the identified pesticides were used to kill termites or garden variety insects. Regardless, it seems that the pesticides entered the stream some time ago and will require time to decay.

Sediment. Much of the sediment accumulating in the channels of Burnt Mill Creek and its tributaries appears to originate within the stream channels. This is likely a response to hydromodification of the watershed. There is no doubt, however, that other sources of sediment exist outside of the drainage network.

EPA defines hydromodification as the alteration of the hydrologic characteristics of surface waters resulting in degradation of resource conditions (USEPA, 1977). While channelization has impacted some reaches in the study area, the type of hydromodification of primary importance is the alteration of watershed hydrology by greater impervious area and the installation of a storm drainage system. These changes greatly increase the frequency and duration of peak flows, which causes greater in-stream erosion and habitat degradation. Essentially, this seems to have moved sediment from the stream banks, and to a lesser extent bottom, to accumulations of fine sediment in the stream pools.

Other watershed sediment sources include runoff from roadways, parking lots, construction sites and a myriad of spots without vegetative cover. The typically sandy soils in the watershed are easily eroded.

Nutrient enrichment. Sources of nutrients and BOD are ubiquitous in a developed watershed such as Burnt Mill Creek. They include atmospheric deposition, and subsequent wash-off from impervious surface through the storm drainage system, or delivery to the stream via groundwater or interflow; leaking sewer lines; illegal connections to the storm sewer system; fertilizer inputs from managed turf areas; animal waste (domestic and wildlife, runoff and direct deposit in stream); and, soils that have naturally high phosphorus content.

As discussed in Section 5.3.3, Mineral Springs Branch subwatershed appears to have relatively high phosphorus levels and management efforts should focus here, at least initially. Also, Ann McCrary Pond appears to reduce nutrient levels to acceptable levels, so BMP installation would be better focused downstream of the pond.

7.3 Other Issues of Note

Perhaps one of the most inhibiting factors to Burnt Mill Creek's recovery is the lack of a good recolonization source. In other words, there is no relatively unimpacted reach that could serve as a source of pollution intolerant macroinvertebrates for the rest of the watershed via downstream drift. See Background Note: The Stress-Recovery Cycle, below.

Background Note: The Stress-Recovery Cycle
Taken from DWQ's WARP Project: Biological Impairment of Upper Swift Creek (NCDWQ, 2003).

Even in relatively pristine streams, aquatic organisms are exposed to periods of stress. Natural stresses due to high flows during storms, low flows during hot dry summer periods or episodic large sediment inputs (e.g., from slope failures in mountain areas or breaching of beaver dams) can have significant impacts on stream communities. Although aquatic communities in high quality streams may be impacted by such disturbances, and some species may be temporarily lost from particular sites, populations are able to reestablish themselves—often very quickly—by recolonization from less impacted areas or refugia (see Yount and Niemi, 1990; Niemi et al., 1990). This process can involve recolonization from backwater areas, interstitial zones (spaces between cobble and gravel substrate), the hyporheic zone (underground habitats just below the stream bed surface layer) or other available microhabitats. Repopulation from headwaters or tributary streams not impacted by the disturbance can also occur. For insects aerial recolonization is important as well.

Without robust mechanisms of recovery, even streams subjected to relatively modest levels of disturbance would be unable to support the diversity of aquatic organisms that they often do (Sedell et al., 1990; Frissell, 1997). This balance between local elimination followed by repopulation is critical to the persistence of fish, macroinvertebrates and other organisms in aquatic ecosystems, and is part of what we mean when we say that these creatures are "adapted" to their environment.

It is now commonly recognized that as watershed experience increased human activity, stream biota are subjected to higher levels of stress. This can include both an increased frequency, duration or intensity of 'natural' types of disturbance, such as high flows, as well as completely new stresses, such as exposure to chlorinated organic chemicals. We less often realize, however, that many of these same activities often serve to inhibit those mechanisms that allow streams to recover from disturbances—in particular movement and recolonization (Frissell, 1997). For example, as watersheds develop:

- channel margin and backwater refugia may be eliminated as bank erosion or direct channel modification (channelization) make channel conditions more uniform and less diverse;
- edge habitat, such as root mats, may be unavailable to biota due to lowered baseflows;
- access to interstitial and hyporheic areas may be limited by sediment deposition;
- impoundments may limit or eliminate drift of organisms from upstream;
- small headwater and tributary streams may be eliminated (culverted or replaced with storm drain systems);
- remaining headwater and tributary streams may be highly degraded (e.g. via channelization, removal of riparian vegetation, incision and widening due to increased stormflows, or decreased baseflows);

- aerial recolonization or macroinvertebrates may be diminished by the concomitant or subsequent degradation of streams in adjacent watersheds; and
- culverts or other barriers often limit fish migration.

As human activity intensifies, aquatic organisms are thus subjected to more frequent and more intense periods of stress, while their ability to recover from these stresses is severely compromised. It is the interaction between these two processes that results in the failure of many streams to support an acceptable population of fish or macroinvertebrates.

Efforts to restore better functioning aquatic communities in degraded streams must consider strategies to both reduce the stresses affecting stream biota and to protect and restore potential refugia and other sources of recolonizing organisms. Under some conditions, the lack of adequate recolonization sources may delay or impede recovery. Protecting existing refugia and those relatively healthy areas that remain in impacted watersheds should be an important component of watershed restoration efforts (McGurrin and Forsgren, 1997; Frissell, 1997).

SECTION 8
Improving Stream Integrity in Burnt Mill Creek: Recommended Strategies

As discussed in the previous section, Burnt Creek is impaired primarily by toxicity, and also by the cumulative impacts of habitat degradation (sedimentation and lack of microhabitat) and nutrient enrichment. This section considers how these problems can be addressed. A summary of recommendations is included at the end of the section.

Once again it is worth noting that, in this project, DWQ closely followed the template created by the Watershed Assessment and Restoration Program (NCDWQ, 2003). The management strategies that program devised for its watersheds were general enough, and the problems were similar enough, that DWQ altered them slightly to address the problems in the Burnt Mill Creek watershed.

8.1 Addressing Current Causes of Impairment

The objective of restoration efforts is to improve water quality and habitat to the level that they support a more diverse and functional biological community in Burnt Mill Creek. To be sure, this will be difficult as the level of development and in-stream impacts are widespread. A return to unimpacted levels, which existed before any development, is probably not possible without a tremendous investment of resources and change in land use regulations. Restoration to unimpaired levels should be doable, however, if sufficient resources are obtained to install retrofit best management practices (BMPs) and stream channel restoration, and curb pollutant sources (NCDWQ, 2003).

As discussed in Section 7, while the key causes of impairment in Burnt Mill Creek have been identified, how the causes interact remains unclear. Additionally, there are inherent uncertainties regarding how individual BMPs interact to affect receiving water chemistry, geomorphology and habitat (Shields et al., 1999; Urbonas, 2002), and in how aquatic organisms will respond to better conditions. Consequently, the level of management action needed to produce an unimpaired level of biological integrity cannot be determined in advance. This section describes the types of actions needed to improve biological conditions in Burnt Mill Creek, but the combination of activities that will be necessary, and the extent of improvement that will be attainable, will only become apparent over time as adaptive management is implemented. Management actions are suggested below to address individual problems, but many of these actions are interrelated (e.g. particular BMPs or systems of BMPs can de designed to serve multiple functions).

8.1.1 Hydrologic Restoration

Though toxic impacts may be the harmful to the aquatic communities in Burnt Mill Creek, DWQ will first address hydromodification, as watershed hydrology is the driver of pollutant transport.

Frequent periods of high-velocity storm flow dislodge benthic organisms and contribute to habitat degradation by removing organic microhabitat and causing bank instability. This will continue unless some of the hydrologic impacts of existing development can be abated. The vast majority of development occurred prior to any BMP requirements. Stormwater controls are necessary to partially restore watershed hydrology by reducing runoff volume and reducing the frequency and duration of erosive flows.

Stormwater retrofits are structural stormwater measures (BMPs) for urban watersheds intended to lessen accelerated channel erosion, promote conditions for improved aquatic habitat and reduce pollutant loads (Claytor, 1999). A range of practices, including a variety of ponds and infiltration approaches, may be appropriate depending on specific local needs and conditions. Practices installed to reduce hydrologic impacts will also provide varying degrees of pollutant removal.

<u>Stormwater retrofit options</u>. Available structural and nonstructural retrofit practices to reduce hydrologic impacts and remove pollutants have been discussed widely in the literature (e.g. ASCE, 2001; Horner et al., 1994) and detailed BMP manuals (e.g. NCDWQ, 1999c; Maryland Department of the Environment, 2000). Some of these include:

- detention ponds;
- retention ponds;
- stormwater wetlands;
- bioretention;
- infiltration structures (porous pavement, infiltration trenches and basins);
- vegetative practices to promote infiltration (swales, filter strips);
- 'run on' approaches (regrading) to promote infiltration;
- reducing hydrologic connectivity (e.g. redirecting of downspouts);
- education to promote hydrologic awareness; and
- changes in design/construction standards.

