Restoring the Burnt Mill Creek Watershed through Stormwater Management and Community Development

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Bottom Neighborhood Empowerment Association
Gregory Elementary School
Williston Middle School
New Hanover Schools Public Facilities
B+O Design
And all other Members of the Burnt Mill Creek Watershed Group (formerly called the New Hanover Watershed Planning Group)

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Executive Summary

A partnership of diverse stakeholders has been working together to plan for and implement watershed improvements to Burnt Mill Creek since the NC Ecosystem Enhancement Program sponsored their first watershed planning project here in 2001. The Creek is listed as impaired for aquatic life and secondary recreation on the state's 303(d) list from impacts of urban stormwater runoff, including toxic impacts from polycyclic aromatic hydrocarbons (PAHs). The watershed plan identified storm water retro-fits as necessary to improve water quality in the watershed, as well as restoring stream segments. NCEEP has been planning and designing a stream restoration project, and City of Wilmington has restored some streambanks in the watershed. This project addressed the stormwater retrofit need with three approaches: engaging the community in identifying and installing commercial or community scale BMPs, monitoring the creek and BMP removal efficiencies to determine potential impacts of the practices, and engaging a neighborhood in intensive residential stormwater retrofits.

The team provided educational presentations to community groups and businesses and engaged them in reducing stormwater runoff pollution by installing on-the-ground Best Management Practices (BMPs). BMPs were successfully installed at the Wilmington Family YMCA (pervious pavement & rain garden treatment train), Stonesthrow Townhomes (stormwater wetland), Port City Java's Cooperative Headquarters on Market Street (parking lot rain garden retro-fit), Mary Bridgers Park (wetland), Gregory Elementary School (rain garden and cistern), and Williston Middle School (rain garden and cistern). Each participant received a guide on installing and maintaining BMPs published by the City of Wilmington.

A partnership was formed with The Bottom Neighborhood Empowerment Association (BNEA), a community advocacy group in the oldest part of the BMC watershed and Wilmington. At three community workshops, citizens learned how to help beautify their neighborhood and reduce stormwater runoff pollution through the installation and maintenance of backyard BMPs. On the BNEAs advice, the project team installed rain gardens in community spaces - two schools, a local church and a nursing home - with the intent to educate others in the community about BMPs. Students at Gregory Elementary School helped install their raingarden. With the help of the project team, community members participated in installing 36 rain barrels and 12 rain gardens throughout the neighborhood. Surveys sent to participants by a graduate student indicated that they had learned about stormwater runoff and were teaching neighbors the concepts.

A three-prong monitoring approach rounded out the project. UNC-Wilmington conducted in-stream sampling at 6 sites in the watershed, NCSU conducted a benthic macro-invertebrate sampling, and successfully monitored 2 of the BMPs for pollutant removal efficiencies. Results from UNC-W are as expected- the creek needs more help to see measureable improvements on a macro-level. However on a micro-scale, the raingarden at Port City Java showed significant reduction of PAHs and TSS, and Stonesthrow Townhomes wetlands showed high reductions in concentrations for all parameters monitored (PAH was not monitored there). Continued application of retro-fits over time in areas likely to contribute pollutants will be needed to see a measureable impact in the mainstem of Burnt Mill Creek.

The project has been more successful than anticipated. Landowners were very receptive to our approach, with most participating readily in BMPs retrofit projects. An intense amount of collaboration and community involvement was applied in this project, spurred by previous research from UNC-W and City of Wilmington in Burnt Mill Creek watershed indicating a hands-on approach was needed to actually get BMPs in the ground. Media coverage, newsletter mailings, and a celebration to publicly thank our volunteer participants helped to raise awareness of the BMP retrofit concept. With continued high community interest, the team applied for and received a NC Clean Water Management Trust Fund grant to continue to identify and design BMP retrofits, and to further investigate the source of PAH toxicity in the watershed.

Introduction /Background

Burnt Mill Creek is listed as impaired for aquatic life and secondary recreation on the state's 303(d) list from impacts of urban stormwater runoff, including toxic impacts from polycyclic aromatic hydrocarbons (PAHs). A group of stakeholders has been working together to plan for and implement watershed improvements since 2001. In 2002, NC Ecosystem Enhancement Program completed a watershed plan for Burnt Mill Creek and Smith Creek. The NCEEP plan indicated general impacts resulting from increased stormwater discharges and associated pollutants. Local community input provided by participants in the local watershed planning process and at public meetings also yielded particular concerns about chronic flooding of homes after rain events, degraded wildlife habitat, and safety of people who may subsistence fish out of the polluted and degraded Burnt Mill Creek. More recently, NCDWQ's Assessment Report of the Burnt Mill Creek watershed (2004) identified toxic impacts from polycyclic aromatic hydrocarbons (PAHs) as the primary cause of biological impairment, with secondary and cumulative causes identified as sedimentation, and nutrient enrichment.

NCDWQ (2004, pp.7-8) indicates that:
1)Feasible and cost-effective stormwater retrofit projects should be implemented throughout the watershed to mitigate the hydrologic effects of development.
2)A strategy to address toxic inputs should be developed and implemented, including a variety of source reduction and stormwater treatment methods.
3)Stream channel restoration activities should be implemented in target areas, in conjunction with stormwater retrofit BMPs, in order to improve aquatic habitat.

Of these strategies, this EPA 319 funded project primarily involved working with the community to identify and implement #1 stormwater retrofits, with research to help identify #2, a strategy to address toxic inputs, while NCEEP and the City of Wilmington have also been working on #3, stream channel restoration activities, through their cost-sharing activities. The project was implemented through a partnership between Watershed Education for Communities and Officials at NCSU, the NCSU Dept. of Biological and Agricultural Engineering, the City of Wilmington, Cape Fear River Watch, New Hanover Cooperative Extension, New Hanover Soil & Water Conservation District, UNC-Wilmington, and several citizen, non-profit, and business organizations

Goals and objectives from original proposal

Stormwater BMPs: To include design and construction of stormwater BMPs to control and treat stormwater runoff from small urban watersheds through a combination of retention, infiltration, evaporation and biological pollutant removal. The following BMPs were proposed for construction dependent upon field verification and landowner cooperation.

Proposed BMPs:

BMP Identification	BMP description
Parking lot retro-fit:	Retro-fit a large superstore parking lot with a bioretention area (private property)
Beaumont Park infiltration basin:	Construct an infiltration basin, add vegetative shelf to creek in city park
Wallace Park stormwater wetland #2:	Construct new wetland in city park
Construct new wetland or bioretention (private property) :	Yet to be identified

Additional 2-3 BMPs to be identified and constructed in partnership with community

<u>*Water Quality Monitoring:*</u> One important objective of the local watershed plan is to better characterize conditions in the watershed, and to document any changes in the watershed system that result from project implementation. Monitoring will be conducted in two parts. Water quality monitoring will be conducted by the Dept. of Biological and Agricultural Engineering before and after BMP construction immediately upstream and downstream of the BMPs. Parameters to be monitored include turbidity, bacteria, nutrients, benthic communities, and stormwater runoff rate and volume. A report issued by NCDWQ (Assessment Report: Biological Impairment in the Burnt Mill Creek Watershed) in 2004 indicates that polycyclic aromatic hydrocarbons (PAHs) are a major cause of impairment, so efforts will be made to assess PAH's. UNC-Wilmington's Lower Cape Fear Program will also add 3 sites to their existing monitoring protocol in the Burnt Mill Creek watershed (currently they monitor sites around Ann McCrary pond in Burnt Mill Creek). These sites will be located further downstream of the BMP sites, and will be used to better detect trends in the watershed. The Watershed Planning Group recommended gathering more information to determine a more precise attainment goal for this watershed. The documentation from this project will aid project partners in determining further action required to remove Burnt Mill Creek from the 303(d) list, and provide transferable knowledge to assist in watershed management in other locations.

<u>*Community outreach and involvement:*</u> Since two of the proposed BMP locations are in public parks, public meetings will be held to educate the adjoining neighborhoods about problems with the creek, and to gather their input and suggestions for designing BMPs that work for the community. In addition, one or two community design meetings will be held, preferably in neighborhoods that have suffered from chronic flooding problems in the watershed. The design meetings will serve as educational tools to involve local residents in education activities about low-impact development retrofit techniques (for stormwater management and pollution prevention); to generate citizen support for BMPs, and identify and recruit landowners who want to implement techniques on their own property. Some funding will be reserved for implementing low-impact development retrofits (such as bioretention areas) that may be identified during the community meetings, and/or to establish "seed partnership grants" for homeowners to build their own BMPs. A media campaign will be launched, based on research results from current City of Wilmington work, previous to the community meetings to drum up awareness and interest in water quality issues. The community outreach and involvement activities will build upon and dovetail with the current public education being conducted by the City of Wilmington's Stormwater Services department.

The New Hanover Local Watershed Group will be involved in publicizing and hosting the community meetings (in addition to assisting with the implementation of BMPs). T he Cape Fear Riverkeeper will play a role in coordinating publicity and outreach for the implementation efforts. All activities will be documented and shared with interested parties via regular newsletter mailings and the WECO website (www.ces.ncsu.edu/WECO).

How these goals changed:
The goals did not change throughout the project, although the location of specific BMP retrofits that were constructed varied some from the original proposed list, and more residential BMPs were constructed than anticipated due to positive response from the community, enhanced leveraging of volunteer (Cape Fear River Watch) and landowner resources, and efficiencies of in-house design and construction (NCSU, City of Wilmington).

Deliverables

- 6 new stormwater BMPs designed and constructed:
    - Gregory Elementary School of Science and Math- Project team members from Dept. BAE and Cape Fear River Watch assisted with the construction of a raingarden. The rain garden is approximately 1,300 square feet and drains a parking lot that is 8,780 square feet. A variety of vegetation including 4 Red Bud trees, 10 False Indigo, 15 Tickseed, 15 Daylilly, 15 Verbena, and 60 Liriope was planted. The rain garden was excavated for a cost of $3,800, the vegetation was approximately $500, and the mulch and topsoil was approximately $180. Much of the labor was provided by the project engineer and the students at Gregory Elementary School. Children from third and fifth grade classes helped to plant the vegetation in the raingarden under supervision of the science coordinator and principal. A 500 gallon cistern was installed to collect rooftop runoff and water class gardens. The cistern was installed at a cost of $1,500 and was installed by the project engineer.

    - Williston Middle School- a 1,200 square foot raingarden was constructed to absorb from the street and a corner of the building. During intense storms runoff from 10th street over flows the stormwater system and flows into one of the building at Gregory Elementary. The rain garden will help to store some of the water that floods Gregory during intense storms as well as treating runoff from approximately 3,000 square feet of roof top. The rain garden was installed at a cost of $5,200. There was a significant cost in materials and labor in routing the downspouts into the rain gareden. Vegetation including Beauty Berry, Joe Pye Weed, Coastal/Native Azalea, Black-eyed Susan, Coneflower, Wax Myrtle, Yaupon Holly , and Zentih Zoysia sod were planted at cost of $1,075. A 2,500 gallon cistern was installed to collect rooftop runoff and water landscaped areas. The cost of the water harvesting system was $5,000. The cistern was more expensive because it was wrapped with wood in order to make it more ascetically pleasing to the school. Children from the 8th grade class were involved in the planting as an educational opportunity. Three local news outlets, WWAY, WECT, and the Wilmington Star covered the final day of construction and planting and featured stories on their respective media outlets.

    - YMCA- A gravel area at the Wilmington Family YMCA was being used as an overflow parking area for members of the YMCA. Because of the areas use for parking the gravel had become compacted such that is was nearly impermeable. Roof top runoff from half of the roof was also directed into the parking lot causing runoff from rain events to wash a substantial amount of sediment into the stormwater system during rain events. Two best management practices were used as a treatment system to manage stormwater on this site. Six thousand square feet of pervious concrete was installed to stabilize the site and two rain gardens totaling 2,500 square feet were used to treat the roof top runoff. Porous concrete will allow the rainfall that falls on the surface to infiltrate preventing runoff. Some storage is also available within and in the materials below the porous concrete. Any time the rain gardens exceed capacity over flow will pass through curb cuts onto the pervious pavement where it will be able to infiltrate. The YCMA purchased the rain garden plants and planted them. Two local television stations filmed the construction and interviewed project team members and partners, with stories being aired that evening.

    - Port City Java- A raingarden/bioretention strip was constructed in the parking lot of the Port City Java corporate headquarters. The bioretention area divided into two cells. The first cell is approximately 585 square feet and cell 2 is approximately 590 square feet. Each cell is 5 feet wide and approximately 1 foot deep. The two cells together drain approximately 15,000 square feet of parking lot. The cells are vegetated with a zoyzia grass cover and planted with Dwarf Wax Myrtle. The bioretention system was installed for approximately $33,000. Underdrains were installed in both cells of the bioretention area. Monitoring of the parking lot runoff and the exfiltrate through the underdrains will determine the effects of the bioretention area on water quality.

- Mary Bridger Park on Chestnut St. -A stormwater wetland approximately 8,605 square feet at base of the slope was constructed in the City of Wilmington owned open space between Chestnut St. and Princess St. at the end of Grace St. referred to as Mary Bridgers Park. Construction took 9 days. The stormwater wetland consists of areas of shallow water, shallow land, and deep pools. The deep pools are approximately 3 feet deep and connected with shallow water channels no more than six inches in depth. The shallow land is no more than six inches above the top of the shallow water channels. The 8605 square feet of stormwater wetland consists of 22% deep pools, 29% shallow water, and 49% shallow land. Approximated 3,500 plants were planted in the wetland with help from local residents, Cape Fear River Watch volunteers, and city and university employees. The cost of the wetland plants and cypress trees were approximately $4,670. The City of Wilmington Stormwater Services staff constructed the wetland using their own equipment, at an estimated cost of $22,276. The total cost of wetland construction and supplies, not including volunteer and NCSU staff labor, was $28,946, most provided as matching by the City. The City of Wilmington Parks & Recreation Dept. constructed a bridge across the wetland.

- Stonesthrow Townhomes- stormwater wetland/bioretention: A stormwater wetland approximately 3860 square feet at base of the slope was constructed along the drainage ditch between the Stonesthrow Townhomes and the MacMillian Oaks apartment complex. The stormwater wetland consisted of areas of shallow water, shallow land, and deep pools. The deep pools are approximately 3 feet deep and connected with shallow water channels no more than six inches in depth. The shallow land is no more than six inches above the top of the shallow water channels. The 3860 square feet of stormwater wetland consists of approximately 24% deep pools, 28% shallow water, and 48% shallow land. The wetland is designed to store stormwater allowing pollutants to settle out and be absorbed by plant uptake. The construction was done by Mid Atlantic Associates at a cost of $17,959.00. Approximately 1,300 plants were planted at a cost of $2,388.85. Ellen Colodney of the Coastal Plain Conservation Nursery donated $680 of her time to help us organize the plants, and the City of Wilmington contributed $1,107 in equipment use and labor. Volunteers, including residents, also helped to plant to vegetation. (Total cost to grant for construction and plants: $20,348) One local media station, WWAY, documented the planting of the wetland with the story airing on their evening news.