Determining which BMPs (or which combination of practices) will be most feasible and effective for a particular catchment depends on numerous site specific and jurisdictional specific issues, including: drainage patterns; size of potential BMP locations; treatment volume needed considering catchment size and imperviousness; soils; location of existing infrastructure; and other goals (e.g. flood control, water quality). Considerations in the identification of retrofit sites are discussed by Schueler et al. (1991) and Claytor (1999). A key design challenge is to maximize hydrologic mitigation and/or pollution removal potential while limiting impacts to infrastructure and existing structures.

DWQ encourages the consideration of a wide variety of practices and approaches. Ponds of various types are probably the practice most familiar to engineers and can indeed be versatile and cost effective. Detention alone, however, does not reduce stormwater volume, though the rate and timing of discharge can be controlled. It is important to carefully examine infiltration practices, including both structures and 'behavioral' changes such as redirecting downspouts to pervious areas. While there are clearly limits to the usefulness of infiltration, based on soils, water table levels and other factors (Livingston, 2000), these practices are often underused. Design approaches to minimize runoff volume are also important tools (Caraco et al., 1998; Prince George County DEP, 2000). Some retrofit methods may have negative side effects that must be carefully considered. For example, regional wet detention facilities, though they may remain a viable alternative in some situations, can disrupt recolonization (limit downstream drift of aquatic macroinvertebrates), alter the food/energy source available to downstream biota, and depending on design and operation, reduce or eliminate downstream baseflows (Maxted and Shaver, 1999; Schueler, 2000a).

<u>Recommendation</u>. What is feasible or cost effective in the way of retrofitting a developed watershed like Burnt Mill Creek is constrained by existing conditions. Conditions change, however, and a long term commitment to partially restoring watershed hydrology will be necessary to create opportunities and take advantage of available options. In order to have a biologically meaningful impact on watershed hydrology, cost effective projects will likely have to be sought out and implemented over an extended time frame.

1. Short-term. Over the next decade, the City of Wilmington can investigate retrofit possibilities and implement those that are feasible given current infrastructure constraints.

2. Mid-term. Road realignment, sewer line repair, bridge replacement and other infrastructure projects will likely make feasible other retrofit opportunities over the next 10-20 years. Such projects can be pursued and the search for retrofit opportunities can be integrated into the capital improvement planning process.

   Stormwater retrofit projects are certainly expensive undertakings if completed as stand-alone projects. They may be done at a fraction of the cost, however, if they can be developed in conjunction with other infrastructure projects, such as those mentioned above.

3. Long-term. Over a more extended period, cost effective restoration opportunities are likely as portions of the watershed are redeveloped incrementally (Ferguson et al., 1999). An ongoing awareness of retrofit needs and changes in development regulations may be necessary to help create and take advantage of these opportunities.

Recently, Wilmington and EEP have completed, or is in the process of completing, stormwater retrofit projects (NCEEP, 2003). The Kerr Avenue and Wallace Park stormwater wetlands are good examples. These are the types of projects that will be needed to restore the hydrology of Burnt Mill Creek and address the biological impairment.

Areas draining directly to the Burnt Mill Creek mainstem or unimpounded tributaries (nearly all of them) should be priority areas for retrofit consideration. There doesn't appear to be one subwatershed that has less urbanization than other subwatersheds. One tributary may be selected, however, as the subwatershed to receive a large share of the retrofit projects. This subwatershed may become the base for biological improvement efforts by becoming a source of pollution intolerant benthic species. These species may be further disseminated through the watershed by downstream drift, and subsequent upstream migration (see Section 7.3 and Background Note-The Stress-Recovery Cycle).

Costs. Stormwater retrofit costs are difficult to estimate until specific practices and locations have been selected. Unit costs vary greatly with the size of the area treated. Using data from the mid 1990s, Schueler (2000b) reported that typical costs for stormwater ponds were about $5,000 per impervious acre treated for projects covering 100 impervious acres, but $10,000 per impervious acre treated for project treating 10 impervious acres. Treating a single acre costs an average of $25,000 or more.

Only gross estimates of total cost are possible. Claytor (1999) suggests that a minimum of 50% of the impervious portion of a watershed be retrofitted. Thus, for example, a two square mile watershed that is 25% impervious has approximately 320 impervious acres (2 square miles, or 1280 acres, times an imperviousness of 25%). Assuming a total cost of $10,000 per impervious acre, it would take approximately $1.6 million to retrofit 160 impervious acres. This approaches $1 million per square mile of total watershed area. This estimate should be used only as a general indication of the likely scale of effort that may be necessary, assuming a sufficient number of viable retrofit projects can be identified. Actual total costs may be higher or lower depending on many factors, including the types of BMPs used and the scale of each project. Some cost reduction may be possible if retrofits are planned and implemented in conjunction with anticipated capital improvements and infrastructure enhancements. The potential connection between watershed restoration and infrastructure issues has been increasingly recognized by local governments (e.g. City of Austin, 2001; Montgomery County DEP, 2001).

8.1.2 Toxic Impacts

High levels of PAHs, organochlorine pesticides, lead and other metals have been observed in Burnt Mill Creek sediment, and aluminum has exceeded NAWQC levels in the water column. Still, the particular mix of pollutants of primary concern is less than certain. Long term impacts of repeated exposures may be important, and the most critical toxicants may vary with time, associated with specific events. Source areas likely lie throughout the watershed.

Two broad approaches can be used to address toxic impacts: structural BMPs to remove pollutants from stormwater, and primarily nonstructural source reduction methods to prevent pollution inputs (NVPDC, 1996; Heaney et al., 1999). These approaches are not mutually exclusive, and a multifaceted strategy, drawing on both approaches, will be more effective than a more narrowly focused effort. A general conceptual strategy to address toxicity in Burnt Mill Creek is outlined below. This should be viewed only as an initial framework for planning and implementing toxicity reduction efforts. Ongoing planning and strategy reassessment will be necessary to refine the scope and nature of management efforts.

1. Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended earlier in order to reduce scour impacts and improve aquatic habitat potential, these BMPs will also remove toxicants from the stormwater system (the extent of removal will vary depending on the specific structures and pollutants involved.).
2. Development of a stormwater and dry weather sampling strategy for the watershed. Selection of particular BMPs can be more efficient and they can be more effective if information on specific target pollutants and source areas is available. Such information would also aid in the targeting of source reduction efforts (discussed below). To address these needs, a monitoring strategy should be developed based on further watershed reconnaissance.
3. Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations. Results of additional monitoring will be important in targeting these BMPs, although some likely "hot spots" (areas of intense activity or high risk) could be identified without further water quality monitoring. Proprietary treatment systems can be considered where adequate space is not available for conventional stormwater BMPs.
4. Development and implementation of a broad set of source reduction activities. Since removing pollutants from stormwater can be difficult and expensive, pollution prevention activities are crucial. Among activities that should be considered for pollution prevention efforts are the following:

    - Reducing nonstorm inputs of toxicity by:
        - a) identification and elimination of illicit connections (actions required under pending phase II stormwater permits);
        - b) review of existing information on groundwater contamination and implementation of appropriate measures if warranted;
        - c) verification that industrial and commercial floor drains empty to the sanitary sewer system or appropriate treatment facilities; and
        - d) education of industrial and commercial operation and maintenance staff regarding proper use of storm drains and the implications of dumping.

    - Reducing pollutants available for washoff during storms by:
        - a) outreach and technical assistance to industrial and commercial facilities regarding materials storage practices, spill prevention procedures, and spill control and cleanup procedures;

b) encourage use of best available technology for scrubbing of automobile exhaust and industrial smokestacks;
c) prohibit open burning of refuse or other waste in county (PAHs);
d) provide collection facilities for proper disposal of used tires, crankcase oil and other automobile parts;
e) encourage use of ceramic brake pads instead of traditional ones that can be primary sources of metals such as copper and zinc;
f) encourage use of biodiesel in place on conventional diesel fuel.

Addressing vehicle related pollution will be a particular challenge. However, this will be crucial as PAHs, likely the key problem parameter, originate in vehicles and likely travel via stormwater runoff from roadways to the channel network. BMPs to treat parking lot runoff may often be feasible, but addressing roadway runoff will be more difficult. Sand filter systems, which are expensive and require significant maintenance but little space, are recommended and may be required at the busiest traffic intersections. Source control may have to wait for changes in vehicle or component design (e.g., scrubbing technologies for internal combustion engines).

Development of a specific pollution prevention strategy is beyond the scope of this study. Some elements of a strategy could probably be implemented by enhancing or redirecting existing program activities. In other cases new initiatives may be necessary. While state agencies such as DWQ and the Division of Pollution Prevention and Environmental Assistance (DPPEA) can play a role, planning and implementation of a strategy is likely to be more effective if carried out by local government, agencies and stakeholders.

8.1.3 Habitat Degradation

Habitat in the study area is limited by scouring stormflows due to the hydrologic impact of historic, recent and ongoing development, and by sedimentation. These factors can be addressed by a combination of stormwater quantity retrofits and stream channel restoration.

Stormwater quantity retrofits, discussed earlier, can partially mitigate existing hydrologic impacts. This will reduce sediment inputs, allow for more rapid healing of unstable areas, and facilitate the development of better in-stream habitat. Such healing is likely to take many years, since the stream is still in the process of adjusting to recent hydrologic alteration of the watershed.