- Anderson Tablernacle church, corner of 17th and Ann Streets- A 100 square foot rain garden was constructed to serve as a demonstration practice for the residents in the Bottoms Neighborhood. The rain garden treats runoff from approximately 700 square feet of rooftop. The rain garden was excavated by project managers and was planted with Yaupon Holly, and several other types of rain garden vegetation at a cost of approximately $100.
- Fannie Norwood Memorial Home- a 200 square foot raingarden that treats runoff from 850 square feet of rooftop was constructed at this assisted living home in the Bottoms Neighborhood. The rain garden was excavated at a cost of $500. The rain gareden was planted with Cone Flower, Itea, and Flox at a cost of approximately $200.

- The City of Wilmington, Dept. BAE, and Cape Fear River Watch stabilized and repaired sections of a streambank on Birch Creek, a tributary to Burnt Mill Creek, as part of an interactive training session for the City's Stormwater Services maintenance crew.

- NCEEP designed BMPs in conjunction with a stream restoration at Mineral Springs Branch/Burnt Mill Creek. They are in the contracting stage for construction.

- Media campaign in Wilmington to educate community before community meetings- Extensive media coverage was garnered for a community recognition and celebration event held on June 2, 2008. Two local news stations (WWAY Newschannel 3 and WECT TV6) and a local gardening show covered the event. An online story was posted by one of the news stations. Throughout the project, press releases were issued before public workshops, with stories often posted in the Wilmington Star newspaper.

- Public meetings held (for neighborhoods adjacent to proposed public park BMP sites)- Two community meetings were held for neighbors to engage in planning and designing the wetland at Mary Bridgers Park.

- A public celebration and volunteer recognition ceremony was held on June 2, 2008 at Gregory Elementary School. Mayor Bill Saffo of Wilmington provided certificates of appreciation to participants in BMP projects. In preparation, Beth Brampton, Gregory Elementary's Science teacher, taught her classes a unit on storm water and BMPs, then held a contest for her 5th grade students to design BMPs on a schools site. Those who submitted winning entries were invited to attend the ceremony and participate in a question and answer session with the Mayor about how rain gardens work (see picture below).

- 1-2 community low-impact-design retrofit meetings with local citizens within the Burnt Mill Creek Watershed:
Three workshops were held in the Bottom Neighborhood, at schools and a church. Participants learned about stormwater runoff impacts and solutions, and twelve rain barrels were distributed. Several participants installed gutters at their own cost, and several rain barrels were installed by a resident who had received and installed one at his own house previously. New locations for potential rain gardens were identified on maps.

- Minimum of 2 low-impact-design retrofit projects within the community (bioretention areas for example): Cape Fear River Watch staff organized volunteers to construct eleven residential rain gardens, and three dozen rain barrels were distributed to residents of the Bottoms Neighborhood.

- Documentation of results of low-impact design retrofit community outreach effort to be posted on WECO website: Presentations on the community outreach effort have been posted on the website.

- Minimum of 6, maximum of 12 meetings with Burnt Mill Creek Watershed Group to coordinate local activities, plan community meetings, and revise local watershed plan as needed: Seven watershed group meetings were held, not including project team meetings.

- Newsletters/ meeting summaries of all New Hanover Local Watershed Planning Group meetings distributed following meetings to provide update of progress to all interested parties (current database of >100 stakeholders/interested parties will be used): Newsletters were sent by postal mail and email, with additional updates presented to the online listserve. The City of Wilmington also covered the project in their stormwater newsletter.

- Monitoring results for upstream/downstream of the constructed BMPs, before and after construction: Monitoring occurred at the Port City Java Bioretention Area, the Stonesthrow wetland, and the Mary Bridger Park wetland. Methods and results are included within this report.

- Monitoring results for watershed trends throughout project: UNC-W sample continued at six sites throughout the watershed (three of which are provided by UNC-W cost-sharing). Methods and results are included within this report

- Educational signs to accompany BMPs on public property: Signs were installed at Port City Java, the YMCA , Stonesthrow townhomes, Gregory Elementary rain garden, and Mary Bridgers Park wetland.

Enhancements to the deliverables:

Some enhancements to these deliverables include capacity building for designing and constructing rain gardens with Cape Fear River Watch and Bottom Neighborhood, and a higher number of residential projects completed than expected, and a public celebration and volunteer recognition event held. A graduate student in the NCSU School of Design, Emily McCoy investigated the Bottom Neighborhood effort as part of her final project. She shared the results of her survey that was distributed to some of the participants. In addition, 11 BMP's were installed at eight sites not including the residential scale projects.

Overall Methodology/Execution

The project had 3 prongs- engaging the public in identifying and constructing large scale BMPs, engaging a community in learning about, identifying and constructing residential BMPs, and watershed monitoring to better characterize conditions in the watershed and the ability of the selected BMPs to reduce pollutants of concern. The methods and results of the monitoring efforts will follow a discussion of overall project methodology, execution, and results.

Project Objectives

To begin, the project team and local stakeholders (the Burnt Mill Creek Watershed Group is a loosely organized group formed to assist the NCEEP planning effort as the formerly named New Hanover Local Watershed Group) discussed and agreed upon monitoring and outreach/education objectives for the project. They agreed that improving water quality and stabilizing stream morphology and the hydrograph were goals for the watershed, but not necessarily feasible objectives for the project. They decided more realistic objectives for the project is to demonstrate that specific practices improve water quality in small subcatchments, with objectives of installing BMPs, and changing the public's behavior through education and involvement. Monitoring and outreach/education plans were developed collaboratively.

Identifying sites for BMPs

The project team sought feedback from the Burnt mill Creek Watershed Group for project site ideas, and conducted several windshield tours of the watershed. When initial field visits confirmed that a location would meet the group's criteria, local contacts in the watershed group helped to introduce us to landowners. The project team would provide presentations to the potential partners at their location/meeting to familiarize them with Burnt Mill Creek project goals and to discuss common interests that could be met by partnering on a retro-fit project. Sometimes the project team returned to provide additional updates to groups or individuals. This approach was very successful for recruiting participation in retro-fit projects on public, private, and residential properties. Criteria for selecting projects included water quality benefits, areas that treat larger watersheds having greater priority, and high visibility or opportunity to set a precedence for future similar projects. For example, finding a commercial partner to retro-fit parking lot runoff was difficult at first, but through persistence we were able to partner with Port City Java for a unique and highly visible bioretention area adjacent to Burnt Mill Creek.

Community involvement

Two community workshops were held for residents near a proposed stormwater wetland in Mary Bridgers Park (alongside Burnt Mill Creek). Citizens provided constructive feedback, requesting design changes and involvement of a landscape architect. The resulting wetland design that included a bridge (constructed by City of Wilmington Parks and Recreation) for pedestrian access and enjoyment met with the neighbors approval.

The Burnt Mill Creek Watershed Group chose to focus targeted community involvement for residential BMPs on one neighborhood. A partnership was developed with the Bottom Neighborhood Empowerment Association (BNEA). The bottom area is a dense urban neighborhood in the lower part of the watershed where many residents have incomes lower than the median income of Wilmington and New Hanover County (Wilmington median income is $42,000, New Hanover County $41,000; areas in BMC between $22,000 and $34,000 depending on census tract) (NC Census, 2000). BNEA is a group of citizens living in the bottom area who are working to improve the quality of life in their neighborhood. We approached the BNEA at their regular meetings to discuss how our interests may coincide. They suggested we target workshops towards yard improvements, advertise through churches, and implement public demonstration projects. We approached a church and Gregory Elementary School for the public projects (installing a large rain garden and 500 gallon cistern at the school, and a rain garden at the church). Three educational workshops were held in the community to share information about stormwater problems and to engage citizens in helping to identify projects on maps.

Cape Fear River Watch recruited volunteers to help install rain gardens that were identified. Eleven rain gardens were installed at private residences, and thirty-six 65 gallon rain barrels were distributed. A smaller residential scale rain garden was installed at a church in the bottom to demonstrate rain gardens for home owners, and a rain garden was installed at an assisted living home. Many residents in the bottom made the financial investment to install gutters on their homes in order to meet the criteria to receive a 65 gallon rain barrel. A survey developed and distributed by an NCSU graduate student showed that each resident who responded found some stormwater educational benefit to participating in the workshops and the retrofit efforts. Many of the respondents indicated that they shared what they learned with their neighbors, a significant accomplishment in accordance with the goals of the overall project.

A final celebration was held at Gregory Elementary School to thank and recognize all participants in the project in June 2008. Wilmington Mayor Bill Saffo helped by providing certificates of appreciation to participants. The event was covered by the local media.

Bmp design & construction

For each retrofit project the curve number method was used to calculated the volume of runoff from the watershed from the first flush event. Wilmington is a CAMA regulated area therefore the first flush is defined as 1.5 inches of rain fall. The surface area of the BMP was calculated using a storage depth that varied with BMP type.

Gregory Elementary School:
Any retrofit is going to have challenges that must be addressed. The parking lot already had a clear drainage pattern that had to be altered. The rain garden was incorporated into existing landscaping with the runoff routed into a grassed open space. A berm was used to divert the water and the curb and gutter was cut so that the runoff could pass into the rain garden. The depth of the rain garden was 6 inches from the lowest point in the curb to the top of the mulch. Overflow was routed to pass behind the berm into the existing drainage system.

Williston Middle School:
Several utilities had to be considered when designing the rain garden at Williston Middle School. The stormwater drain had to be avoided. Downspouts were routed to one point in a drop inlet and then piped under a sidewalk and into the rain garden. The rain garden was easily incorporated into the existing landscaping at the school. The rain garden was excavated to have 9 inches of storage. The storage was increased at this site to be able to hold larger volumes during high intensity storms.

Wilmington Family YMCA:
The Wilmington Family YMCA is a non profit association that has a CEO as well as a board of directors that both had to approve the project before they could be cooperators, which took a substantial amount of time and coordination The CEO and board of directors were hesitant at first because the project reduced the available parking close to the building, however, they were aware of the environmental impact the sediment loss was having on Burnt Mill Creek. We assured them that we would provide as much parking as possible. Treating the stormwater from the rooftop was challenging because the bioretention areas could not be to close to the building yet we did not want to route the runoff directly onto the pervious concrete. The downspouts had to be routed to a stormwater box and then piped under the pervious concrete into the bioretention area. Because the YMCA is a non-profit organization they did not have sufficient funds to properly landscape the rain garden and areas surrounding the parking lot. Plants had to be added several months after the construction was completed in order to provide adequate vegetation. Sufficient time for coordination between all members should be allowed when working with non-profit organizations.

Port City Java:
The timing of the project was critical because parking required for the normal operation of their coffee shop would have to be blocked off during installation of the bioretention area. A fire in their coffee shop caused them to have to rebuild over the course of several months allowing the installation of the bioretention area to coincide with the reconstruction eliminating any disruption in their operation. Because it was a parking lot retrofit certain requirement for the parking lot had to be maintained. The curb stops placed around the bioretention could only be 5 feet apart limiting the width of the bioretention cells. Because of the limited amount of surface area available the storage depth was set to 1 foot. This is slightly deeper than the typical bioretention area but the soils were sandy enough that the water was able to infiltrate within several hours of the end of the storm. Because it was a commercial site there was constant traffic in and out of the parking area. There were several instances where patrons managed to drive over the curb stops and into the bioretention area requiring the vehicles to be towed out. This caused damage to the bioretention area that had to be attended to. Larger curb stops or more effective signage would be recommended for future parking lot bioretention retro-fits. The grass in the bioretention area has established and the Dwarf Wax Myrtle provided the diverse vegetation and aesthetic appeal that was intended. Planting larger vegetation could also provide a visual barrier that would help drivers avoid the bioretention area.

Mary Bridgers Stormwater Wetland:
The surface area was calculated using 1.5 feet of storage in the wetland. The greatest challenge was getting the approval of some of the surrounding homeowners. Some design considerations were given to the patho`1gen levels in the park. The temporary inundation zone was increased to allow increased sunlight

penetration. The water levels in Burnt Mill Creek at the outlet of the wetland were documented to fluctuate 2 feet several times a day. The normal pool elevation was set to minimize the amount of water that would flow from the creek into the wetland.

Stonesthrow Townhomes:
The surface area of the wetland was calculated using 1 foot of storage in the wetland. Conditions in the ditch behind the townhomes did not lend themselves to the obvious choice of one BMP over another. The hydrology of the ditch required a stormwater wetland rather than a bioretention area because of the flows that would be passing through the area. The soils in the ditch were found to be sandy and the water table was deep, conditions where bioretention would typically be more appropriate than a stormwater wetland. The project was designed as a wetland to control the hydrology of the site. Shallow water areas were decreased and deep pools were constructed slightly deeper to attempt to reach the water table. The largest design consideration was the types of vegetation that was chosen. Plants that typically would be acceptable for wetlands as well as bioretention areas in wetter conditions were chosen. No aquatic vegetation was chosen knowing that the deep pools would occasionally dry out. Vegetation is currently thriving in the drier conditions.

Anderson Tabernacle and Fannie Norwood Retirement home:
Both project required coordination with the property owners. Design for the two projects was straight forward. The surface area was determined using a storage depth of 6 inches. As many downspouts as possible were routed into the rain gardens to treat the stormwater runoff.

Methods and Results for 3-pronged Monitoring Effort

The monitoring effort included in-stream sampling by UNC-Wilmington, a macro-invertebrate survey by NCSU Water Quality Group, and BMP monitoring by NCSU Department of Biological and Agricultural Engineering. The methods and results for each of these efforts follow.

Burnt Mill Creek Stream Water Quality Sampling for 2005-2008

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Methods

Sampling Sites: Stream sampling was conducted on 26 dates from January 2005 through August 2008. Samples were collected from six stations on the main body of the creek. Nearest the headwaters, the two uppermost stations were the inflow (BMC-KA1) and outflow (BMC-KA3) channels of the Kerr Avenue constructed wetland (Table 1; Fig. 1). Construction of the 0.28 ha (0.7 acre) Kerr Avenue Wetland was funded by the N.C. Wetlands Restoration Program, now known as the Ecosystem Enhancement Program. The Kerr Avenue wetland construction was completed in November 2000 and the first aquatic macrophyte planting (sponsored by Cape Fear River Watch) occurred later that month (various rushes, sedge, pickerelweed, lizard’s tail, water tupelo, wax myrtle, black gum, pond pine, bald cypress, etc.). Since then there have been many supplemental plantings as well as tree donations. The vegetation coverage is presently so dense that macrophytes from this site have been transplanted into other wetland restoration sites. The wetland has a forebay to collect sediment, and the system is designed to retain and treat the first 1.3 cm (0.5 inches) of a rainfall event before an overflow channel is utilized. The wetland drains a 6.1 ha (15 acre) area that is about 87% developed, mainly by businesses including large and small retail operations, several restaurants, a car wash and two auto repair businesses. A portion of the University of North

Carolina Wilmington drains into Burnt Mill Creek here as well, with some nearby multifamily residential dwellings.

Table 1 GPS coordinates for Burnt Mill Creek water quality sampling stations

BMC-KA1	N 34.22207	W 77.88506
BMC-KA3	N 34.22280	W 77.88601
BMC-AP1	N 34.22927	W 77.86658
BMC-AP2	N 34.22927	W 77.89792
BMC-AP3	N 34.22927	W 77.90143
BMC-WP	N 34.24083	W 77.92419
BMC-PP	N 34.24252	W 77.92510

About one km downstream of that wetland is Ann McCrary Pond, a large regional wet detention pond on Randall Parkway which was sampled just upstream (BMC-AP1) and about 40 m downstream (BMC-AP3) of the pond (Tabled 1; Fig. 1). Ann McCrary Pond is a large (11.7 ha or 28.8 acres) regional wet detention pond draining 722 ha (1,785 acres), with an apartment complex at the upper end near BMC-AP1. The pond itself periodically hosts growths of submersed aquatic vegetation, with *Hydrilla verticillata, Egeria densa, Alternanthera philoxeroides*, *Ceratophyllum demersum* and *Vallisneria americana* having been common at times. There have been efforts to control this growth, including addition of triploid grass carp as grazers. The ability of this detention pond to reduce suspended sediments and fecal coliform bacteria, and its failure to reduce nutrient concentrations, was detailed previously in a journal article (Mallin et al. 2002). Numerous waterfowl utilize this pond as well.

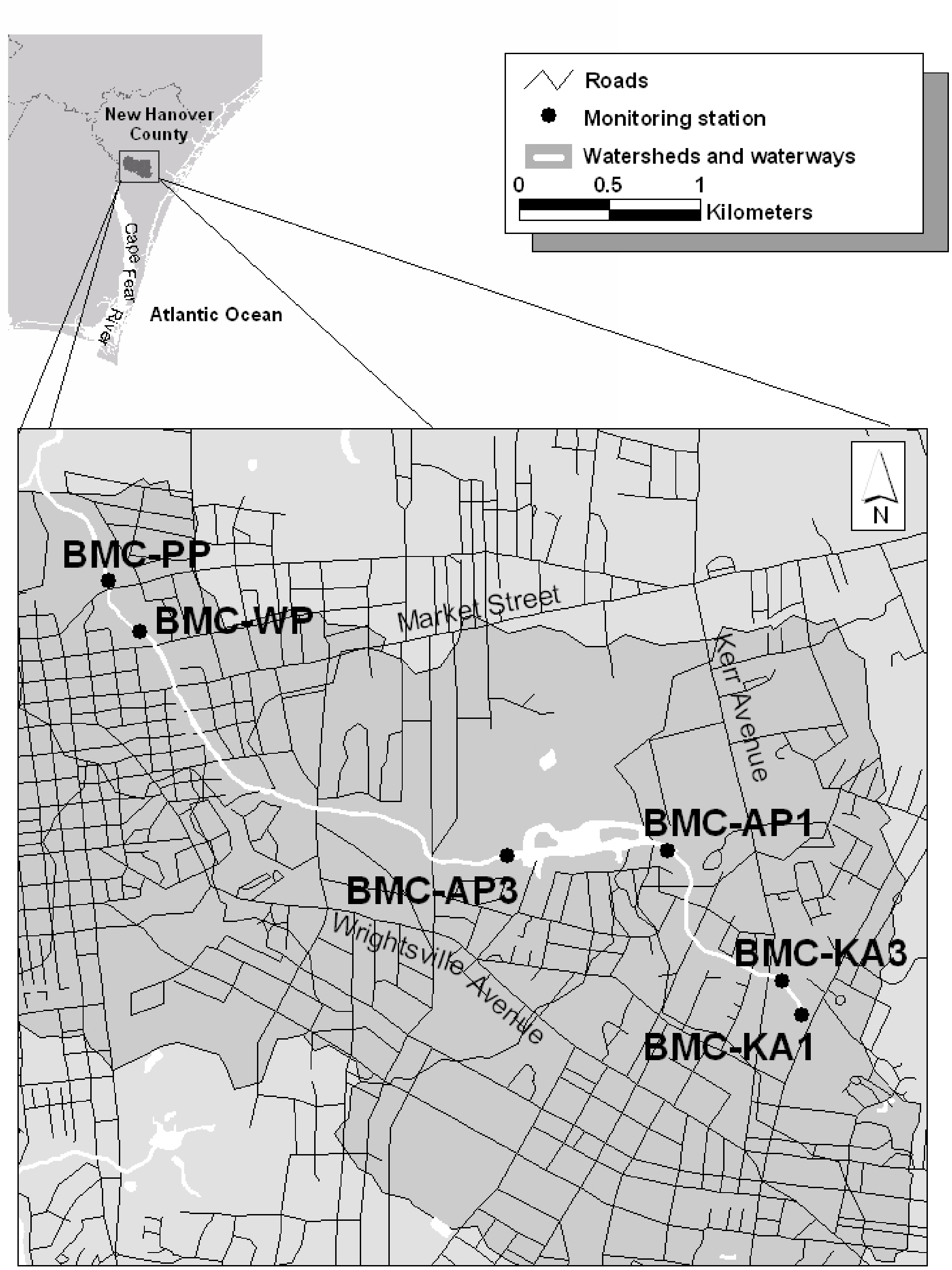


Figure 1 Burnt Mill Creek Watershed and water quality sampling sites

Several km downstream of Ann McCrary Pond are the final two stream stations, BMC-WP and BMC-PP, located in Wallace Park and at the Princess Place bridge over the creek, respectively (Table 1; Fig. 1). These are main stem stations in what is considered to be the mid-to-lower portion of Burnt Mill Creek, in a mixed residential and retail area. The cost for sampling three of the sites (BMC-KA1, BMC-KA2, and BMC-WP) has been funded by this project. The cost of sampling BMC-AP1, BMC-AP3 and BMC-PP has been funded by the City of Wilmington, through its Stormwater Services section.

Sample Parameters and Analyses: Data were collected at all stations for water temperature, conductivity, salinity, dissolved oxygen, pH and turbidity using a YSI 6920 Multiparameter Water Quality Probe (sonde) linked to a YSI 650 MDS display unit. While on-site, samples were collected for total suspended sediments, total nitrogen, nitrate-N, ammonium-N, total phosphorus, orthophosphate-P, fecal coliform bacteria, and chlorophyll *a*. Samples for five-day biochemical oxygen demand (BOD5) were collected at three stations; KA1, KA2 and BMC-WP (Fig. 1). Samples were immediately stored on ice, and returned to the laboratory. Nutrients, BOD5 and fecal coliform bacteria analyses were conducted at a state-certified laboratory using protocols described in Standard Methods (APHA 1995). These included nitrate (Method 4500-NO3 F), ammonium (Method 4500-NH3 H), total Kjeldahl nitrogen (TKN-Method 4500-Norg B), orthophosphate (Method 4500-P E), and total phosphorus (TP-Method 4500-P E with persulfate digestion), and total suspended solids (Method 2540-D). Total nitrogen (TN) was computed as TKN plus nitrate. Fecal coliform bacteria concentrations were determined using a membrane filtration (mFC) method that utilizes a 24 h incubation time at 44.5 ^{o}C and an enriched lactose medium (Method 9222-D - APHA 1995), and reported as colony-forming units (CFU) 100 ml^{-1}. The analytical method used to measure chlorophyll *a* is described in Welschmeyer (1994); an acetone extraction analyzed for chlorophyll *a* concentration using a Turner AU-10 fluorometer. Chlorophyll *a* analysis was performed at the UNC Wilmington Aquatic Ecology Laboratory, which is state-certified for chlorophyll *a* measurements as well as field data collections (conductivity, pH, dissolved oxygen and temperature).

For the Kerr Avenue Wetland and Ann McCrary Pond we used these data to test for statistically significant differences in pollutant concentrations between wetland and pond input and output stations. The data were first tested for normality using the Shapiro-Wilk test. Normally distributed data parameters were tested using the paired-difference t-test, and non-normally distributed data parameters were tested using the Wilcoxon Signed Rank test. Statistical analyses were conducted using SAS (Schlotzhauer and Littell 1997).

Results and Discussion

The Upper Creek

The most obvious feature of the upper creek is the Kerr Avenue Wetland. BMC-KA1 is the input station to this wetland, and Station BMC-KA3 is located at the drainage from the wetland just before the creek passes under Kerr Avenue (Fig. 1). Inputs to the wetland were not unusually high in terms of particulate matter. Total suspended solids exceeded 25 mg/L on only one occasion, and turbidity concentrations were below 25 NTU except for one unusual peak value of 385 NTU in May 2006. Incoming waters were frequently low in dissolved oxygen, however, with 50% of the samples below the NC freshwater standard of 5.0 mg/L (Table 2).

We were able to utilize data from 26 sampling trips within the period 2005-2008 to assess the efficacy of this wetland as a pollutant removal device. In terms of particulate matter, results showed that neither turbidity nor suspended solids showed a significant change between entering and leaving the wetland (Table 2). However, both ammonium and nitrate showed significant decreases in passing through the wetland, with ammonium decreasing on average 63% and nitrate decreasing on average 40% (Table 2). There were no significant differences in total nitrogen, orthophosphate, or total phosphorus entering and leaving the wetland, and there was no significant difference in BOD5 entering or leaving the wetland. Fecal coliform bacteria maintained high concentrations entering and exiting the wetland, with no statistical difference entering or leaving the pond. The presence of a number of dumpsters surrounding the site, and consequent small mammals foraging and defecating, may be a localized source of fecal coliform bacteria, BOD and organic nutrients. Additionally, there is a stormwater drainage pipe that enters the wetland within 20 m of the outfall at BMC-KA3 that essentially circumvents the wetland during rain events. In addition to the two above factors, the size of the wetland itself (0.7 acres) is considered too small to properly treat the 15 acre drainage area, thus the lack of significant decreases in many of the water quality pollutant parameters (Table 2).

About one km downstream from Kerr Avenue along Randall Parkway is the large regional wet detention pond known as Ann McCrary Pond. Data were collected at the input (BMC-AP1) and outflow (BMC-AP3) stations from 2005-2008. Turbidity and suspended solids concentrations entering and leaving this large regional pond were low to moderate, with no statistical difference between inflow and outflow (Table 2). Fecal coliform concentrations entering Ann McCrary Pond at BMC-AP1 were high (Table 2), possibly a result of pet waste runoff from the apartment complex and runoff from urban upstream areas (including the Kerr Avenue wetland). Over the sampling period 84% of the samples collected at BMC-AP1 had counts exceeding 200 CFU/100 mL, and 48% of the samples from BMC-AP3 exceeded the standard. On average there was a statistically significant, 77% reduction in fecal coliform abundance through the pond.

There was only one major algal bloom at BMC-AP1 that exceeded the North Carolina water quality standard of 40 µg/L during the study, whereas at BMC AP-3 there were six major algal blooms that exceeded the State standard. This resulted in significantly higher chlorophyll *a* concentrations exiting the pond compared with entering the pond (Table 2). The efficacy of Ann McCrary Pond as a nutrient removal device was poor throughout the study; in fact, nitrate showed a significant increase from inflow to outflow (Table 2). None of the other nutrient parameters showed a significant change passing through the pond. It is likely that inputs of nutrients enter the pond from a suburban drainage stream midway down the pond, short circuiting the ability of the pond to remove nutrients. Also, intensive waterfowl use of the pond, particularly at a tributary near the outfall, may have contributed to nitrogen and phosphorus loading in the lower pond and along its shoreline. However, the concentrations of nutrients entering the pond were not high to begin with. There was a significant decrease in conductivity through the pond. Dissolved oxygen significantly increased through the pond (by 46% on average), probably because of in-pond photosynthesis and aeration by passage over the final dam at the outfall. There was a significant increase in pH, probably due to utilization of CO_2 during photosynthesis in the pond.

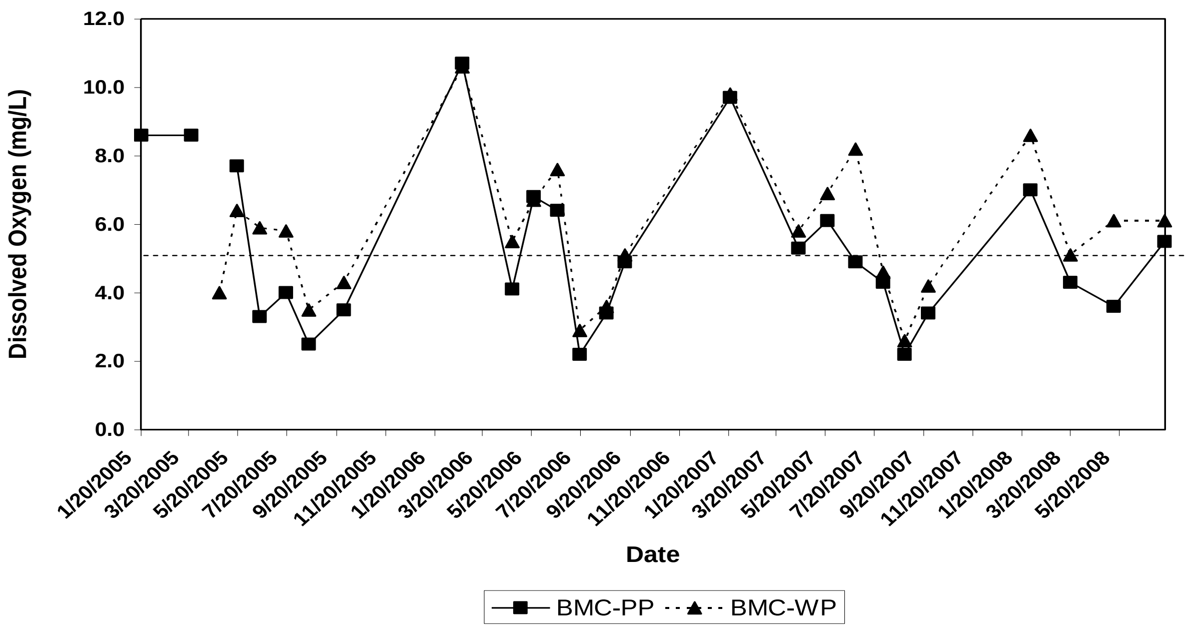
Table 2 Water quality data in upper Burnt Mill Creek, January 2005 – July 2008, as mean (standard deviation)/range. Fecal coliforms as geometric mean; N/P as median

Parameter	BMC-KA1	BMC-KA3	BMC-AP1	BMC-AP3
DO (mg/L)	5.5 (2.5) 1.8-10.6	5.7 (2.0) 2.9-10.6	6.8 (1.7) 3.9-10.6	9.9 (1.4)** 7.9-12.5
Cond. (μS/cm)	306 (117) 19-483	307 (97) 71-400	245 (62) 84-297	226 (39)* 144-275
pH	7.1 (0.5) 6.0-7.9	7.1 (0.3) 6.5-7.8	7.2 (0.3) 84-297	8.0 (0.4)** 144-275
Turbidity (NTU)	22 (77) 0-385	12 (11) 0-42	10(11) 1-54	8 (5) 0-24
TSS (mg/L)	7 (6) 2-26	15 (20) 1-83	18 (28) 1-101	10 (7) 4-29
Nitrate (mg/L)	0.086 (0.084) 0.010-0.370	0.052 (0.077)* 0.010-0.300	0.059 (0.064) 0.010-0.030	0.076 (0.070)** 0.010-0.350
Ammonium (mg/L)	0.113 (0.085) 0.010-0.260	0.042 (0.059)* 0.005-0.260	0.045 (0.028) 0.005-0.130	0.046 (0.057) 0.005-0.290
TN (mg/L)	0.825 (0.350) 0.250-1.930	0.754 (0.791) 0.035-3.900	0.825 (0.435) 0.260-2.150	0.846 (0.306) 0.380-1.670
OrthoPhos. (mg/L)	0.047 (0.135) 0.005-0.660	0.018 (0.028) 0.005-0.140	0.013 (0.011) 0.005-0.060	0.009 (0.002) 0.004-0.013
TP (mg/L)	0.110 (0.201) 0.020-1.010	0.127 (0.163) 0.030-0.640	0.079 (0.079) 0.010-0.350	0.068 (0.036) 0.040-0.190
N/P molar ratio	24.4	6.6	14.9	27.7
Chlor. *a* (μg/L)	8.7 (24.2) 0.2-121.0	7.7 (7.4)* 1.2-27.6	20.1 (56.2) 0.7-286.6	29.0 (30.2)** 1.3-104.9
Fec. col. (/100 mL)	1473 45-60,000	1054 118-26,000	823 49-6,000	192** 3-3,000
BOD5	2.2 (1.9) 0.5-7.3	2.2 (1.9) 0.6-9.6	NA	NA

* Indicates statistically significant difference between inflow and outflow at p<0.05
NA = not analyzed.