Channel restoration techniques could be used to speed the recovery process. Along some stream channel in the watershed, however, much of the riparian zone consists of areas of healthy forested vegetation, some of which lie in protected natural areas. The process of channel reconstruction could have negative impacts in these areas and from a long term perspective it is probably more prudent to confine channel restoration activities to areas where problems are particularly severe.

Specific recommendations are as follows:

1. A geomorphic survey of the stream channel network should be conducted to determine the areas that are suited to reconstruction. This has been completed to some degree through the EEP project (NCEEP, 2003).
2. Stream channel restoration should probably be postponed until progress has been made on stormwater retrofits/hydromodification. If not, gains in channel structure and habitat potential may be quickly eliminated by damaging stormflow.
3. Reestablish woody riparian vegetation in areas where this is absent.

Stream channel restoration involves re-establishing a stable channel dimension (cross-section), pattern (sinuousity and planform) and longitudinal profile. While other options exist (see NCSU, 2001 and 2002), the most feasible approach to the restoration of most channels in this watershed is probably to construct appropriate floodplain area and channel form within the existing channel (Rosgen priority 2 or priority 3 approach). The specific restoration strategy selected will depend on the stream corridor width available (belt width), among other factors (NSCU, 2001 and 2002; Rosgen, 1997). Based on the recent experience of the North Carolina Wetlands Restoration Program (Haupt et al., 2002) and a number of Maryland counties that have active restoration programs (Weinkam et al., 2001), cost of at least $200 per linear foot (about $1 million per mile) should be expected for the restoration of urban stream channels.

Riparian areas are poorly vegetated along much of Burnt Mill Creek and its tributaries. Reestablishment of woody riparian vegetation is probably necessary to ensure an adequate supply of woody material to the stream channels. In addition, properly functioning riparian areas can also serve to reduce inputs of nutrients and other pollutants.

8.1.4 Nutrient Enrichment

Nutrient loading can be addressed in a variety of ways, including stormwater treatment. Additional BMPs constructed to address other problems (see above) are likely to reduce BOD loading. BMPs targeted at BOD and nutrient removal may be warranted at high loading areas. EEP’s Local Plan included nutrient modeling that may help to identify such areas (NCEEP, 2002).

Organic and nutrient loading can also be reduced via established practices such as: identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilization use; street sweeping; and catch basin clean-out practices. The identification and elimination of illicit connections to the storm system are required as part of the NPDES Phase II stormwater program. Wilmington, through their NPDES stormwater permit, is part of this program.

8.1.5 Other Concerns

Many water quality impacts can result from the incremental and cumulative impacts of land management decisions made by individual residents and property owners throughout the watershed. Educational efforts directed at homeowners and managers of commercial and industrial areas in the watershed would be useful to promote improved riparian zone management (e.g. leave woody vegetation) and the appropriate use of pesticides and fertilizers.

8.2 Addressing Future Threats

Since the study area is largely developed, potential threats from construction related sediment inputs and hydromodification from post-construction stormwater are likely to be less substantial than in less built-out watersheds. It is nonetheless important that effective enforcement of existing sediment and erosion control regulations occur on the part of Wilmington and New Hanover County.

To avoid significant channel erosion, it is critical that effective stormwater management occur throughout Burnt Mill Creek watershed. This probably means going beyond controlling the first one-inch of runoff from high density areas, as this is not likely to provide adequate channel protection.

8.3 A Framework for Improving and Protecting Stream Integrity

Watershed restoration of the type necessary to significantly improve Burnt Mill Creek is clearly ambitious, but has become more common over the past decade. Local governments and watershed-based organizations have increasingly sought to plan and implement long-term restoration and management strategies that integrate channel, riparian and watershed measures to address stream issues in an integrated manner. The most long-standing example is probably the restoration of the Anacostia River in the Washington, D.C. area, for which planning was initiated in the 1980s (Anacostia Restoration Team, 1991; Metropolitan Washington COG, 1998; Galli, 1999; Schueler and Holland, 2000). Among the other local areas that have begun to address these issues are Austin, Texas (City of Austin, 2001); Atlanta, Georgia (CH2M-Hill, 1998); and Montgomery County, Maryland (Montgomery County DEP, 2001).

Restoration projects of this scale require an iterative process of ‘adaptive management’ (Reckhow, 1997; USEPA, 2001). Considering the scope of activities, logistical complexities and scientific uncertainties, it is not possible to anticipate all necessary actions in advance. An initial round of management actions must be planned and implemented, the results of those activities monitored over time, and the resulting information used as the basis for planning subsequent efforts. Additional measures should be implemented as appropriate. Improvement in stream condition is likely to be incremental.

An organizational framework for ongoing watershed management is essential in order to provide oversight of project implementation, to evaluate how current restoration and protection strategies are working, and to plan for the future. While state agencies can play an important role in this undertaking, planning is often more effectively initiated and managed at the local level. A coordinated planning effort involving local governments in the watershed (Wilmington, New Hanover County), as well as a broad range of other stakeholders, will be critical if conditions in Burnt Mill Creek are to be improved. This effort must include the development of a long term vision for protecting and restoring the watershed, as well as the specific work that will be necessary to support a patient approach to planning and implementing projects to move toward that vision.

8.4 Summary of Watershed Strategies for Burnt Mill Creek

The following actions are necessary to address current sources of impairment in Burnt Mill Creek, and to prevent further degradation. Actions one through five are important to restoring and sustaining aquatic communities in the watershed, with the first three recommendations being the most important.

1. **Feasible and cost-effective stormwater retrofit projects should be implemented throughout the watershed to mitigate the hydrologic effects of development** (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). This should be viewed as a long-term process. Although there are many uncertainties, costs in the range of $1 million per square mile can probably be anticipated.

    a) Over the short term, currently feasible retrofit projects should be identified and implemented.
    b) In the longer term, additional retrofit opportunities should be sought out in conjunction with infrastructure improvements and redevelopment of existing developed areas.
    c) Priorities should include evaluating the retrofit potential of areas draining directly to Burnt Mill Creek.
    d) Grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund and the Ecosystem Enhancement Program.

2. **A strategy to address toxic inputs should be developed and implemented, including a variety of source reduction and stormwater treatment methods.** As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:
    a) Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended above to improve aquatic habitat potential, these BMPs will also remove toxicants from the stormwater system.
    b) Development of a stormwater and dry weather sampling strategy in order to facilitate the targeting of pollutant removal and source reduction practices.

c) Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations.
d) Development and implementation of a broad set of source reduction activities focused on: reducing nonstorm inputs of toxicants; reducing pollutants available for washoff during storms; and managing water to reduce storm runoff. Suggestions for potential source reduction practices are provided.

3. **Stream channel restoration activities should be implemented in target areas, in conjunction with stormwater retrofit BMPs, in order to improve aquatic habitat.** EEP has initiated this process, as detailed in the Local Watershed Plan (NCEEP, 2003). Before beginning stream channel restoration, a geomorphologic survey should be conducted to determine the best areas for stream channel restoration. Additionally, it would probably be advantageous to implement retrofit BMPs before embarking on stream channel restoration, as restoration is probably best designed for flows exemplifying reduced stormwater runoff. Costs of approximately $1 million per mile of channel should be anticipated. Again, grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund and the Ecosystem Enhancement Program.

4. Actions recommended above (e.g. stormwater quantity and quality retrofit BMPs) are likely to reduce nutrient/organic loading and its impacts to some extent**.** Activities recommended to address this loading include the identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilizer use; <u>street sweeping</u>; catch basin clean-out practices; and the installation of additional BMPs targeting BOD and nutrient removal at appropriate sites.

5. Prevention of further channel erosion and habitat degradation will require effective post construction stormwater management for all new development in the study area. Also, reestablishment of woody riparian vegetation in areas where it is absent would improve habitat and runoff filtering.

6. Effective enforcement of sediment and erosion control regulations on the part of Wilmington and New Hanover County will be essential to the prevention of additional sediment inputs from construction activities. Development of improved erosion and sediment control practices may be beneficial.

7. Watershed education programs should be continued by local governments with the goal of reducing current stream damage and prevent future degradation. At a minimum, the program should include elements to address the following issues:
a) redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters;
b) protecting existing woody riparian areas on ephemeral streams;
c) replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent; and

d) reducing and properly managing pesticide and fertilizer use.

Section 9
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APPENDIX A

Benthic Macroinvertebrate Sampling

Division of Water Quality
Biological Assessment Unit
18 May, 2001

MEMORANDUM

To:	Jimmie Overton
Through:	Trish Finn MacPherson
From:	Kathy Herring
Subject:	Results of Macroinvertebrate Collections from Burnt Mill Creek (New Hanover County)

BACKGROUND

Chris Roessler of the Modelling/TMDL Unit of the Division of Water Quality (DWQ) requested that the Biological Assessment Unit (BAU) of DWQ conduct benthic sampling in selected watersheds as part of the CAWS project (Collaborative Assessment of Watersheds and Streams). This project is funded by a 104(b)(3) grant and will emulate the WARP project (Watershed Assessment and Restoration). The CAWS project is aimed at determining the causes and sources of benthic impairments to streams. The sites surveyed are all on the impaired streams list, and were selected in a meeting between members of the BAU, Intensive Survey Unit (ISU) and CAWS on February 19, 2001. The request followed a recommendation from the ISU, based on watershed surveys in October, 2000, and from the WARP project outline, to evaluate the spatial extent of the benthic impairments. The purpose of further benthic sampling in these streams was to guide the search for sources of impairment and to determine if the impairment is limited to the previous site sampled, or indicative of a widespread problem. The question is whether the historical data that placed the site on the 303(d) impaired streams list adequately characterized conditions in the watershed.

HISTORICAL DATA

Burnt Mill Creek, New Hanover County – Benthos collected from this stream at Metts Avenue in Wilmington in 1998 indicated Poor water quality.

METHODS

Habitat assessments were performed at each sampling location using DWQ's Coastal Plain Evaluation Form. This evaluation is based on best professional judgment of 8 habitat metrics including analysis of channel modification, four instream habitat measurements, one streambank measurement, and two riparian zone measurements. Scores are given for each of the eight metrics (seven for coastal streams) and are then totaled (100 points possible). Streams, or monitoring stations, within major ecoregion types and size categories can be compared to one another and to reference locations. Documentation of habitat characteristics at a sampling site can identify limiting factors that can affect biological communities. Habitat assessment provides baseline information on stream conditions so that changes resulting from natural or human causes can be identified or predicted. Habitat assessments can also determine the consequences on the biota of alteration of stream conditions, such as land use changes and channelization.

Burnt Mill Creek

Benthic macroinvertebrates were collected here using the Division of Water Quality's EPT sampling procedure. This type of collection is intended to quickly assess between-station differences in water quality. Four composite samples were taken at each site: 1 kick, 1 sweep, 1 leafpack and visual collections. Only intolerant "EPT" groups (Ephemeroptera, Plecoptera, Trichoptera) were collected and identified. The primary output was a taxa list, with some indication of relative abundance for each taxon. Organisms were classified as Rare (1-2 specimens), Common (3-9 specimens), or Abundant ($\geq$10 specimens).

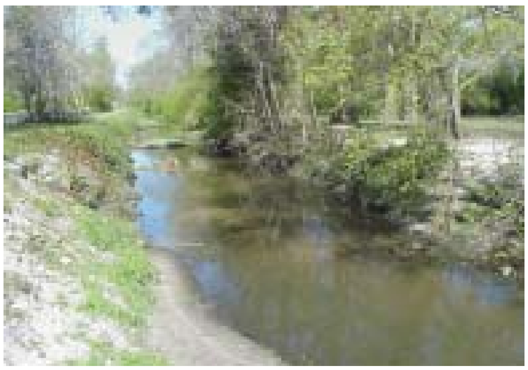
Several data-analysis summaries (metrics) can be produced from EPT samples to detect water quality problems. These metrics are based on the idea that unstressed streams and rivers have many invertebrate taxa and are dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index.

EPT taxa richness (EPT S) was used to assign water quality ratings using DWQ criteria for Coastal Plain streams. Higher EPT taxa richness values usually indicate better water quality. EPT abundance and EPT biotic index values were used to compare sites, but cannot be used with these limited collections to assign site ratings. In general, higher EPT abundance values and lower EPT biotic index values suggest better water quality.

One rock/log wash also was collected from Burnt Mill Creek in order to collect midge species to look for possible deformities. This sample was kept separate from the other collection methods so that the site could be assigned a rating based on EPT criteria, as it had in the past. This Qual 5 method, as its name implies, is an abbreviation of the standard qualitative method, where all organisms are picked. In this method, 5 samples are collected: 1 Kick, 1 Sweep, 1 Leaf-pack, 1 rock/log wash, and "visuals". All organisms are picked. Qual 5 samples are not presently assigned a bioclassification, but differences in benthic communities are compared to assess impacts. The Watershed and Assessment Restoration Program (WARP) began collecting many samples from small streams in impaired watersheds in 2000. This program began using what was called a Qual 4 method (same samples as an EPT, but all organisms were picked). After collecting this data from small streams, especially in impaired watersheds, it was decided that an abbreviated method was needed that also collected a representative sample of the chironomid population, and a rock/log wash was added. The Qual 5 method is being tested as a possible efficient way to provide enough data from small streams to eventually lead to a way to determine water quality impairments or assign bioclassifications.

SURVEY SITE DESCRIPTIONS
The following sites were sampled for benthic macroinvertebrates in March 2001:

<u>Burnt Mill Creek, Forest Hills Dr., Wilmington, New Hanover County, Cape Fear subbasin 23, 3/28/01</u>. This site was located one bridge crossing upstream of the previously sampled location at Metts Avenue in Wilmington. Farther upstream was too small to sample, and further downstream of Metts Avenue, there was no visible current, possibly due to tidal influence.


Burnt Mill Creek Forest Hills Drive

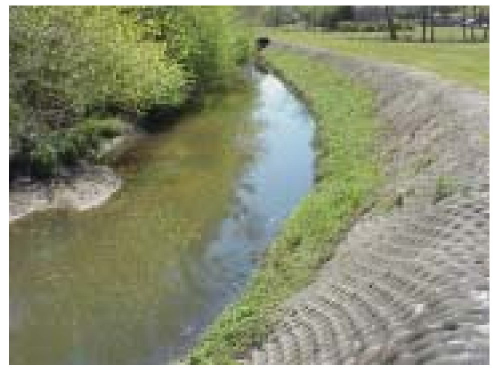

Burnt Mill Creek Metts Avenue

Table 1. Site Locations and Descriptions for Burnt Mill Creek, New Hanover County.

Stream	**Burnt Mill Cr**	**Burnt Mill Cr**	**Burnt Mill Creek**
Collection Date	02/19/98	07/21/98	3/28/01
Location	Metts Ave	Metts Ave	Forrest Hills Dr.
Width (m)	6	5	5
Average Depth (m)	0.8	0.1	0.1
Canopy	0	0	10
Aufwuchs	Abundant	Abundant	Abundant
Bank Erosion	Gabioned	Gabioned	Severe
Substrate (%)			
Boulder	0	0	0
Rubble	0	0	0
Gravel	5	5	0
Sand	75	70	90
Silt	25	25	10
Habitat Score (0-100)	35	48	36
Conductivity (µmhos/cm)*	205	285	270
Temperature (^{o}C)	16	32	13
Do (mg/l)	8.7	8.0	8.3

*corrected to 25^{0}C

Burnt Mill Creek in downtown Wilmington is a completely channelized system that has been altered to function as urban drainage and flood control. The lower half of Burnt Mill Creek receives drainage from the older residential areas of Wilmington, while the upper half receives drainage from the newer commercial and residential areas near NC 132. During the initial survey in October, storm sewer pipes draining into the creek were observed throughout the system with grey colored water discharging at several sites in the Market Street and Metts Avenue area. The conductivity measured at the time of this survey was very high (270µmhos/cm) indicating the presence of urban storm water drainage.

As in all channelized streams, habitat available for macroinvertebrate colonization was lacking. The habitat score here was 36. The banks were eroding and there was virtually no canopy or riparian zone. The previous samples were taken at the Metts Ave. location. Habitat conditions here were even worse; there were at least a few snags available for colonization at the Forest Hills site.

Table 2. Taxa Richness and Summary Values for Burnt Mill Creek.

Burnt Mill Creek			
Collection Date	2/19/98	7/21/98	3/28/01
Location	Metts Ave	Metts Ave	Forest Hills Dr
Ephemeroptera	2	1	1
Plecoptera	0	0	0
Trichoptera	3	3	1
Coleoptera	1	0	2
Odonata	6	1	4
Megaloptera	0	0	0
Diptera: Chironomidae	14	0	13
Misc. Diptera	3	0	1
Oligochaeta	5	0	4
Crustacea	2	1	2
Mollusca	1	3	4
Other	2	2	2
Total Taxa Richness	**40**	**11**	**34**
EPT Richness	**5**	**4**	**2**
EPT Abundance	**23**	**15**	**13**
Biotic Index	**7.99**	**7.36**	**7.84**
EPT Biotic Index	**6.69**	**5.00**	**6.49**
Bioclassification	**NR**	**Poor**	**Poor**

The benthic community was sampled from Burnt Mill Creek at Metts Avenue twice in 1998, once in the winter and again in the summer when it was evident that this system could not be considered a swamp system limited to winter flow. According to DWQ protocol swamp have constant flow only during winter and should only be sampled during this time. The summer 1998 collection resulted in a bioclassification of Poor. Only 4 EPT species were collected and the biotic index was high (7.36) indicating a very pollution-tolerant community. Very similar results were found when sampled at Forest Hills Drive, during this survey (Table 5), also resulting in a bioclassification of Poor using EPT criteria for coastal plain streams. Dominant intolerant taxa collected here included: *Cheumatopsyche*, *Caenis*, a low flow indicator, *Cricotopus bicinctus*, *Physella*, and leeches (*Erpobdella/Mooreobdella)*. This rating appears to be a valid rating for the entire stream.