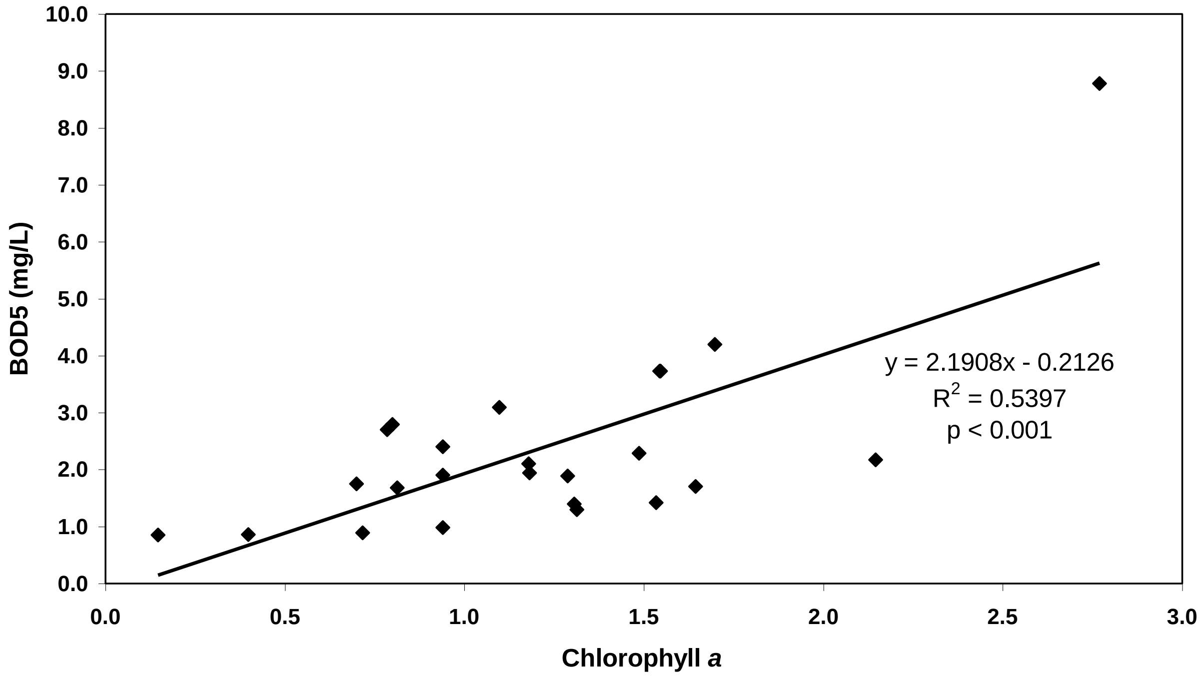
<u>Lower Burnt Mill Creek</u>: Both the Wallace Park (BMC-WP) and the Princess Place location (BMC-PP) experienced severe water quality problems during the sampling period. One parameter that is key to aquatic life health is dissolved oxygen. Dissolved oxygen was substandard (between 2.0 and 5.0 mg/L) on 33% of occasions sampled at BMC-WP and 52% of occasions sampled further downstream at BMC-PP (Fig. 2). The state standard for turbidity in freshwater is 50 NTU; there was only one exceedence of this value in the entire data set. Total suspended solids (TSS) concentrations have no ambient state standard. Based on our long term observances in the lower Cape Fear River basin, for the lower Coastal Plain a reasonable TSS "interest concentration" is 25 mg/L. This concentration was exceeded on only two occasions in the lower creek.

Figure 2. Dissolved oxygen concentrations in mainstem Burnt Mill Creek, 2005-2008.



However, the lower creek was prone to algal bloom formation, with chlorophyll *a* concentrations on several occasions exceeding 100 µg/L (Table 3; Fig. 3). As mentioned, the North Carolina water quality standard for chlorophyll *a* is 40 µg/L; this was exceeded on six occasions at BMC-PP and four occasions at BMC-WP. BMC-WP also hosted several blooms with chlorophyll *a* concentrations between 30 and 40 µg/L . Algal blooms can cause disruptions in the food web, depending upon the species present (Burkholder 2001). However, blooms can also play a direct role in lowering stream dissolved oxygen concentrations. This occurs when algal blooms die and decompose into labile organic matter, which exerts a biochemical oxygen demand (BOD). Concentrations of chlorophyll *a* have been strongly correlated with BOD5 in urban lakes, tidal creeks, and the Cape Fear River in southeastern North Carolina (Mallin et al. 2006). BOD5 analyses were performed at Wallace Park, with median concentrations (1.9 mg/L) higher than rural streams but typical of urban streams in the Wilmington area (Mallin et al. 2006). However, on five occasions BOD5 exceeded 3.0 mg/L, once reaching 8.8 mg/L. In lower Burnt Mill Creek chlorophyll *a* and BOD5 were significantly correlated ($R = 0.73$, $p < 0.001$). Regression analysis shows that algal blooms as chlorophyll *a* account for approximately 54% of the variability in BOD5 (Fig. 3). While other particulate and dissolved materials that exert a BOD undoubtedly enter the creek, clearly algal blooms are one important part of the low dissolved oxygen problem.

Figure 3. BOD5 as a function of log chlorophyll *a* in lower Burnt Mill Creek, 2005-2008.



An important question is what drives algal bloom formation in Burnt Mill Creek? Nutrient concentrations were unremarkable at either site. Examination of inorganic nitrogen to phosphorus ratios (Tables 2 and 3) shows that in most areas of the creek mean N/P ratios are generally in the 20-34 range, while median N/P ratios are lower. In waters where the N/P ratio is well below 16 (the Redfield Ratio for algal nutrient composition) it is generally considered that algal production is limited by the availability of nitrogen (i.e. phosphorus levels are sufficient); where N/P ratios are well above 16, additions of phosphate should encourage algal blooms. In Burnt Mill Creek it appears that in most circumstances phosphate is the limiting factor (and needs to be controlled); however, periodically (particularly in summer) the N/P ratios are very low indicating control of nitrogen inputs is needed. Thus, there is a need for control of inputs of both N and P to help reduce algal blooms in Burnt Mill Creek.

Table 3. Water quality data in lower Burnt Mill Creek, January 2005 – July 2008, as mean (standard deviation)/range. Fecal coliforms as geometric mean; N/P as median.

Parameter	BMC-WP	BMC-PP
DO (mg/L)	5.8 (2.1) 2.6-10.6	5.3 (2.4) 2.2-10.7
Cond. (μS/cm)	1142 (2031) 241-8450	1573 (2863) 237-9987
pH	7.3 (0.2) 6.8-7.5	7.2 (0.2) 6.9-7.5
Turbidity (NTU)	8 (4) 0-20	8 (6) 0-29
TSS (mg/L)	8 (6) 3-26	7 (5) 2-30
Nitrate (mg/L)	0.121 (0.072) 0.010-0.240	0.116 (0.104) 0.005-0.490
Ammonium (mg/L)	0.076 (0.048) 0.010-0.160	0.079 (0.058) 0.010-0.220
TN (mg/L)	1.130 (0.833) 0.570-3.810	1.111 (1.206) 0.350-6.750
OrthoPhos. (mg/L)	0.023 (0.020) 0.005-0.080	0.028 (0.025) 0.005-0.100
TP (mg/L)	0.105 (0.086) 0.012-0.450	0.108 (0.050) 0.030-0.230
N/P molar ratio	19.2	16.6
Chlor. *a* (μg/L)	46.6 (118.8) 1.4-588.0	65.2 (150.2) 0.9-646.0
Fec. col. (/100 mL)	924 75-29,000	559 22-15,500
BOD5	2.4 (1.7) 0.9-8.8	NA

NA = not analyzed

Important from a public health perspective are the excessive fecal coliform counts, which maintained geometric means (924 CFU/100 mL at BMC-WP and 559 CFU/100 mL at BMC-PP) well in excess of the

State standard for human contact waters (200 CFU/100 mL). Fecal coliform counts were greater than the State standard 73% of occasions sampled at Wallace Park and 68% of occasions sampled at Princess Place (Fig. 4). It is notable that fecal coliform bacteria counts increased along the passage from BMC-AP3 (geometric mean 192 CFU/100 mL) to the Wallace Park location, while dissolved oxygen decreased (Tables 1 and 2). It is likewise notable that nutrient concentrations increased from the inflow to Ann McCrary Pond downstream to the two lower main stem stations (Fig. 5). Nutrients appear to peak at the Wallace Park station and decline slightly further downstream at the Princess Place location; fecal coliform counts also decline from BMC-WP to BMC-PP (Fig. 4).

Figure 4. Geometric mean fecal coliform bacteria abundance in Burnt Mill Creek, 2005-2008, moving downstream from the headwaters.

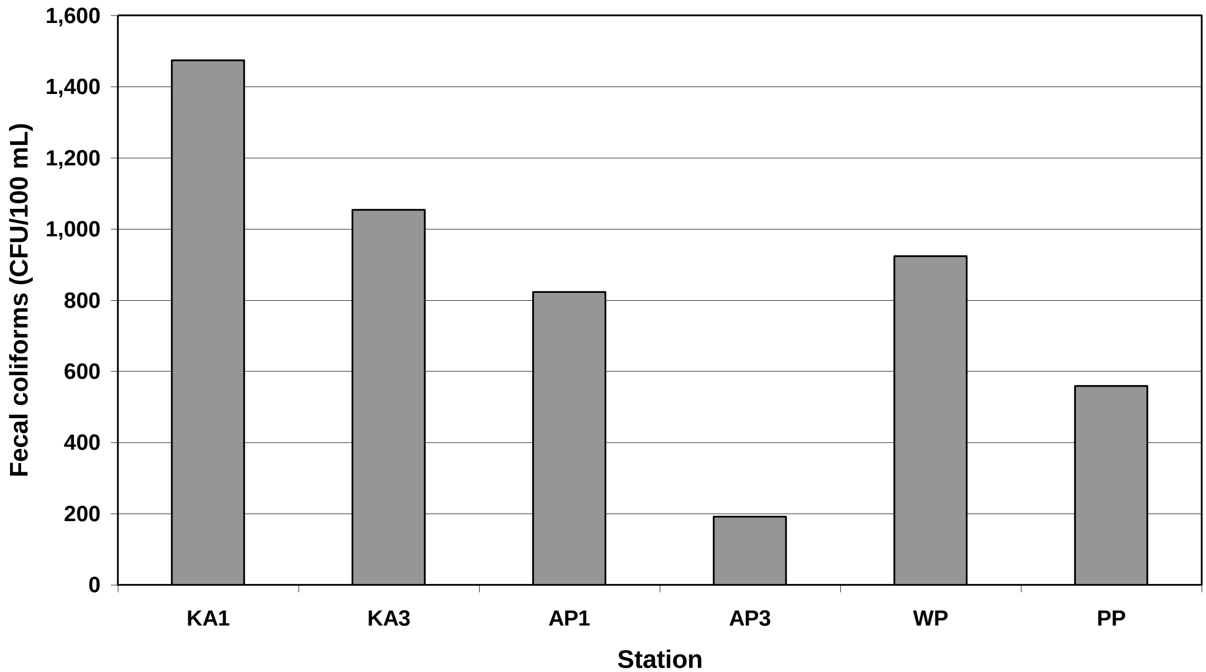
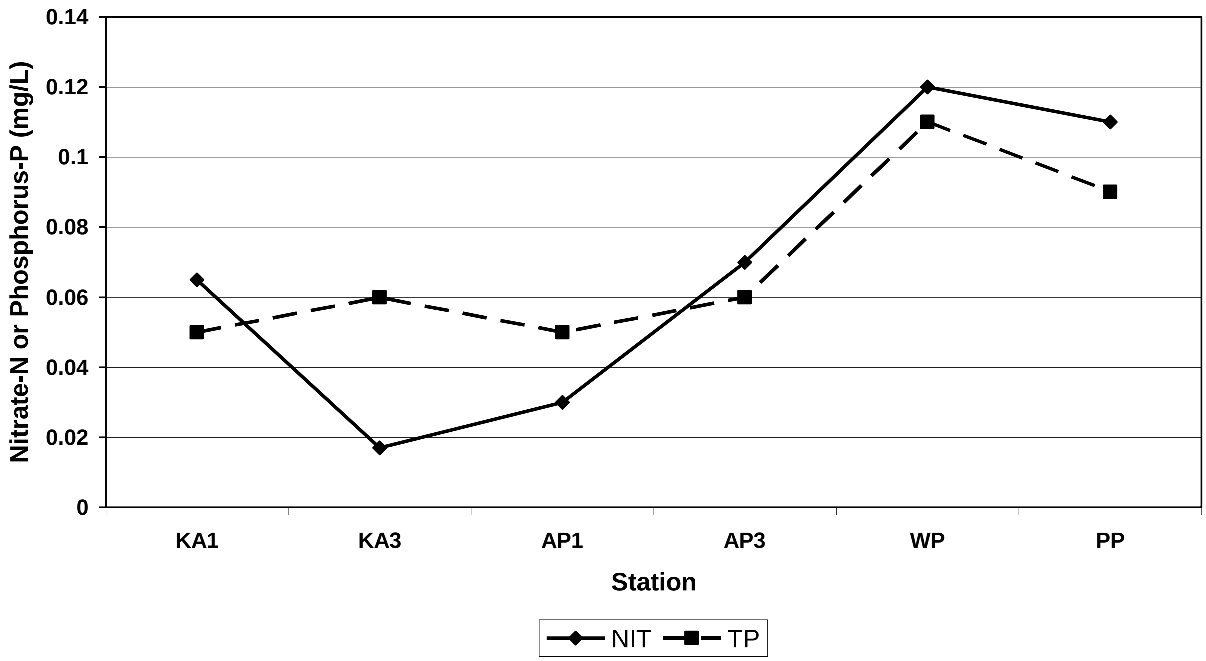


Figure 5. Median nitrate and total phosphorus concentrations in Burnt Mill Creek, 2005-2008, moving downstream from the headwaters.



To summarize, Burnt Mill Creek has problems with low dissolved oxygen (hypoxia) at some of the upper stations but most notably in the lower creek stations. Dissolved oxygen (DO) is elevated after the water passes through the large regional wet detention pond known as Ann McCrary Pond, but decreases considerably a few km downstream at Stations BMC-WP and BMC-PP. Part of the hypoxia problem is caused by elevated BOD caused by decaying algal blooms. These blooms occur with some frequency at BMC-WP and BMC-PP, and to a lesser extent in the detention pond upstream as measured at BMC-AP3. The N/P ratios in the creek indicate that inputs of either nitrogen or phosphorus are likely to stimulate algal bloom formation, depending upon season and inputs. It is notable that nutrient concentrations increase from the upper portion of the regional wet detention pond as one moves downstream toward the lower creek. An important human health issue is the high fecal bacteria counts found at most sampling stations, with the exception of BMC-AP3 below the detention pond. As NPDES point source discharges are not directed into this creek, the fecal bacteria (and nutrient) loading appears to be caused either by non-point source stormwater runoff, illegal discharges, or leakage from sanitary sewer lines.