SUMMARY

Based on the results of the latest sampling events (March 2001) the previous bioclassification assigned to the streams in this study are valid and applicable to the entire stream. The historical data that placed these sites on the 303(d) impaired streams list adequately characterized conditions in the watershed.

Burnt Mill Creek is a completely channelized drainage. It has been altered to function as urban flood control.

In order to grow crops and build homes and businesses in certain areas of the coastal plain it was necessary to drain land by ditching watersheds such as these. The structure and character of this stream has been forever altered. It is very doubtful that much expense and effort toward management or restoration, beyond what is already in place, will lead to any long-term improvements, or enough improvements, in the macroinvertebrate communities of these two systems to remove them from the 303(d) list.

References:

Lenat, D.R. 1993. Using mentum deformities of *Chironomus* larvae to evaluate the effects of toxicity and organic loading in streams. Journal of the North American Benthological Society 12(3):265-269.

CC:
Chris Roessler; TMDL/Modelling group Archdale Building
Michelle Woolfolk; TMDL/Modelling group Archdale Building
Jay Sauber
Harold Quidley

Note: This study disagrees with the last statement made in this report. After further investigation, it appears that with concerted stormwater management and stream restoration in the subwatersheds between Ann McCrary Pond and Metts Avenue, the benthic community should improve and perhaps attain a 'Good-Fair' rating, which would remove the stream from the 303(d) list of impaired streams.

APPENDIX B

Water Quality Conditions

A wide range of chemical, physical and toxicological analyses were conducted in the Burnt Mill Creek watershed over the course of this study. This appendix describes the general approach and methods used, and summarized monitoring results.

Appendix B is largely taken from DWQ's Watershed Assessment and Restoration Project, which had identical goals to this project (NCDWQ, 2003).

Section 1
Approach and Methodology

Chemical-physical and toxicity monitoring conducted during this study had two broad goals:

1. General water quality characterization. This goal involved developing a synoptic picture of the chemical and physical water quality characteristics of the study area, using a standard set of parameters.
2. Stressor-source area identification. Identifying the causes of biological impairment and the sources of these causal factors were primary goals of the project. Related to chemical-physical and toxicity monitoring, this goal included:
   - identifying the major chemical-physical stressors to which benthic macro-invertebrates in the stream are exposed;
   - providing information on the nature of exposure to these stressors (e.g. concentration, timing);
   - evaluating the toxicity of waters of concern and determining the pollutants causing any toxicity identified; and
   - determining major sources or source areas.

The nature of stressor-source identification demands a monitoring approach that is dynamic and flexible, changing over time as new information regarding biological condition, stream chemistry and watershed activities becomes available.

1.1 General Water Quality Characterization

Routine sampling was conducted at two integrator stations located on the mainstem of Burnt Mill Creek, in the middle of the study area. The integrator stations were located at Forest Hills Drive and Metts Avenue, downstream from the bridges. DWQ collected surface grab samples (depth of 0.1 meter, or 3 inches) during both baseflow and storm conditions. We defined baseflow periods as those in which no measurable rain fell in the watershed during the 48-hour period preceding the sampling, based on staff judgment using available information (www.intellicast.com was the primary source). Integrator sampling included a standard set of parameters similar to those collected by DWQ at ambient stations (Table B.1).

Table B.1 Parameters for Water Quality Characterization, Burnt Mill Creek at Forest Hills Drive and Metts Avenue.

Field Parameters	*Laboratory Parameters*	
Dissolved Oxygen	Turbidity	*Metals:*
Air Temperature	Total Dissolved Solids	Aluminum
Water Temperature	Total Suspended Solids	Arsenic
Specific Conductance	Hardness	Cadmium
pH	Fecal Coliform	Chromium
	Total Phosphorus	Copper
	Ammonia-N	Iron
	Nitrate/Nitrite-N	Lead
	Total Kjeldahl Nitrogen	Manganese
	Calcium	Mercury
	Magnesium	Nickel
	Sodium	Silver
		Zinc

1.2 Stressor-Source Identification

1.21 Chemical-Physical Monitoring

DWQ collected several types of water column samples, reflecting the needs for both stressor and source identification. Stressor identification sites were selected to identify chemical stressors present in the study waters and to provide information for evaluating whether those stressors contribute to biological impairment. Source identification sites were chosen to identify or evaluate source areas or individual pollutant sources. While stressor and source identification can be separated conceptually, in practice stressor and source determination were often carried out jointly.

The sampling effort was intended to provide information relevant to the evaluation of causal relationships by tying selection of sampling sites, parameter and timing of sampling to available information on stressors and sources (e.g. macroinvertebrate surveys and watershed activities). This approach differed from many commonly used sampling frameworks, because the goal was not to characterize typical conditions or estimate pollutant loads, but to provide information to help evaluate whether particular stressors are likely contributors to biological impairment. The timing and location of sampling were selected to identify critical conditions such as periods of high levels of toxins.

<u>Station location</u>. The number and location of sites was determined based on the size of the watershed, the location and degree of the biological impairment, the nature and distribution of watershed activities, and existing chemical data. Station locations for stressor identification purposes were generally linked closely to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to specific

watershed activities believed to represent potential sources of impairment. Sampling stations in the Burnt Mill Creek watershed were listed in Section 5 of this document.

Parameter selection. Monitoring focused primarily on candidate stressors initially identified based on watershed reconnaissance and a review of existing information. We added additional parameters, as necessary.

For purposes of toxicity assessment, DWQ analyzed for the following analytes and parameter groups:

- metals;
- chlorinated pesticides and PCBs (polychlorinated biphenyls; EPA Method 608);
- select current use pesticides (EPA Method 614 and 619);
- PAHs (polycyclic aromatic hydrocarbons; EPA Method 625);
- phenols (EPA Method 625);
- semi-volatile organics (EPA Method 625); and
- MBAS (methylene blue active substances, an indicator of anionic surfactants);

Type and number of samples. Manual grab sampling was used for nonstorm and storm sampling. Manual grab samples were collected at the surface (depth of 0.1 meters, or approximately 3 inches). The number of samples collected was variable, depending on analytical results to date, and the outcome of other components of the study. Because of resource constraints (e.g limited number of trips due to the long trip from Raleigh to Wilmington), DWQ often targeted more general source areas, rather than specific watershed activities.

1.22 Toxicity Assessment

DWQ conducted four ambient toxicity tests at Metts Avenue. Laboratory bioassays provide a method of assessing the presence of toxicity from either single or multiple pollutants and can be useful for assessing the cumulative effect of multiple stressors. DWQ preferred chronic tests to acute tests (3 chronic tests versus 1 acute test), because chronic tests are more sensitive. The following specific tests were used:

- Ambient tests for acute toxicity using protocols defined as definitive in USEPA document EPA/600/4-90/027F (USEPA, 1993) using *Ceriodaphnia dubia* with a 48-hour exposure.
- Ambient tests for chronic toxicity using the North Carolina Ceriodaphnia Chronic Effluent Toxicity Procedure (NC Division of Water Quality, 1998).

1.3 Stressor-Source Identification: Bed Sediment

Sediment toxicity was evaluated to determine if it was a likely contributor to degradation of the benthic macroinvertebrate community in Burnt Mill Creek at Metts Avenue where benthic community composition and midge deformity analysis indicated likely toxic impacts.

DWQ conducted analysis on a composite of grab samples collected from the top 5 cm of stream substrate. In general, we tried to collect more fine-grained, organic-rich substrate as pollutants are most likely to adhere to that sediment type. In the target reach, we collected sediment from both mid-channel depositional areas and from the channel margins, where organic material is most abundant.

Sediment toxicity was evaluated using Microtox®. We ran one test using this tool. With a composite sample collected on August 5, 2003 from several locations at the Metts Avenue site, DWQ ran a serial dilutions of sediment suspended in a sodium chloride solution. At 32,900 mg/kg (3.29%) sediment, dry weight, the test sediment showed toxic effects. This concentration is the EC50, or percent of sample that causes a 50% reduction in light intensity emitted by the test bacteria, as compared to the control organism light emission. See Section 5.1.1 for further explanation. **The test results indicate that the sediment may impact the receiving water ecosystem.**

DWQ does not have the capability to run the standard bed sediment bioassay, which uses the organism *Hyallela azteca* (USEPA, 2000). This is something that would benefit DWQ's program, as it stands to reason that bed sediment is an important media to test for toxicity as, through adsorption, it holds pollutants that have been delivered over time. Also, benthic organisms are almost constantly exposed to stream sediment.

Chemical analyses conducted on sediment included pesticides (EPA Methods 8000B, 8081A, 8082, 8141), herbicides (EPA Method 8151A), PCBs, PAHs (modified EPA Method 8270C), semi-volatile organics (EPA Method 8270C), and metals. Unfortunately, DWQ does not have to equipment to measure total organic carbon (TOC) and particle size distribution. These are important parameters for normalizing toxicant results. The ability to measure TOC and particle size should be added to the DWQ program in the near future.

1.4 Toxicity Benchmarks

When performing ecological risk assessments and water quality evaluations, contaminants are often compared to screening benchmarks to determine if the reported concentrations of those contaminants are high enough to warrant further consideration. In this study, toxicological benchmarks derived for the protection of aquatic life were used to screen observed contaminant concentrations for potential aquatic ecological effects. Laboratory detection limits were also compared to benchmark values.

Benchmark screening values denote thresholds of elevated risk, but not predict actual impacts in particular situations. Actual site-specific and event-specific impacts depend on the interaction of numerous factors, including the level, timing and duration of exposure; the form and bioavailability of the particular chemicals (often dependent on pH or other variables); and simultaneous exposure to other stressors (NCDWQ, 2003).

Water. Many different sources of screening benchmarks exist, with differing levels of conservatism. A detailed discussion of these can be found in Suter and Tsao (1996). The primary screening benchmarks used in the Burnt Mill Creek watershed assessment were:

1) EPA's acute and chronic National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999);
2) EPA's Tier II values (USEPA, 1995).

The acute NAWQC were established by EPA to correspond to concentrations that would cause less than 50% mortality in 5% of the exposed populations in a brief exposure. EPA established the chronic NAWQC by dividing acute values by the geometric mean of at least three median lethal concentrations (LC50). Tier II values were developed as part of the Great Lakes Program (USEPA, 1995) for use with chemicals for which NAWQC are not available. They are based on fewer data than are required to establish NAWQC.

For the WARP study (and hence, this study), DWQ took NAWQC for priority pollutants from EPA's online Water Quality Standards Database (http://www.epa.gov/wqsdatabase/). NAWQC for nonpriority pollutants, which are not included in the online database, were taken from USEPA (1999). DWQ obtained Tier II values and other benchmarks from the ecological benchmark listing available through the Risk Assessment Information System operated by the Oak Ridge National Laboratory (http://risklsd.ornl.gov/homepage/eco_tool.shtml).

NAWQC for many metals (cadmium, chromium III, copper, lead, nickel, silver and zinc) are a function of water hardness. NAWQC are reported by EPA for a hardness of 100 mg/L and must be adjusted for site specific hardness levels. In this study benchmarks for all of the above metals, except chromium, were adjusted for hardness using the formulas recommended in USEPA (1999). The NAWQC for chromium VI, which does not require hardness adjustment, was used instead of chromium III, since the former provides a more conservative screening level. For cadmium the chronic benchmark was used instead of the acute value because hardness adjustment reduced the acute value below the chronic level.

NAWQC for many metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver and zinc) are calculated as the concentration of dissolved metals in the water column. Comparison of the ambient total metals concentrations measured in this study to dissolved metals criteria is a conservative approach in that less than 100% of a metal in any particular ambient sample may be in dissolved form. This approach is appropriate for screening purposes. Final evaluation of the likely potential for metals and other analytes to negatively impact aquatic biota considered all lines of evidence available, including toxicity bioassays, sediment toxicant levels and benthic macroinvertebrate data, in addition to data on analyte concentrations in the water column.

Observed pollutant concentrations can also be compared to the North Carolina's Water Quality Standards (NCWQS) for freshwater aquatic life, which serve as important regulatory benchmarks. The present study, however, is concerned not with regulatory compliance but with assessing the risks of site-specific, and sometimes event-specific impacts. The NAWQC are more appropriate for this purpose. NAWQC were based solely on data and scientific judgments on the relationships between pollutant concentrations and environmental and human health effects, and do not reflect considerations of technological feasibility or economic impact (USEPA, 1999). They allow for the specific evaluation of either chronic or acute concerns and for the consideration of site specific conditions (e.g. by adjusting metals criteria for local hardness levels).

Sediment. Sediment data were compared to a set of sediment benchmarks published by EPA (2002). These benchmarks were grouped into conservative (threshold) and non-conservative (probable) effect ranges. Conservative levels are threshold values, below which there is a low probability of toxicity. Non-conservative levels are probable effect values, above which there is a high probability of toxicity. If a measured value falls between the threshold and probable effect levels, toxicity is possible and the probability of toxicity increases with concentration.

<u>Section 2</u>
Detection limits

WATER COLUMN DETECTION LIMITS

Metals
PQL = Practical Quantitation Limit

Metal	PQL (ug/L)	Metal	PQL (ugL)
Cadmium	2	Calcium	
Chromium	25	Iron	
Copper	2	Magnesium	
Nickel	10	Manganese	
Lead	10	Arsenic	10
Zinc	10	Selenium	5
Silver	5	Mercury	0.2
Cobalt	50		

Chlorinated Pesticides in water by Electron Capture Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/L)	Pesticide – Target Compound	PQL (ug/L)
ALACHLOR	0.15	ENDRIN	0.025
ALDRIN	0.025	ENDRIN ANDEHYDE	0.025
ATRAZINE	3.0	ENDRIN KETONE	0.030
BHC-ALPHA	0.025	ETHAZOLE	0.060
BHC-BETA	0.025	HEPTACHLOR	0.025
BHC-DELTA	0.025	HEPTACHLOR EPOXIDE	0.025
BHC-GAMME (LINDANE)	0.025	HEXACHLOROBENZENE	0.015
CHLORDANE, Technical	0.50	MALATHION	0.20
CHLORDANE-ALPHA	0.020	METHOXYCHLOR, PP	0.10
CHLORDANE-GAMMA	0.020	MIREX	0.030
CHLORDENE	0.025	TRANS-NONACHLOR	0.020
CHLORNEB	0.20	OXYCHLORDANE	0.050
CLOROBENZILATE	0.60	MIXED-PERMETHRIN	1.20
CHLORPYRIFOS	0.050	PROPACHLOR	0.30
CLOROTHALONIL	0.025	TECNAZENE	0.010
DCPA	0.025	TRIFLURALIN	0.035
DDD, OP	0.050	AROCLOR 1016	1.0
DDD, PP	0.025	AROCLOR 1221	1.0
DDE, OP	0.040	AROCLOR 1232	1.0
DDE, PP	0.025	AROCLOR 1242	1.0
DDT, OP	0.030	AROCLOR 1248	1.0
DDT,PP	0.025	AROCLOR 1254	1.0
DIELDRIN	0.025	AROCLOR 1260	1.0
ENDOSULFAN I	0.025	AROCLOR 1262	1.0
ENDOSULFAN II	0.025	TOXAPHENE	3.0
ENDOSULFAN SULFATE	0.025		

Organophosphate Pesticides in water by Flame Photometric Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/L)	Pesticide – Target Compound	PQL (ug/L)
CARBOPHENOTHION	0.80	FENTHION	0.40
CHLORPYRIFOS	0.40	FENSULFOTHION	2.2
DEF (OXIDIZED MERPHOS)	0.40	MEVINPHOS	0.40
DEMETON	0.80	MONOCROTOPHOS	1.0
DIAZINON	0.40	NALED	2.7
DICHLORVOS	2.1	ETHYL PARATHION	0.40
DIMETHOATE	0.40	METHYL PARATHION	0.40
DISULFOTON	0.80	PHORATE	0.40
DISULFOTON SULFONE	1.0	RONNEL	0.40
DISULFOTON SULFOXIDE	NE	SULFOTEPP	0.40
EPN	0.40	TERBUFOS	0.40
ETHION	0.40		
ETHOPROP	0.40		

NE – NO ESTABLISHED PQL

Nitrogen Pesticides in water by NP Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/L)	Pesticide – Target Compound	PQL (ug/L)
ALACHLOR	15	METRIBUZIN	15
AMETRYN	4.5	MGK 264	150
ATRAZINE	4.5	MOLINATE	4.5
BROMACIL	4.5	NAPROPAMIDE	15
BUTACHLOR	15	NORFLURAZON	15
BUTYLATE	4.5	PEBULATE	4.5
CARBOXIN	15	PROMETON	4.5
CHLORPROPHAM	15	PROMETRYN	4.5
CHLORPYRIFOS	1.5	PRONAMIDE	15
CYNANAZINE	15	PROPAZINE	4.5
CYCLOATE	4.5	SIMAZINE	4.5
DIAZINON	15	SIMETRYN	4.5
DIPHENAMID	15	TREBUTHIURON	15
EPTC (EPTAM)	4.5	TERBACIL	90
FENAMIPHOS	15	TERBUFOS	15
HEXAZINONE	15	TERBUTRYN	4.5
METOLACHLOR	15	VERNOLATE	4.5

Semi-volatile Organics in water detected by Gas Chromatography/Mass Spectrometry
PQL = Practical Quantitation Limit