Sediment Metals and PAH Concentrations

As part of the stream restoration effort funded through NCSU and the EPA 319 program, we collected sediment samples on one occasion annually throughout Burnt Mill Creek for analysis of sediment metals and polycyclic aromatic hydrocarbons (PAHs). The State of North Carolina has no official guidelines for sediment concentrations of metals and organic pollutants in reference to protection of invertebrates, fish and wildlife. However, academic researchers (Long et al. 1995) have produced guidelines (Table 4) based on extensive field and laboratory testing that are used by the US Environmental Protection Agency in their National Coastal Condition Report II (US EPA 2004).

Table 4. Guideline values for sediment metals and organic pollutant concentrations (ppm, or mg/kg, or μg/g, dry wt.) potentially harmful to aquatic life (Long et al. 1995; U.S. EPA 2004). ERL = (Effects range low). Concentrations below the ERL are those in which harmful effects on aquatic communities are rarely observed. ERM = (Effects range median). Concentrations above the ERM are those in which harmful effects would frequently occur. Concentrations between the ERL and ERM are those in which harmful effects occasionally occur.

Metal	ERL	ERM
Arsenic (As)	8.2	70.0
Cadmium (Cd)	1.2	9.6
Chromium (Cr)	81.0	370.0
Copper (Cu)	34.0	270.0
Lead (Pb)	46.7	218.0
Mercury (Hg)	0.15	0.71
Nickel (Ni)	20.9	51.6
Silver (Ag)	1.0	3.7
Zinc (Zn)	150.0	410.0
Total PCBs	0.0227	0.1800
Total PAHs	4.02	44.80
Total DDT	0.0016	0.0461

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds with a fused ring structure. PAHs with two to five rings are of considerable environmental concern. They are compounds of crude and refined petroleum products and coal and are also produced by incomplete combustion of organic materials. They are characteristic of urban runoff as they derive from tire wear, automobile oil and exhaust particles, and leaching of asphalt roads. Other sources include domestic and industrial waste discharge, atmospheric deposition, and spilled fossil fuels. They are carcinogenic to humans, and bioconcentrate in aquatic animals. In these organisms they form carcinogenic and mutagenic intermediaries and cause tumors in fish (US EPA 2000). All of the PAH sediment samples exceeded the ERM except for Station AP3, below Ann McCrary Pond, where PAHs were below the detection limit except for the 2008 collection (Table 5). The two Kerr Avenue wetland stations maintained the highest PAH concentrations on a consistent basis, year after year. The highest individual sample collected was of total PAHs exceeding 53,000 mg/kg at the Wallace Park station BMC-WP in 2008. 2007).

Most of the stations had sediment metals concentrations that were well below levels considered potentially toxic to benthic organisms. One exception was lead, in which both the mean and medians for the four annual samples exceeded the ERL at the Princess Place station (BMC-PP) and at the Wallace Park station

BMC-WP (Table 5). Lead concentrations at times approached the ERL at BMC-KA1 as well. Mercury concentrations were low with the exception of BMC-PP, where Hg concentrations approached but did not exceed the ERL during 2005 and 2008. Of the other metals, Zinc exceeded the ERL at BMC-PP in 2008 but was not problematic on any other occasion. Thus, the Burnt Mill Creek sediments consistently contained excessive total PAH concentrations at five of six locations, and excessive lead concentrations consistently at the two lower main stem sites. Excursions exceeding or approaching harmful levels for other metals did occur but were rare. On a related note, Burnt Mill Creek has been listed as Impaired for aquatic life because of a Poor benthic community rating by the North Carolina Division of Water Quality (NCDENR 2005), with toxic impacts and habitat degradation listed as stressors.

Table 5. Median concentrations of sediment metals and polycyclic aromatic hydrocarbons (PAHs) in Burnt Mill Creek, 2005-2008 (as mg/kg = ppm). Medians are from four samples collected. Concentrations in bold type exceed the level at which harmful effects to benthic organisms may occur, and italicized concentrations are near potentially harmful levels (see Table 4 for more detail).

Parameter	KA1	KA3	AP1	AP3	WP	PP
Antimony	0.073	0.059	0.059	0.024	0.054	0.119
Arsenic	0.059	0.066	0.067	0.060	0.070	.072
Beryllium	0.058	0.038	0.012	0.028	0.181	0.135
Cadmium	0.171	0.086	0.026	0.068	0.596	0.400
Chromium	2.885	2.015	0.356	1.550	8.270	4.530
Copper	5.370	5.980	1.007	2.000	14.540	8.805
Lead	13.890	7.340	2.135	2.010	**69.200**	**56.450**
Mercury	0.003	0.003	0.003	0.004	0.037	0.077
Nickel	1.770	0.981	0.219	1.038	3.035	2.585
Selenium	0.085	0.070	0.070	0.091	0.080	0.080
Silver	0.060	0.063	0.070	0.060	0.070	0.080
Thallium	0.012	0.013	0.014	0.012	0.050	0.030
Zinc	48.800	14.000	5.380	28.30	74.200	60.50
Total PAH	**10,472**	**12,707**	**3,665**	BDL	**2,936**	**608**

BDL = below detection limit

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Burnt Mill Creek Summary of Benthic Macroinvertebrates

November 2006 Sampling Event

Dave Penrose, NCSU Water Quality Group

Collection Methods and Metrics

Collection Methods: All samples were collected using protocols developed by the North Carolina Division of Water Quality. Swamp methods were used at both locations; nine sweep net samples are collected proportionally from major habitat types (macrophytes, bank areas, mid-channel “riffles”). All specimens are then preserved in the field and identified to the lowest practical taxonomic level in the laboratory.

Metrics: Benthic macroinvertebrates were collected from this catchment to assist with the interpretation of water quality data associated with the implementation of multiple Best Management Practices. Care was taken to only collect samples in stream reaches that we felt had perennial flow, were permanently freshwater and did not experience any saltwater intrusion. The Burnt Mill Creek catchment in Wilmington is highly urbanized and the benthic fauna is expected to be dominated by very tolerant taxa and will respond to the effects of seasonality and flow. Data will be collected from similar months each year of this grant attempting to account for any variability in the data due to seasonality. Additionally urban catchments have very flashy hydrology, which also may negatively impact the benthic fauna. Extremely high flow conditions were experienced prior to the 2006 investigation which may have created scour of benthic substrates eliminating members of the fauna. Estimates of taxa richness and the presence of relatively intolerant, indicator taxa will be determined as part of this assessment.

Station Locations

Two monitoring locations were established as part of this investigation; Burnt Mill Creek above the Kerr Avenue wetland near BMC-AP1 and Burnt Mill Creek above Market Street near BMC-WP. The upstream location is near an apartment complex and receives substantial stormwater runoff from a very impervious catchment. The stream at this point appears to be somewhat enriched as macrophytes and diatom growths are prolific. Burnt Mill Creek and it's tributaries above this location quickly becomes small, channelized features that may have intermittent flow. Burnt Mill Creek at the Market Street Bridge is relatively wide, shallow with good flow. However, it appears that this reach has been channelized in the past. The substrate at this site is primarily shifting sand, but the banks are stable and provide descent habitat for the benthic fauna. Burnt Mill Creek become much deeper below the Market Street Bridge and flow is reduced. These conditions may be due to the influence of the nearby receiving stream which may be intertidal.

Results

Data from these two surveys are summarized on Table 1. Both sites are dominated by tolerant taxa, especially Chironomidae and Crustacea. Slightly higher numbers of organisms and taxa richness are found at the upstream location. Only two rare EPT taxa were collected from this location (*Caenis* and *Cheumatopsyche*), both very tolerant taxa. Sightly lower numbers were collected from the downstream location near the Market Street Bridge. These taxa are also very tolerant and the only abundant taxa at this location are *Limnodrilus hoffmeisteri* (a very tolerant Oligochaete) and *Crangonyx* a Crustacea.

Table 6. Benthic macroinvertebrates from Burnt Mill Creek, New Hanover County. 29 November, 2006.

Taxa/Location	Near BMC-AP1	Near BMC-WP
Ephemeroptera		
Caenis	R	
Trichoptera		
Cheumatopsyche	R	
Coleoptera		
Hydroporus	C	
Odonata		
Argia	C	
Enallagma		R
Diptera - Chironomidae		
Conchapelopia	R	
Chironomus		C
Cricotopus bicintus	C	R
Polypedilum illinoense	C	R
Polypedilum halterale	R	C
Procladius		R

Cryptochironomus fulva		R
Oligochaeta		
Lumbriculidae	R	
Ilyodrilus templetoni		R
Limnodrilus hoffmeisteri		A
Peloscolex		R
Crustacea		
Astacidae (immature)	R	C
Procambarus	R	
Hyalella azteca	A	C
Crangonyx	A	A
Mollusca		
Sphaerium		R
Ferrisia	R	
Other Taxa		
Helobdella	R	
Total number of taxa	15	14
Total number of EPT taxa	2	0

Monitoring and Performance of Three Stormwater Best Management Practice Retrofits

Jason Wright, NCSU Dept. BAE

Data Collection

Data was collected from three sites in the Burnt Mill Creek Watershed, The Port City Java parking lot retrofit, the Stonesthrow Townhomes Stormwater Wetland, and the Mary Bridgers Stormwater Wetland (Figure 6). These three sites were selected based on their location in the watershed and their suitability for monitoring. Underdrains were installed in the Port City Java bioretention in order to collect exfiltrate from the bioretention cells.

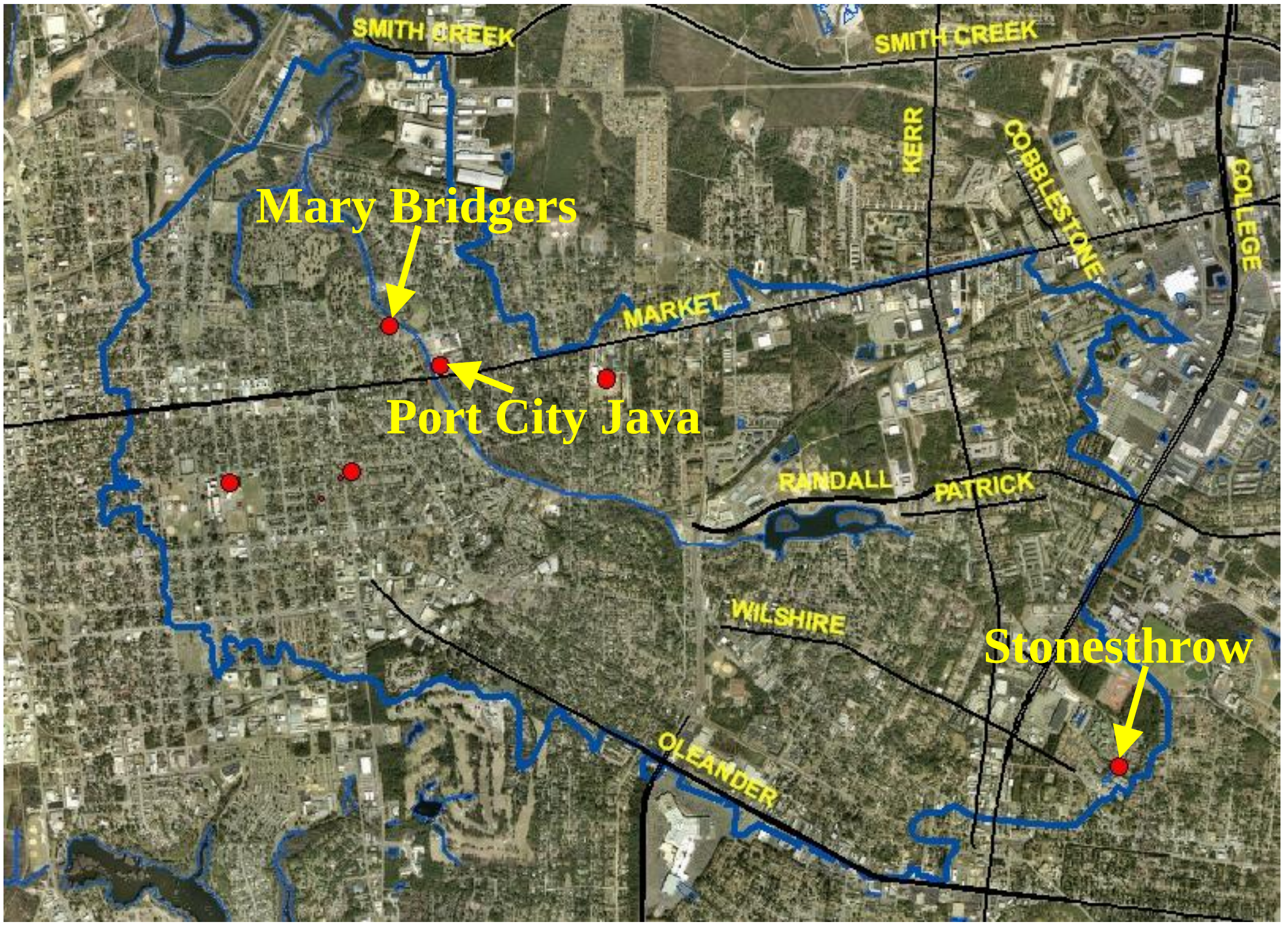

Figure 6 BMP Monitoring Sites

Port City Java

Inflow volume was calculated based upon watershed characteristics and rainfall data recorded at the site. An ISCO rain gage was used to measure rainfall and trigger an ISCO 6712 sampler. The sampler was enabled and began taking samples when water was detected and took samples with every 3.8 mm (0.15 in.) of rain. A steel "trough" was constructed to pool a small amount of water at the edge of the parking lot so a sample could be taken. The location of the inlet sample was selected so that an area representative of the watersheds of both bioretention systems could be intercepted. To monitor outflow from the underdrains, steel weir boxes were constructed and mounted inside the concrete drop inlet, where underdrains daylighted, for both bioretention systems. Effluent flowed over a 30-degree weir plate for measurement.

ISCO 730 bubbler modules were used to measure the depth of flow over the weirs and calculate flow rate. The bubblers triggered ISCO 6712 automatic samplers to take flow-weighted composite samples for the storm. The sampler received pulses from the bubbler each time a pre-defined volume of water passed over the weir and then took a sample. Runoff from storm events up to 25 mm (1 inch) in size was expected to be fully captured by the bioretention cells.

Stonesthrow Stormwater Wetland

Inflow volume at the Stonesthrow wetland was calculated based on the flow in the inlet pipe. An ISCO 730 bubble module measured the depth of flow in the inlet pipe. Flow was then calculated using the manning equation (Grant and Dawson, 2001). The bubbler module triggered an ISCO 6712 automatic sampler each time a predefined volume of water passed through the inlet and a sample was taken. A bubbler module was used to calculate the flow over the outlet weir and samples were taken in the same manner that the inlet sample was taken.

Mary Bridgers Stormwater Wetland
Samples at the Mary Bridgers Stormwater Wetland were collected using the same procedures as the Stonesthrow stormwater wetland.