Semivolatiles - Target Compound	PQL (ug/L)	Semivolatiles – Target Compound	PQL (ug/L)
ANILINE	10	2,6-DINITROTOLUENE	10
PHENOL	10	3-NITROANILINE	50
BIS(2-CHLOROETHYL)ETHER	10	ACENAPHTHENE	10
2-CHLOROPHENOL	10	2,4-DINITRO PHENOL	50
1,3-DICHLOROBENZENE	10	4-NITRO PHENOL	50
1,4-DICHLOROBENZENE	10	DIBENZOFURAN	10
BENZYL ALCOHOL	20	2,4-DINITROTOLUENE	10
1,2-DICHLOROBENZENE	10	DIETHYL PHTHALATE	10
2-METHYL PHENOL	10	4-CHLOROPHENYL PHENYL ETHER	10
BIS(2-CHLOROISOPROPYL) ETHER	10	FLOURENE	10
4-METHYL PHENOL	10	4-NITROANILINE	50
N-NITROSO-DI-N-PROPYLAMINE	10	4,6-DINITRO-2-METHYL PHENOL	50
HEXACHLOROETHANE	10	N-NITROSODIPHENYLAMINE	10
NITROBENZENE	10	4-BROMOPHENYL PHENYL ETHER	10
ISOPHORONE	10	HEXACHLOROBENZENE	10
2-NITRO PHENOL	10	PENTACHLORO PHENOL	50
2,4-DIMETHYL PHENOL	10	PHENANTHRENE	10
BENZOIC ACID	50	ANTHRACENE	10
BIS(2-CHLOROETHOXY) METHANE	10	DI-N-BUTYL PHTHALATE	10
2,4-DICHLORO PHENOL	10	FLUORANTHENE	10
1,2,4-TRICHLOROBENZENE	10	PYRENE	10
NATHTHANLENE	10	BUTYLBENZYL PHTHALATE	10
4-CHLOROANILINE	20	3,3'-DICHLOROBENZIDINE	20
HEXACHLOROBUTADIENE	10	BENZO(A)ANTHRACENE	10
4-CHLORO-3-METHYL PHENOL	20	CHRYSENE	10
2-METHYL NAPHTHALENE	10	BIS(2-ETHYLHEXYL) PHTHALATE	10
HEXACHLOROCYCLOPENTADIENE	10	DI-N-OCTYL PHTHALATE	10
2,4,6-TRICHLORO PHENOL	10	BENZO(B)FLUORANTHENE	10
2,4,5-TRICHLORO PHENOL	10	BENZO(K)FLUORANTHENE	10
2-CHLORO NAPHTHALENE	10	BENZO(A)PYRENE	10
2-NITROANILINE	50	INDENO(1,2,3-CD)PYRENE	10
DIMETHYL PHTHALATE	10	DIBENZO(A,H)ANTHRACENE	10
ACENAPHTHYLENE	10	BENZOPERYLENE	10

The GC/MS Method also detects other semi-volatile compounds (up to 30 highest peaks).

Purgeable Organics measured in water by Photo Ionization Detector (PID), Electrolytic Conductivity Detector (ELCD) and Mass Spectrometer (MS).
PQL = Practical Quantitation Limit

VOA Target Compound	PQL (ug/L)	**VOA Target Compound**	PQL (ug/L)
1,1-DICHLOROETHENE	0.25	1,2,3-TRICHLOROPROPANE	0.30
METHYLENE CHLORIDE	10	BROMOBENZENE	0.25
TRANS-1,2-DICHLOROETHENE	0.25	2-CHLOROTOLUENE	0.25
1,1-DICHLOROETHANE	0.25	4-CHLOROTOLUENE	0.25
2,2-DICHLOROPROPANE	0.25	1,3-DICHLOROBENZENE	0.25
CIS-1,2-DICHLOROETHENE	0.25	1,4-DICHLOROBENZENE	0.25
CHLOROFORM	0.25	1,2-DICHLOROBENZENE	0.25
BROMOCHLOROMETHANE	0.25	1,2-DIBROMO-3-CHLOROPROPANE	0.30
1,1,1-TRICHLOROETHANE	0.25	1,2,4-TRICHLOROBENZENE	0.30
1,1-DICHLOROPROPENE	0.25	HEXACHLOROBUTADIENE	0.30
CARBON TETRACHLORIDE	0.25	1,2,3-TRICHLOROBENZENE	0.30
1,2-DECHLOROETHANE	0.25	METHYL-TERT-BUTYL ETHER	5
TRICHLOROETHENE	0.25	BENZENE	1
1,2-DICHLOROPROPANE	0.25	TOULENE	1
BROMODICHLOROMETHANE	0.30	ETHYL BENZENE	1
DIBROMOMETHANE	0.25	M,P-XYLENES	2
CIS-1,3-DICHLOROPROPENE	0.25	O-XYLENE	1
TRANS-1,3-DICHLOROPROPENE	0.25	STYRENE	1
1,1,2-TRICHLOROETHANE	0.25	ISOPROPYLBENZENE	1
TETRACHLOROETHANE	0.25	N-PROPYLBENZENE	1
1,3-DICHLOROPROPANE	0.25	1,3,5-TRIMETHYLBENZENE	1
DIBROMOCHLOROMETHANE	0.30	TERT-BUTYLBENZENE	1
1,2-DIBROMOETHANE	0.25	1,2,4-TRIMETHYLBENZENE	1
CHLOROBENZENE	0.25	SEC-BUTYLBENZENE	1
1,1,1,2-TETRACHLOROETHANE	0.25	P-ISOPROPYLTOLUENE	1
BROMOFORM	0.30	N-BUTYLBENZENE	1
1,1,2,2-TETRACHLOROETHANE	0.30	NAPHTHALENE	2

The PID Method also detects other volatile compounds (up to 10 highest peaks).

SEDIMENT DETECTION LIMITS

Chlorinated Pesticides in sediment by Electron Capture Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/Kg)	Pesticide – Target Compound	PQL (ug/Kg)
ALACHLOR	5.0	ENDRIN	0.83
ALDRIN	0.83	ENDRIN ANDEHYDE	0.83
ATRAZINE	100	ENDRIN KETONE	1.0
BHC-ALPHA	0.83	ETHAZOLE	2.0
BHC-BETA	0.83	HEPTACHLOR	0.83
BHC-DELTA	0.83	HEPTACHLOR EPOXIDE	0.83
BHC-GAMME (LINDANE)	0.83	HEXACHLOROBENZENE	0.50
CHLORDANE, Technical	17	MALATHION	6.7
CHLORDANE-ALPHA	0.50	METHOXYCHLOR, PP	3.3
CHLORDANE-GAMMA	0.50	MIREX	1.0
CHLORDENE	0.83	TRANS-NONACHLOR	0.50
CHLORNEB	6.7	OXYCHLORDANE	1.70
CLOROBENZILATE	20	MIXED-PERMETHRIN	40
CHLORPYRIFOS	1.7	PROPACHLOR	10.0
CLOROTHALONIL	0.83	TECNAZENE	0.33
DCPA	0.83	TRIFLURALIN	1.2
DDD, OP	1.7	AROCLOR 1016	33
DDD, PP	0.83	AROCLOR 1221	33
DDE, OP	1.3	AROCLOR 1232	33
DDE, PP	0.83	AROCLOR 1242	33
DDT, OP	1.0	AROCLOR 1248	33
DDT,PP	0.83	AROCLOR 1254	33
DIELDRIN	0.83	AROCLOR 1260	33
ENDOSULFAN I	0.83	AROCLOR 1262	33
ENDOSULFAN II	0.83	TOXAPHENE	100
ENDOSULFAN SULFATE	0.83		

Acid Herbicides in sediment by Electron Capture Method
PQL = Practical Quantitation Limit

Herbicide – Target Compound	PQL (ug/Kg)	Herbicide – Target Compound	PQL (ug/Kg)
ACIFUORFEN (BLAZER)	3.3	DICHLORPROP	20
BENTAZON	13	DINOSEB	6.7
CHLORABEN	3.3	4-NITROPHENOL	13.0
2,4-D	6.7	PENTACHLOROPHENOL (PCP)	3.3
2,4-DB	27	PICLORAM	6.7
DCPA (MONOACID METABOLITE)	NE	2,4,5-T	3.3
DICAMBA	3.3	2,4,5-TP (SILVEX)	3.3
3,5 DICHLOROBENZOIC ACID	3.3		

Organophosphate Pesticides in sediment by Flame Photometric Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/Kg)	Pesticide – Target Compound	PQL (ug/Kg)
CARBOPHENOTHION	27	FENTHION	13
CHLORPYRIFOS	13	FENSULFOTHION	16
DEF (OXIDIZED MERPHOS)	13	MEVINPHOS	13
DEMETON	27	MONOCROTOPHOS	33
DIAZINON	13	NALED	NE
DICHLORVOS	13	ETHYL PARATHION	13
DIMETHOATE	13	METHYL PARATHION	13
DISULFOTON	27	PHORATE	13
DISULFOTON SULFONE	33	RONNEL	13
DISULFOTON SULFOXIDE	NE	SULFOTEPP	13
EPN	13	TERBUFOS	13
ETHION	13		
ETHOPROP	13		

NE – NO ESTABLISHED PQL

Nitrogen Pesticides in sediment by NP Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/Kg)	Pesticide – Target Compound	PQL (ug/Kg)
ALACHLOR	500	METRIBUZIN	500
AMETRYN	150	MGK 264	3000
ATRAZINE	150	MOLINATE	150
BROMACIL	500	NAPROPAMIDE	500
BUTACHLOR	500	NORFLURAZON	500
BUTYLATE	150	PEBULATE	150
CARBOXIN	500	PROMETON	150
CHLORPROPHAM	500	PROMETRYN	150
CHLORPYRIFOS	50	PRONAMIDE	500
CYNANAZINE	500	PROPAZINE	150
CYCLOATE	150	SIMAZINE	150
DIAZINON	500	SIMETRYN	150
DIPHENAMID	500	TREBUTHIURON	500
EPTC (EPTAM)	150	TERBUFOS	500
FENAMIPHOS	500	TERBUTRYN	150
HEXAZINONE	500	VERNOLATE	150
METOLACHLOR	500		

Semi-volatile Organics in sediment detected by Gas Chromatography/Mass Spectrometry
PQL = Practical Quantitation Limit

Semivolatiles - Target Compound	PQL (ug/Kg)	Semivolatiles – Target Compound	PQL (ug/Kg)
ANILINE	660	2,6-DINITROTOLUENE	660
PHENOL	660	3-NITROANILINE	3300
BIS(2-CHLOROETHYL)ETHER	660	2,4-DINITRO PHENOL	660
2-CHLOROPHENOL	660	4-NITRO PHENOL	3300
1,3-DICHLOROBENZENE	660	DIBENZOFURAN	3300
1,4-DICHLOROBENZENE	660	2,4-DINITROTOLUENE	660
BENZYL ALCOHOL	1300	DIETHYL PHTHALATE	660
1,2-DICHLOROBENZENE	660	4-CHLOROPHENYL PHENYL ETHER	660
2-METHYL PHENOL	660	FLOURENE	660
BIS(2-CHLOROISOPROPYL) ETHER	660	4-NITROANILINE	3300
4-METHYL PHENOL	660	4,6-DINITRO-2-METHYL PHENOL	3300
N-NITROSO-DI-N-PROPYLAMINE	660	N-NITROSODIPHENYLAMINE	660
HEXACHLOROETHANE	660	4-BROMOPHENYL PHENYL ETHER	660
NITROBENZENE	660	HEXACHLOROBENZENE	660
ISOPHORONE	660	PENTACHLORO PHENOL	3300
2-NITRO PHENOL	660	PHENANTHRENE	660
2,4-DIMETHYL PHENOL	660	ANTHRACENE	660
BENZOIC ACID	3300	DI-N-BUTYL PHTHALATE	660
BIS(2-CHLOROETHOXY) METHANE	660	FLUORANTHENE	660
2,4-DICHLORO PHENOL	660	PYRENE	660
1,2,4-TRICHLOROBENZENE	660	BUTYLBENZYL PHTHALATE	660
NATHTHANLENE	660	3,3'-DICHLOROBENZIDINE	1300
4-CHLOROANILINE	1300	BENZO(A)ANTHRACENE	660
HEXACHLOROBUTADIENE	660	CHRYSENE	660
4-CHLORO-3-METHYL PHENOL	1300	BIS(2-ETHYLHEXYL) PHTHALATE	660
2-METHYL NAPHTHALENE	660	DI-N-OCTYL PHTHALATE	660
HEXACHLOROCYCLOPENTADIENE	660	BENZO(B)FLUORANTHENE	660
2,4,6-TRICHLORO PHENOL	660	BENZO(K)FLUORANTHENE	660
2,4,5-TRICHLORO PHENOL	660	BENZO(A)PYRENE	660
2-CHLORO NAPHTHALENE	660	INDENO(1,2,3-CD)PYRENE	660
2-NITROANILINE	3300	DIBENZO(A,H)ANTHRACENE	660
DIMETHYL PHTHALATE	660	BENZOPERYLENE	660
ACENAPHTHYLENE	660		

The GC/MS Method also detects other semi-volatile compounds (up to 30 highest peaks). Other compounds seen in Corpening Creek samples include: methyl butanol acetate C7.H14.O2, hexadecanoic acid, alkane, sistosterol.

Metals in sediment
PQL = Practical Quantitation Limit

Metal	PQL (mg/Kg)	Metal	PQL (mg/Kg)
Cadmium	0.2	Calcium	
Chromium		Iron	
Copper		Magnesium	
Nickel		Manganese	
Lead		Arsenic	
Zinc		Selenium	
Silver		Mercury	0.02
Aluminum			

Section 3
Sediment Benchmarks

Substance	Unit	Threshold Effect Concentations						
		TEL	**LEL**	**MET**	**ERL**	**TEL-HA28**	**SQAL**	**TEC**
METALS	mg/kg DW							
Arsenic		5.9	6	7	33	11	NG	9.79
Cadmium		0.596	0.6	0.9	5	0.58	NG	0.99
Chromium		37.3	26	55	80	36	NG	43.4
Copper		35.7	16	28	70	28	NG	31.6
Lead		35	31	42	35	37	NG	35.8
Mercury		0.174	0.2	0.2	0.15	NG	NG	0.18
Nickel		18	16	35	30	20	NG	22.7
Zinc		123	120	150	120	98	NG	121
PAHs	ug/kg DW							
Anthracene		NG	220	NG	85	10	NG	57.2
Fluorene		NG	190	NG	35	10	540	77.4
Naphthalene		NG	NG	400	340	15	470	176
Phenanthrene		41.9	560	400	225	19	1800	204
Benz(a)anthracene		31.7	320	400	230	16	NG	108
Benzo(a)pyrene		31.9	370	500	400	32	NG	150
Chrysene		57.1	340	600	400	27	NG	166
Dibenz(a,h)anthracene		NG	60	NG	60	10	NG	33
Fluoranthene		111	750	600	600	31	6200	423
Pyrene		53	490	700	350	44	NG	195
Total PAHs		NG	4000	NG	4000	260	NG	1610
PCBs	ug/kg DW							
Total PCBs		34.1	70	200	50	32	NG	59.8
Organochlorine Pesticides	ug/kg DW							
Chlordane		4.5	7	7	0.5	NG	NG	3.24
Dieldrin		2.85	2	2	0.02	NG	110	1.90
Sum DDD		3.54	8	10	2	NG	NG	4.88
Sum DDE		1.42	5	7	2	NG	NG	3.16
Sum DDT		NG	8	9	1	NG	NG	4.16
Total DDTs		7	7	NG	3	NG	NG	5.28
Endrin		2.67	3	8	0.02	NG	42	2.22
Heptachlor epoxide		0.6	5	5	NG	NG	NG	2.47
Lindane (gamma-BHC)		0.94	3	3	NG	NG	3.7	2.37

The threshold effect sediment quality guidelines (SQGs) include:

- TEC = Threshold effect concentration (MacDonald et al., 2000)
- TEL = Threshold effect level; dry weight (Smith et al., 1996)
- LEL = Lowest effect level, dry weight (Persaud et al., 1993)
- MET = Minimum effect threshold; dry weight (EC & MENVIQ, 1992)
- ERL = Effects range low; dry weight (Long and Morgan, 1991)
- TEL-HA28 = Threshold effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)
- SQAL = Sediment quality advisory levels; dry weight at 1% OC (USEPA, 1997)

Sediment Benchmarks from USEPA, 2002.

		Probable Effect Concentations					
Substance							
		PEL	**SEL**	**TET**	**ERM**	**PEL-HA28**	**PEC**
METALS	mg/kg DW						
Arsenic		17	33	17	85	48	33
Cadmium		3.53	10	3	9	3.2	4.98
Chromium		90	110	100	145	120	111
Copper		197	110	86	390	100	149
Lead		91.3	250	170	110	82	128
Mercury		0.486	2	1	1.3	NG	1.06
Nickel		36	75	61	50	33	48.6
Zinc		315	820	540	270	540	459
PAHs	ug/kg DW						
Anthracene		NG	3700	NG	960	170	845
Fluorene		NG	1600	NG	640	150	536
Naphthalene		NG	NG	600	2100	140	561
Phenanthrene		515	9500	800	1380	410	1170
Benz(a)anthracene		385	14800	500	1600	280	1050
Benzo(a)pyrene		782	14400	700	2500	320	1450
Chrysene		862	4600	800	2800	410	1290
Fluoranthene		2355	10200	2000	3600	320	2230
Pyrene		875	8500	1000	2200	490	1520
Total PAHs		NG	100000	NG	35000	3400	22800
PCBs	ug/kg DW						
Total PCBs		277	5300	1000	400	240	676
Organochlorine Pesticides	ug/kg DW						
Chlordane		8.9	60	30	6	NG	17.6
Dieldrin		6.67	910	300	8	NG	61.8
Sum DDD		8.51	60	60	20	NG	28
Sum DDE		6.75	190	50	15	NG	31.3
Sum DDT		NG	710	50	7	NG	62.9
Total DDTs		4450	120	NG	350	NG	572
Endrin		62.4	1300	500	45	NG	207
Heptachlor epoxide		2.74	50	30	NG	NG	16
Lindane (gamma-BHC)		1.38	10	9	NG	NG	4.99

The probable effect sediment quality guidelines (SQGs) include:

- PEC = Probable effect concentration (MacDonald et al., 2000)
- PEL = Threshold effect level; dry weight (Smith et al., 1996)
- SEL = Severe effect level, dry weight (Persaud et al., 1993)
- TET = Toxic effect threshold; dry weight (EC & MENVIQ, 1992)
- ERM = Effects range median; dry weight (Long and Morgan, 1991)
- PEL-HA28 = Probable effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)

APPENDIX B. REFERENCES

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