Results and Discussion

Port City Java
Ten storm events were captured for analysis of the pollutant reduction efficiency from the PCJ Shallow cell of the bioretention areas and twelve events from the PCJ Deep cell. The rainfall amount, inflow, and outflow volumes for PCJ Shallow and PCJ Deep are presented in Table 7 and Table 8. The results of the concentration analysis as well as the reduction efficiency are presented in Table 9.

Table 7 Rain fall and Flows from PCJ Shallow

	Rainfall		Runoff (Shallow)		Outflow (Shallow)		
	accum	dur.	vol.	dur	vol.	peak	dur
Date	in	hr	L	hr	L	l/s	hr
June 4, 2007	1.65	26.15	16732	22.33	8802	0.86	22.00
June 21, 2007	0.83	2.50	8417	2.42	2583	0.52	3.50
July 31, 2007	2.20	6.77	22310	5.25	9099	0.89	6.75
August 28, 2007	1.95	17.37	19775	4.17	10534	1.58	4.42
September 13, 2007	0.67	2.75	6794	3.00	1774	0.83	2.08
October 25, 2007	1.19	3.15	12068	2.83	6635	1.80	3.67
December 17, 2007	0.39	2.67	3955	16.08	8327	1.13	7.00
February 14, 2008	1.09	32.34	11056	7.50	5312	0.54	7.83
February 19, 2008	0.92	10.47	9335	8.83	7641	1.47	5.83
April 21, 2008	0.45	22.00	4563	4.25	543	0.24	2.83

Table 8 Rainfall and flows from PCJ Deep

	Rainfall		Runoff (Deep)		Outflow (Deep)		
	accum	dur.	vol.	dur	vol.	peak	dur
Date	in	hr	L	hr	L	l/s	hr
June 4, 2007	1.6	26.15	42619	22.33	21148	0.79	25.67
June 21, 2007	0.8	2.50	21439	2.42	7648	0.88	9.17
July 31, 2007	2.2	6.77	56825	5.25	11222	1.10	10.08
August 28, 2007	2.1	17.37	53209	4.17	15104	4.12	6.00
September 13, 2007	0.7	2.75	17306	3.00	4754	0.70	5.17
October 25, 2007	1.2	3.15	30737	2.83	17583	2.42	7.92
November 16, 2007	0.4	2.67	9299	2.75	4441	0.46	7.83

November 27, 2007	0.3	32.34	6716	17.08	Reported Errors		
December 17, 2007	0.4	10.47	10074	16.08	15876	0.97	16.67
February 14, 2008	1.1	22.00	28162	7.50	19525	0.95	18.33
April 2, 2008	0.4	0.84	11107	24.58	17431	1.35	17.83
August 1, 2008	1.18	18.06	30479	1.67	4897	1.20	15.17

The November 27th storm was used in the concentrations analysis but was excluded in the loads analysis because of a malfunction in the level meter.

Table 9 Concentrations and Removal Efficiencies for PCJ

Concentration	Median Influent (n=10)	Median Effluent (Shallow)	Reduction Efficiency	Median Effluent (Deep)	Reduction Efficiency
Fecal (CFU/100mL)	5650	6132	-9%	2737	52%
Enterococcus (MPN)	272	692	-155%	460	-69%
TKN (mg/L)	1.88	0.56	70%	0.42	77%
NO_3&NO_2 (mg/L)	0.17	0.31	-81%	0.47	-176%
TN (mg/L)	2.05	0.87	58%	0.90	56%
NH_3-N (mg/L)	0.10	0.04	59%	0.03	68%
TP (mg/L)	0.28	0.19	34%	0.12	59%
Ortho P (mg/L)	0.03	0.07	-112%	0.02	22%
TSS (mg/L)	157.71	17.69	89%	11.00	93%
PAH (ng)	459	112	76%	39	91%

The bioretention cells showed some pollutant reduction except for fecal coliforms, Enterococcus, nitrate nitrite (referred to subsequently as nitrate), and ortho phosphorus (OP). The concentration of OP entering the bioretention area are relatively low, and it is difficult to obtain significant reductions from these concentrations. When pollutants are at such a low level it is difficult to reduce the concentrations any further. The increase in nitrate is somewhat expected due to the fact that the bioretention is designed to dry out. Nitrate and nitrite requires anaerobic environments to be fully reduced to nitrogen gas. The fact that there is an increase in fecal coliform bacteria and Enterococcus indicates that the bioretention area may not be drying out completely as bacteria thrive in damp environments. This is somewhat contradictory to the explanation for the increase in nitrate. However, the field monitoring data presented earlier show elevated fecal bacteria concentrations in the Princess Place and Wallace park areas of the creek, the same general area as this bioretention facility. The bioretention areas did perform well in the area of TSS removal as expected. There was also a significant reduction of PAH's. Concentrations of PAH's were only detected in the first two storms and were undetectable in the remaining storm events. The parking lot was seal coated immediately prior to the completion of the bioretention project. Any PAH's in the seal coat were apparently washed out in the first few events. There were also some differences in the concentration reduction efficiencies between the shallow and deep cells. The deep cells showed greater reduction efficiencies for each pollutant except for nitrate and TP. The greater reduction in fecal bacteria and increase in nitrates indicates that the deeper cell dries out at the surface more often than the shallow cell. Because of the proximity to Burnt Mill Creek it is possible that the water from the creek influenced the outlet of the shallower cell although there is no data to support this theory.

Loading data from the shallow cell are presented in Table 11. The loading data for the shallow cell are resented graphically in Figure 7, Figure 8 and Figure 9.

Table 10 Pollutant Load from PCJ Shallow

Shallow Load (n=10)	Median Influent	Median Effluent	Reduction Efficiency
TKN (kg)	0.0150	0.0028	81%
NO_3&NO_2 (kg)	0.0026	0.0017	34%
TN (kg)	0.0177	0.0045	74%
NH_3-N (kg)	0.0008	0.0002	71%
TP (kg)	0.0024	0.0010	58%
Ortho P (kg)	0.0002	0.0003	-44%
TSS (kg)	1.5517	0.0873	94%
PAH(mg)	7.6861	0.2323	97%
Water Volume (L)	125248	61250	51%

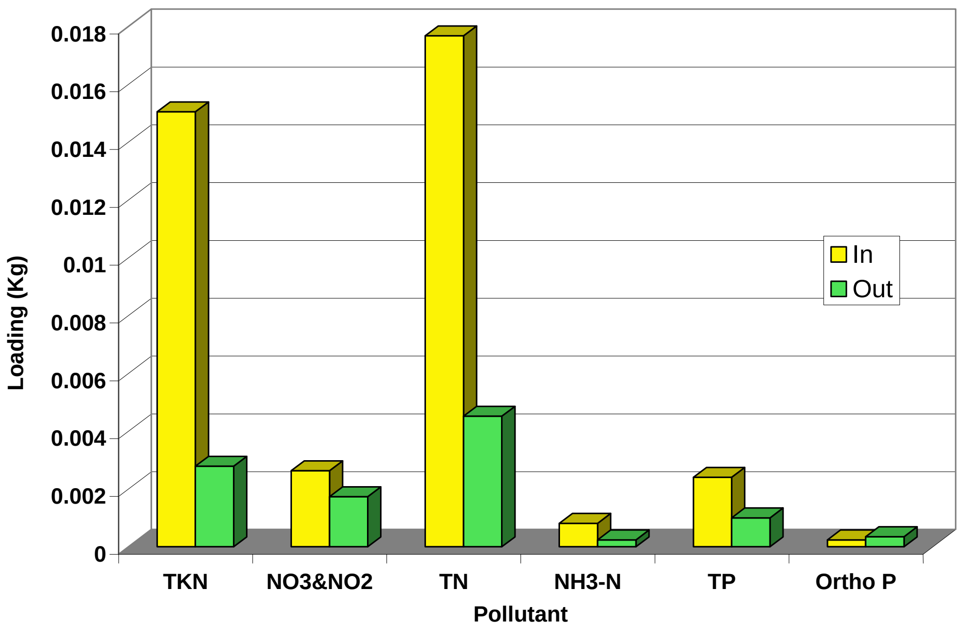

Figure 7 Nutrient Loads From PCJ Shallow

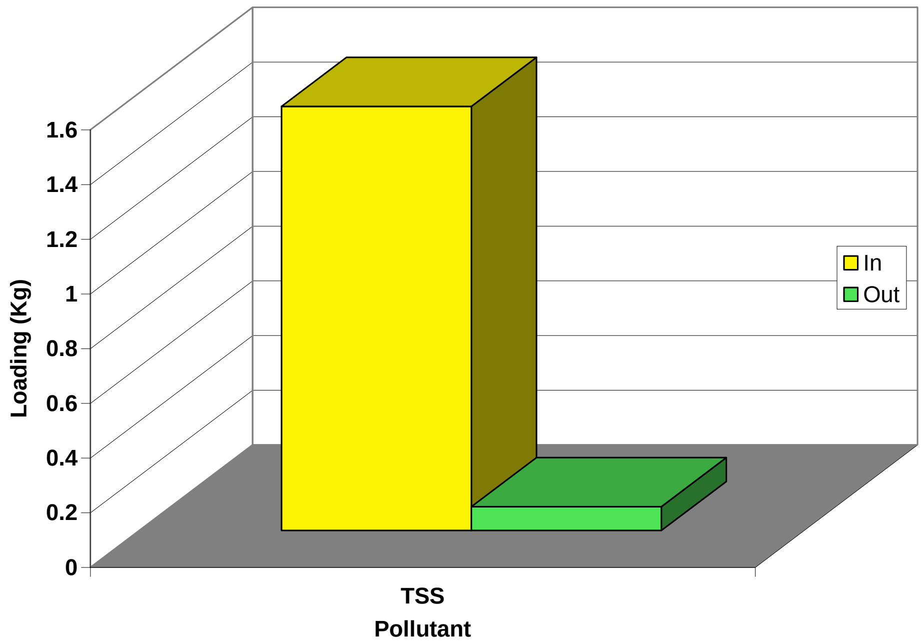

Figure 8 TSS Load in PCJ Shallow

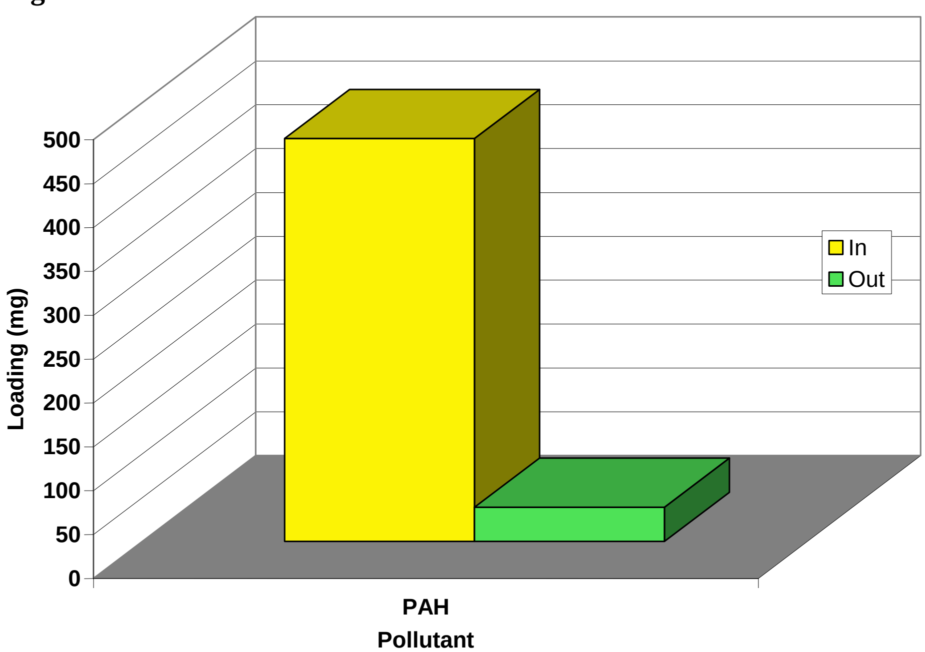

Figure 9 PAH Load in PCJ Shallow

When the effect of the reduction in volume from the shallow bioretention is considered there is a reduction in each pollutant except for Ortho P. The level of Ortho P is below regulatory limits. Similar results were found in the load reductions form PCJ Deep (Table 11, Figure 10, Figure 11, Figure 12).

Table 11 Pollutant Load from PCJ Deep

Deep Load (n=11)	Median Influent	Median Effluent	Reduction Efficiency
TKN (kg)	0.0284	0.0050	82%
NO3&NO2 (kg)	0.0065	0.0048	26%
TN (kg)	0.0349	0.0098	72%
NH3-N (kg)	0.0021	0.0004	80%
TP (kg)	0.0050	0.0016	69%
Ortho P (kg)	0.0005	0.0003	34%
TSS (kg)	2.3520	0.1343	94%
PAH(mg)	19.5773	0.6045	97%
Water Volume (L)	313580	138742	56%

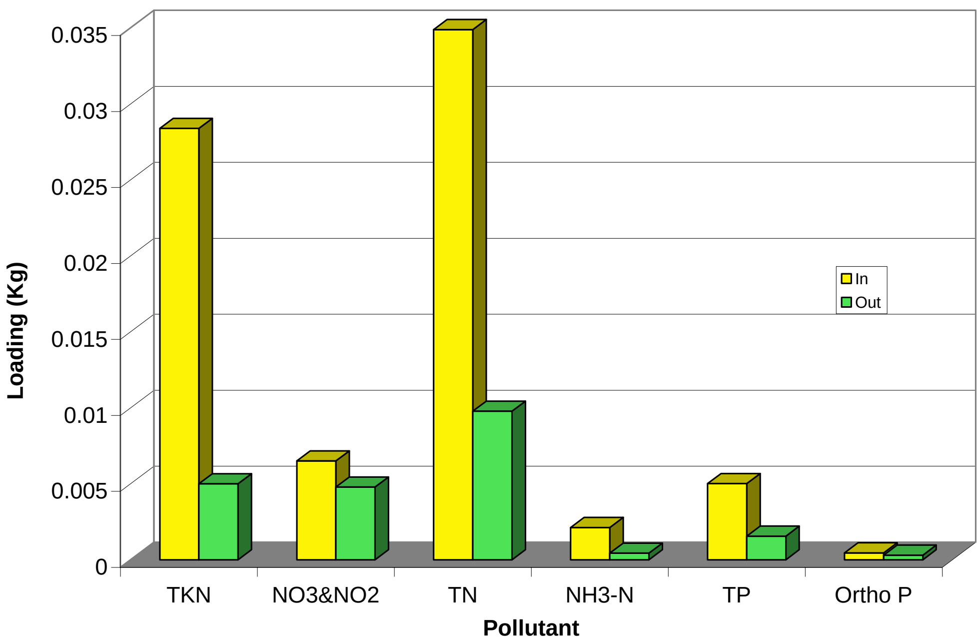

Figure 10 Nutrient Load in PCJ Deep

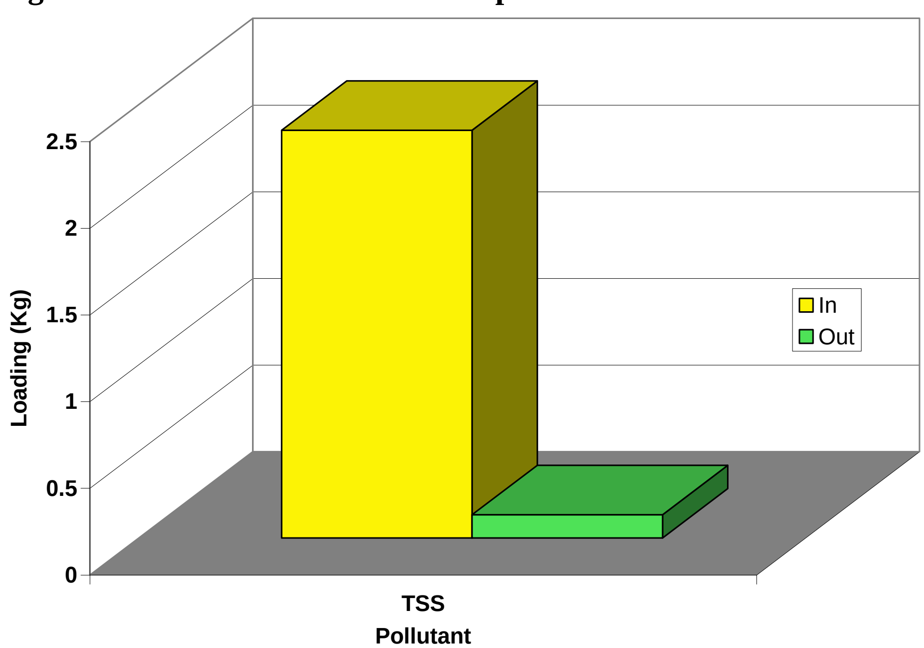

Figure 11 TSS Load in PCJ Deep

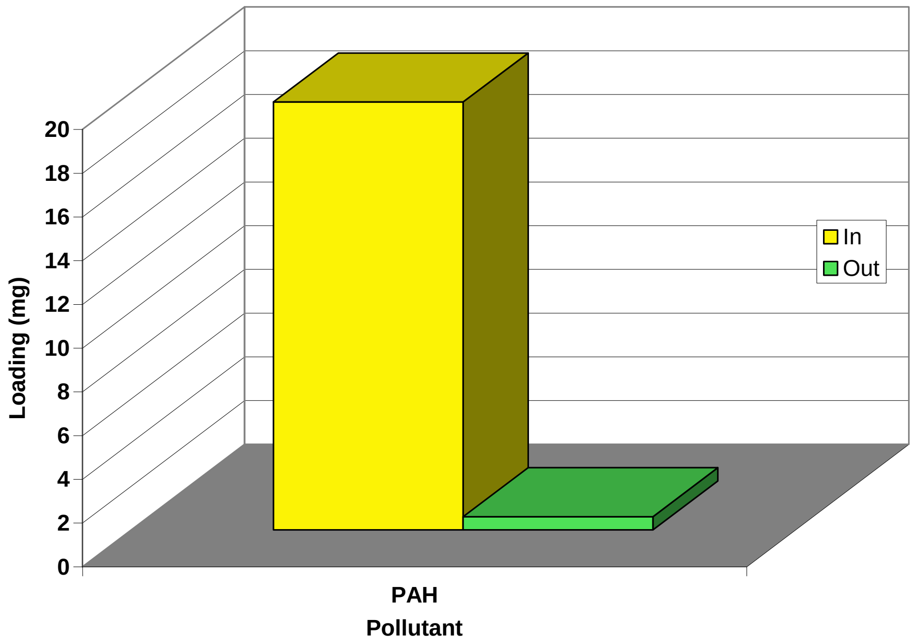

Figure 12 PAH Load in PCJ Deep

The deeper cell showed a slightly greater volume reduction. This, in conjunction with greater concentration reductions, showed reductions in each pollutant in the bioretention cell.

Stonesthrow Townhomes

Because of a malfunctioning sampler at the inlet samples were not collected between June and October of 2007. Table 12 shows rain fall data collected at the site and flow data from 10 storm events.

Table 12 Rainfall and Flow for the Stonesthrow Wetland

	Rainfall		Runoff			Outflow		
Date	accum in	dur. hr	vol. L	peak l/s	dur hr	vol. L	peak l/s	dur hr
July 31, 2007	2.20	0.28	28258	10.25	5.67	Reported Error		
October 25, 2007	1.19	0.13	48767	19.26	5.08	0.00		0.00
November 16, 2007	0.36	0.12	24327	7.46	19.33	0.00		0.00
November 27, 2007	0.26	1.35	35067	6.66	39.17	0.00		0.00
December 17, 2007	0.39	0.44	109863	26.52	23.08	25069	0.53	25.92
February 14, 2008	1.25	0.76	91744	23.04	20.75	40158	0.52	40.58
February 19, 2008	0.92	0.42	87360	40.39	10.92	Reported Error		
April 21, 2008	0.44	0.11	15807	7.77	5.00	0.00	0.00	0.00
August 14, 2008	1.01	0.75	127046	18.06	30.50	Reported Error		

Nine storm events were captured for concentration analysis from the Stonesthrow Stormwater wetland. The results are presented in Table 13.

Table 13 Concentration Reduction Efficiency from Stonesthrow Townhomes

N=10	Median Influent	Median Effluent	Reduction Efficiency
Fecal (CFU/100mL)	84623.80	2648.40	97%
Enterococcus (MPN)	1107.67	360.56	67%
TKN (mg/L)	1.20	0.30	75%
NO_3&NO_2 (mg/L)	0.26	0.05	82%
TN (mg/L)	1.46	0.35	76%
NH_3-N (mg/L)	0.12	0.03	79%
TP (mg/L)	0.26	0.08	68%
Ortho P (mg/L)	0.19	0.04	78%
TSS (mg/L)	30.57	4.98	84%

The Stonesthrow stormwater wetland showed high reductions in concentrations for all parameters. High reductions were observed partly because there were 4 storms where no outflow was recorded. Infiltration rates in the stormwater wetland were higher than typically observed in stormwater wetlands that allowed for a high volume reduction capacity. The water level between storms was observed to be lower than normal pool. On several occasions the deep pools dried out completely. The fact that the wetland was drier than typical stormwater wetlands my account for the high levels of pathogen removal. While overall there was a significant reduction in pathogens there were a few storms where there was an increase in pathogens.

Six storm events were used for the load reduction analysis. There were three events where the volume of flow was not able to be accurately determined. In these cases water from the ditch at the outlet of the wetland over topped the weir and caused a tail water condition at the outlet generating false readings in the water level meter. Figure 13 illustrates the conditions observed during those events.

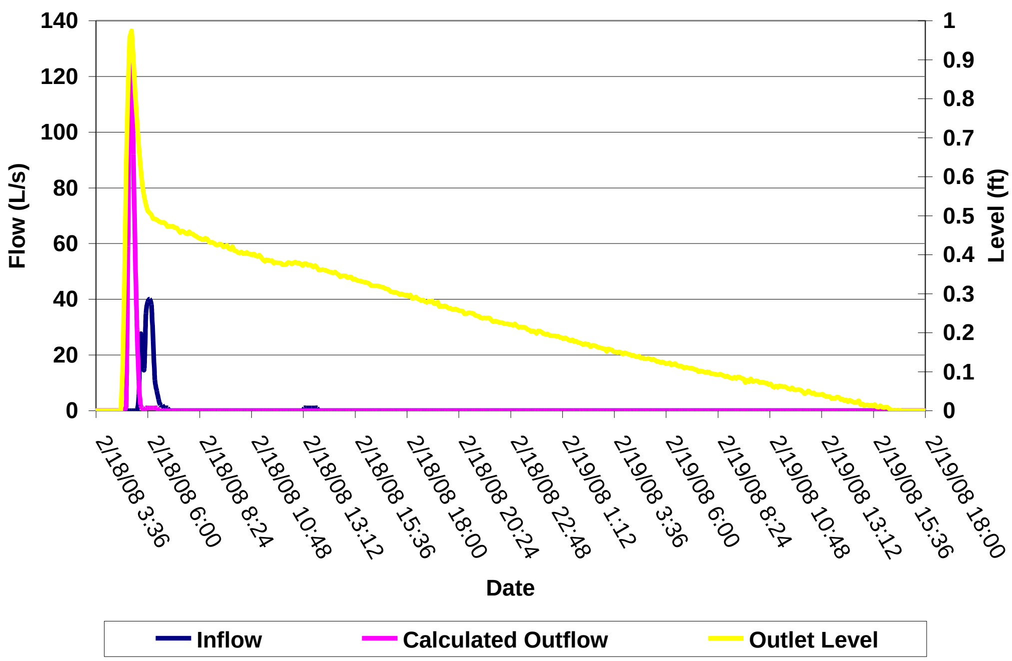

Figure 13 Example of Outlet Flow Tail Water Conditions

Figure 14 shows an example of outflow conditions where there is no tail water condition. The peak in the level and outflow conditions in Figure 13 gives the indications that the tail water conditions were present.

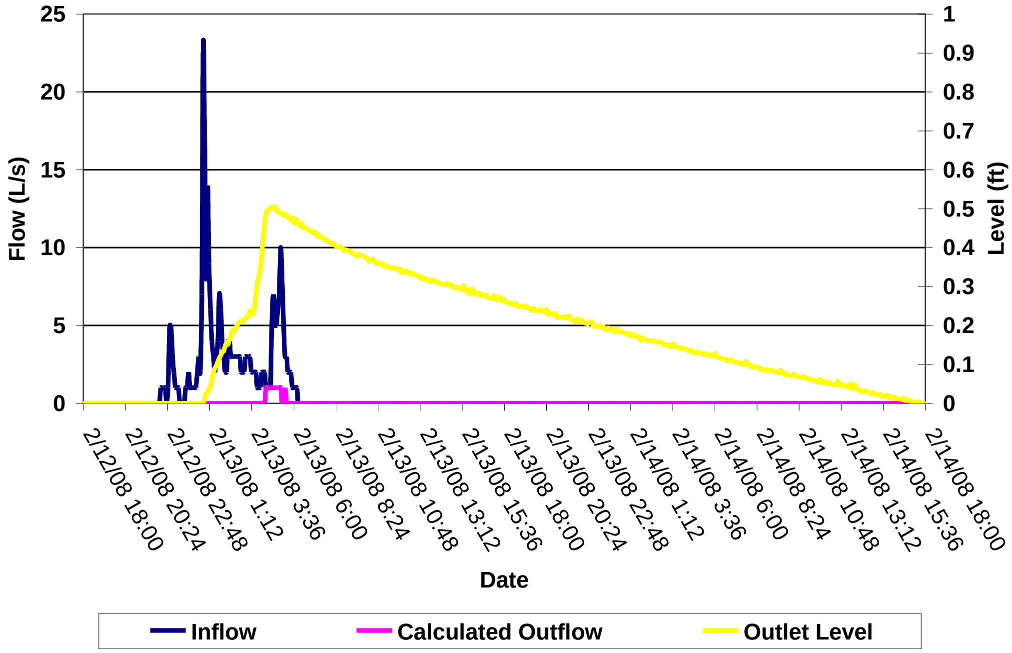

Figure 14 Example of Outlet Flow under normal conditions

When the volume reduction in the wetland was considered reduction efficiencies increased (Table 14, Figure 15, Figure 16)

Table 14 Load Reduction Efficiency from Stonesthrow Townhomes

N=6	Median Influent	Median Effluent	Reduction Efficiency
TKN (kg)	0.056	0.006	89%
NO3&NO2 (kg)	0.014	0.002	86%
TN (kg)	0.069	0.008	89%
NH3-N (kg)	0.006	0.001	91%
TP (kg)	0.015	0.001	90%
Ortho P (kg)	0.011	0.001	93%
TSS (kg)	1.511	0.140	91%
Water Volume (L)	325575	65227	80%

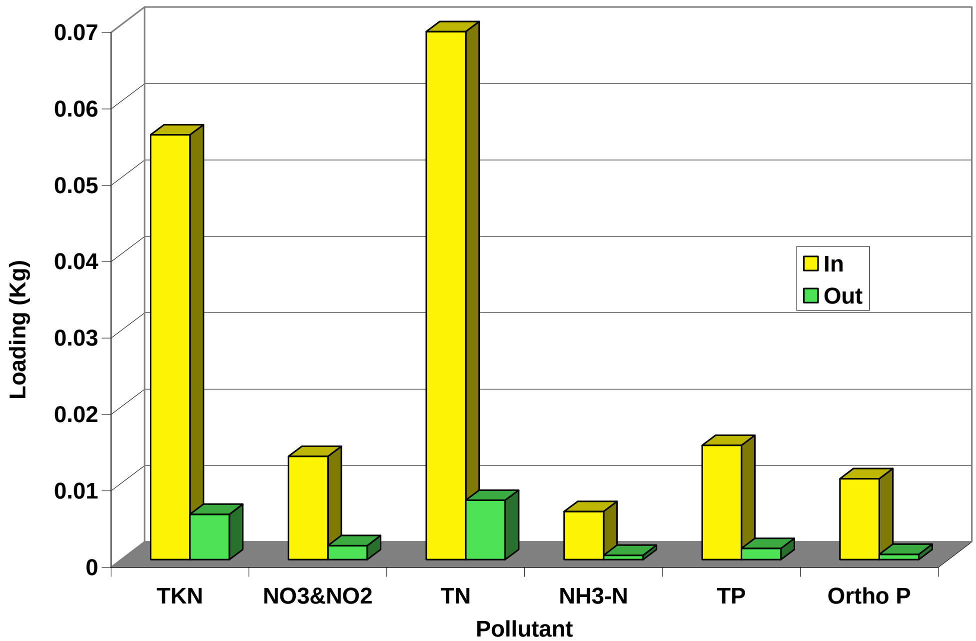

Figure 15 Nutrient Loads in the Stonesthrow Townhomes Wetland

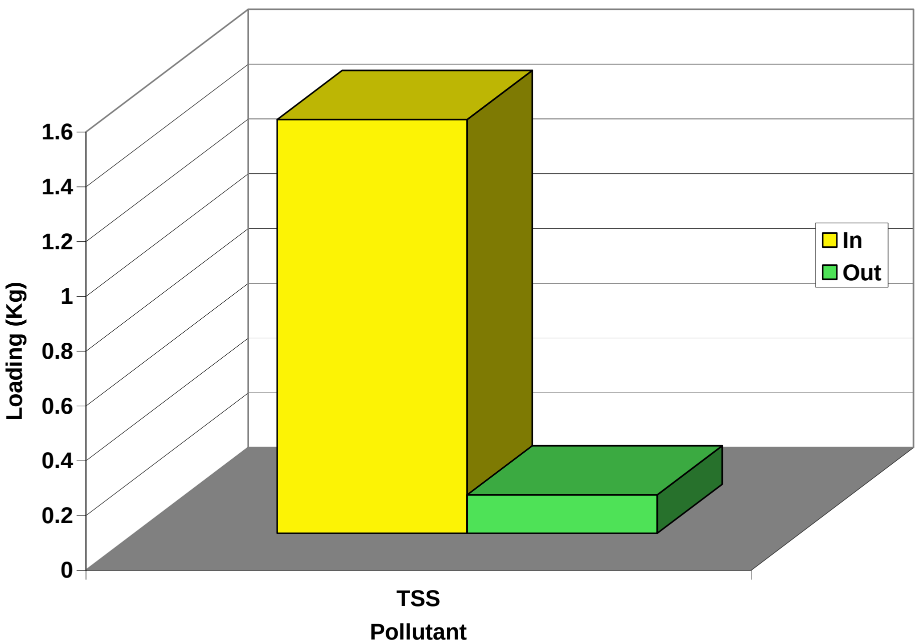

Figure 16 TSS Loads in the Stonesthrow Townhomes Wetland

High load reduction efficiencies were seen for all parameters.

Mary Bridgers

Because of the low number of samples that were collected no data analysis was performed. Data collection at the Mary Bridgers Stormwater Wetland was limited due to equipment complications and the later date that the equipment was installed. The data that were collected is presented in Table 15.

Table 15 Mary Bridgers Data Summary

	Date	Fecal (CFU/100mL)	Enterococcus (MPN)	TKN (mg/L)	NO_3&NO_2 (mg/L)	TN (mg/L)	NH_3-N (mg/L)	TP (mg/L)	Ortho P (mg/L)	TSS (mg/L
MB Inlet	August 28, 2007	37400	2005	1.75	0.20	1.96	0.08	0.35	0.13	145
MB Inlet	September 13, 2007	2700000	2005	5.28	0.66	5.94	0.07	0.88	0.31	327
MB Inlet	October 25, 2007	370000	2005	4.83	0.31	5.13	0.10	1.27	0.44	440
MB Inlet	August 1, 2008	48400	9210	1.21	0.28	1.49	0.20	0.30	0.12	113
MB Outlet	August 28, 2007	TNTC[1]	2005	1.47	0.07	1.54	0.05	0.33	0.10	15
MB Outlet	September 13, 2007	4600	2005	1.37	0.03	1.40	0.08	0.35	(NS)[2]	15
MB Outlet	August 1, 2008	265	20	1.15	0.08	1.23	0.07	0.18	0.01	38

[1] To Numerous To Count
[2] No Sample

The inlet pipe where the samples were taken was a 24 inch concrete pipe. The size of the pipe made sample collection difficult. Because of the large diameter the depth of water in the pipe was often below the detectable limits of the sampling equipment causing inaccurate flow measurements. Often the water level in the pipe was below the sampling tube causing "NO LIQUID DETECTED" errors with in the sampler. In retrospect, a small weir should have been installed in the pipe to monitor flow. Figure 17 shows the monitoring setup at the inlet. Sample analysis was also difficult because of the unexpectedly high Enterococcus and Fecal Coliform levels in the samples. For most samples the lab did not use the proper dilution levels rendering results that were to numerous to count. A result was estimated by the lab but in reality the pathogen counts were likely much higher than reported.

Figure 17 Mary Bridgers's Inlet

Water levels in Burnt Mill creek were found to be tidal, fluctuating as much as two feet multiple times a day. The tidal influence on Burnt Mill Creek had historically been controlled by use of tide gates. There was a breach around these gates which allowed the tide to have influence up the creek. City staff was working to fix this breach around the tidegates to prevent the fluctuation in the future. Because of this extreme tidal fluctuation water levels from Burnt Mill Creek flowed back into the wetland causing falsely elevated levels and high flows. Figure 18 illustrates the tidal fluctuation during a storm event on October 25th. Because of the flows from the creek the concentrations that were reported are most likely more representative of the concentrations in Burnt

Mill Creek rather than the concentrations found in the Mary Bridgers' Wetland causing any removal efficiencies that may be calculated to be inaccurate. Illustrations of the water level in Burnt Mill Creek for each storm event can be found in the appendices.

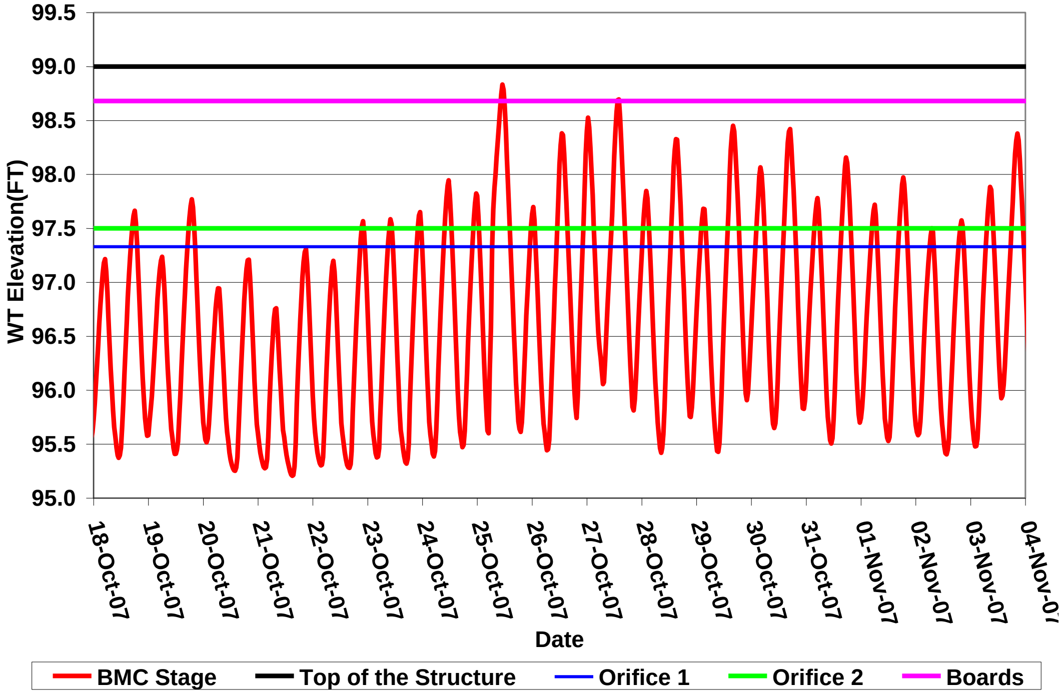

Figure 18 Water Levels In Burnt Mill Creek

The greatest challenge involved with constructing retro-fits in a highly urbanized area was coordinating with land owners. When the owners of Port City Java were first approached they declined because the time line of the project was not convenient for them. The timing of the project was critical because parking required for the normal operation of their coffee shop would have to be blocked off during installation of the bioretention area. A subsequent fire in the coffee shop caused the owners to rebuild the store, thus allowing the installation of the bioretention area to coincide with the reconstruction. This eliminated any construction disruption to their sales operation. Reported observations indicated that the bioretention areas are capable of treating the design storm of 2.5 cm (1 inch) with overflow when rainfall exceeded 2.5 cm.

Stonesthrow Townhomes was identified as a potential site because of a relationship between the homeowners association and the City of Wilmington. Several homeowner association meetings were attended by project personnel to present potential stormwater BMP projects that could be constructed to partially address concerns about flooding in the parking lot. During periods of drought the pools infiltrate causing drier conditions that would typically be expected in a wetland. This appeared to have no detrimental effects to the vegetation planted in the wetland and has provided more storage than expected.

The homeowners in the neighborhood surrounding Mary Bridgers park now consider the area to be an amenity to the neighborhood. Initial proposals were met with resistance; however, the majority of the homeowners were pleased with the project once it was completed.

Conclusion

Each of the stormwater BMPs installed has been well received by each of the land owners. All of the land owners have agreed to maintain the BMPs on their property, and have been provided BMP management guidebooks that were published by the City of Wilmington's Stormwater Services. All of the landowners were aware that stormwater runoff is an issue that must be addressed but were uncertain of how to proceed. More demonstration sites and education workshops will be required to guide them in the process and provide the educational tools needed.

The Port City Java Bioretention area appears to be performing as expected based on the load reductions. There were higher than expected loads with respect to ortho phosphorus, however, the concentrations where low enough that reduction efficiencies may be difficult. The deeper cell showed greater load reductions indicating that the deeper media is more effective for pollutant removal including TSS, PAH, and pathogens where the pollutant removal generally occurs at the surface. The deeper cell may have greater capacity for infiltration allowing the surface to dry more than the surface of the shallower cell. Moisture probes have been added at the surface of both cells to determine if moisture content at the surface is a factor in pathogen removal.

The Stonesthrow stormwater wetland appeared to be performing above expectations based on the load reductions due in most part to the drier than expected conditions. The wetland appears to be performing more like a bioretention area than a stormwater wetland infiltrating much of the stormwater that enters the wetland.

It is not possible to determine the performance of the Mary Bridgers' Stormwater Wetland at this time. While monitoring was difficult and it is not possible to directly quantify the reduction the wetland still has the potential to reduce the pollutant load to Burnt Mill Creek. The wetland treats runoff from the neighborhood surrounding the wetland and also directly treats the limited volume that flows into the wetland during high tide conditions. There are no visual indications that the wetland is not performing at least at the level of a typical stormwater wetland.

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Burnt Mill Creek Project Results and Conclusions

The project not only met, but exceeded the goals of the project. Community members were successfully engaged in identifying and implementing stormwater retro-fit BMPs on public and private (residential, commercial, and non-profit organization) lands. The impact of BMPs on water quality was monitored and evaluated. Some additional benefits that were not anticipated included:

- Building the capacity of Cape Fear River Watch staff and volunteers by training and experience in rain garden design, construction and maintenance
- Many residents provided cost sharing by installing gutters to prepare for a BMP
- The positive response of the Bottom Neighborhood exceeded our expectations- opportunities beyond this grant exist if funding can be found

As Burnt Mill Creek is an urban watershed, finding BMP retrofits that treated large drainage areas was difficult. Our strategy evolved as we realized that we needed to "get in the door" with landowners on smaller, but effective projects. Timing with landowners is an important factor that we cannot control for, but we can keep in mind. Our first approach to a commercial landowner was rejected due to market conditions and likely misunderstanding of what we were trying to do, however the same landowner two years later has invited us to approach him with a presentation. It took multiple contacts to connect with Port City Java due to their schedule and concerns, but once we were able to get in their door they were fantastic partners. One key to success in engaging landowners has been to offer to meet on their turf, on their time. As landowners have stepped forward to volunteer for retro-fit projects, the momentum has been building in this watershed. Media coverage throughout the project, signs, and word of mouth has helped to inform the community of the effort, and opportunities to participate. Our only barrier to completing additional projects above and beyond those included in the deliverables was limited staff time. The high levels of community involvement in this project took significant time and effort to coordinate. Working individually with landowners to educate them about the project, complete a design, and oversee construction takes time that must be budgeted for in watershed improvement projects.

We are encouraged that the data show the BMPs in general considerably reduced TSS and most nitrogen and phosphorus species passing through the systems. However, the creek still has problems with high fecal bacteria, algal blooms, low DO and high PAHs and Pb in the sediments. The algal bloom problem contributes to a low dissolved oxygen problem. The data suggest that capturing more runoff in future BMPs will continue to reduce nutrient inputs to the creek which will lead to multiple benefits. We are also encouraged that the BMPs at Port City Java greatly reduced PAHs, which appear to strongly impact the benthic macroinvertebrate community in the creek. The aerated BMPs effectively reduce fecal bacteria, thus more research and effort along these lines (especially in lower creek areas) should continue to be pursued. Tidal influence may be affecting the macroinvertebrate community in the lower watershed as well. The tidal influence on Burnt Mill Creek had historically been controlled by use of tide gates that are installed near the confluence with Smith Creek. A breach around these gates allows the tide to have influence up the creek. City of Wilmington is working on a fix for this breach around the tidegates. Continued retro-fits and stormwater management BMPS during redevelopment are needed to see measurable improvements in the creek. Were projects, such as the ones implemented in Burnt Mill Creek, to be implemented through out the watershed a measurable effect on Burnt Mill Creek could be observed. Increasing nutrient reduction to reduce algal blooms and reducing bacterial loading downstream from Ann McCrary Pond to Wallace Park, and further addressing the PAH issue is needed.

Given the high level of interest in participating in projects, we applied for and received a Clean Water Management Trust Fund grant to plan for more projects. Based on recent information about high PAH levels coming from coal-based parking lot sealcoats, we will investigate this issue more thoroughly to see if coal-based sealcoat is a potential contributor, and will attempt to focus future projects on parking lot retrofits similar to the Port City Java and Gregory Elementary parking lot retrofits.

Budget

Table 16: Original Budget, plus amendments and extension submitted Sept. 2007, (which included previous rebudget requests approved by NCDWQ between 11/04-08/07) and actual expend. Budget revisions reflected the changes in the project where work was conducted by NCSU staff instead of hiring contractors for BMP design and construction oversite. Hence funds were transferred from the BMP construction line item to staff time and supplies. Adding an extra year also required moving funds to staff time to allow us to approach and educate additional landowners for additional BMPs, and to add a public celebration at the end of the project. Financial efficiencies in construction and design left us with funding that we were unable to spend in the grant time period, although all deliverables were met and exceeded.

Source of Funds	Descriptions	Original Budget	Budget amended 2007	Actual Expend
Section 319(h)				
Staff	▪ Christy Perrin, WECO Program Mgr. to manage project and coordinate public involvement/education at 25% for 4 (originally 3) yrs. ▪ Patrick Beggs, WECO Project Coordinator to assist with all tasks at 10% for 4 (originally 3) yrs. ▪ Jason Wright, Dept. of BAE, to design BMPs and conduct water quality monitoring at 40% time for 4 (originally 3) yrs. ▪ Dept. of BAE assistant to collect monitoring samples at 20% time	$119,260	$196,720	$185,752
Benefits	For above staff at 23% for NCSU employees,(25% Nov 07-Aug 08)	$27,430	$46,226	$42,870
Travel	For travel to project area, sharing results at professional conferences, and any other travel needed to support project	$11,000	$17,250	$17,634
Supplies	Sampling supplies for Dept. of BAE, Computer (pro-rated) for collecting and analyzing data, survey equipment, facilitation supplies, materials for community LID retro-fit workshops, materials and plants for all BMPs, signs for BMPs	$30,550	$65,550	$80,884

Other	Sample analysis for Dept. of BAE monitoring (outside lab service)	$8,000	$8,000	$6,092
Other (Contracted services)	Cape Fear Riverwatch for contacting landowners, and intern to help with outreach	$10,000	$16,000	$9,588
Sub-Contractual	UNC-Wilmington for monitoring	$45,000	$60,000	$44,277
Construction	Contracted services for assistance with BMP construction	$300,000	$138,494	$129,842
Other (communications)	Long distance calls and postage for mass mailings of newsletters to stakeholders	$1,500	$2,000	$1,298
Other	Student aid	0	$2,500	$934
Other (overhead)	10% overhead	$55,274	$55,274	$51,917
Total Request		$608,014	$608,014	$571,089
Non-Federal Match				
Staff & benefits	Staff from Stormwater Services Dept. and Dept. Parks and Rec, City of Wilmington;	$25,200	$9,600	$15,240
Design & mgt. services	NC EEP for Mineral Springs/Burnt Mill Creek restoration design/mgt.	$180,000	$277,374	$187,302
Construction Feasibility study	NC EEP for Mineral Springs/Burnt Mill Creek restoration	$325,000	$10,165	$10,165
Construction	City of Wilmington to provide for BMPs and stream restoration on public property	$15,000	$39,253	$53,318
Other	Monitoring by Lower Cape Fear River Program, UNC-W	$30,000	$40,000	$52,000
Other	Cape Fear River Watch Center for meetings	$1,400	$1,400	$1,400
Other	Under-recovered overhead provided by University	$85,238	$88,438	$83,067
Total matching		$661,838 (44%)	$476,230 (44%)	$402,492 (41%)

Appendices: