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ENGAGING YOUTH IN IMPROVING BURNT MILL CREEK THROUGH HIGH PRIORITY STORMWATER RETROFITS

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Christy Perrin, Water Resources Research Institute
Dr. Bill Hunt, Jonathan Page, Bree Tillet; Dept. Biological and Agricultural Engineering, NC State University
Jennifer Butler, City of Wilmington Stormwater Services

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From the City of Wilmington:

David Mayes

Derek Pielech

Carl Scott and the rest of the Stormwater Services crew

Jay Carter and the Streets Division crew

From DREAMS of Wilmington

Matt Carvin

Amber Watkins

Emily Colin

Tracy Wilkes

Warren Wilson

Heather Kelijan , The Ability Garden

Eddie Anderson, New Hanover County School System

New Hanover High School

Ted Wilgus, NC Coastal Federation

Cape Fear River Watch

Sabrina Woofter, (formerly) New Hanover County Cooperative Extension

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1. Executive Summary

The restoration of Burnt Mill Creek, an urban stream impaired by impacts from stormwater runoff, continued with this effort to engage youth in stormwater management technologies for parking lots. Parking lot stormwater retrofits were installed at New Hanover High School and DREAMS of Wilmington (an after school arts center for at-risk and underserved youth) that will reduce stormwater runoff and associated pollutants to Burnt Mill Creek. New Hanover High School's parking lot was retrofitted with bioretention cells and bioswales designed to capture runoff from over an acre of parking lot that was previously untreated. Pre and post-retrofit monitoring of the parking lot revealed that the undersized practices are reducing stormwater runoff volumes, with modest pollutant removal. Monitoring of this highly used parking lot showed no detectable evidence of PAHs, a main contributor to the stream's impairment. As this lot also has no evidence of parking lot sealant being used, this can contribute to the evidence that abstaining from the use of parking lot sealants may be a strategy for preventing PAH pollution of the stream. At DREAMS of Wilmington, staff and students were involved at points throughout the entirety of the parking lot retrofit project. Students provided feedback during conceptual design, engaged in a day-long field trip to learn about the water cycle and stormwater, participated in a bioretention upkeep service project, and participated in several interactive learning activities about stormwater with guest speakers. The award-winning rebuilt parking lot includes a large bioretention cell that treats a half-acre of impervious asphalt, and permeable parking stalls. The success of this project was due in no small part to the commitment of DREAMS staff and City of Wilmington staff. Their dedication to ensuring the parking lot's successful completion and continued maintenance was evident throughout turnover in administrative staff at DREAMS, and an increased effort beyond that originally anticipated by City of Wilmington. While improvement to an intensely urbanized stream like Burnt Mill Creek is a long term endeavor, annual water quality monitoring contracted to UNC-Wilmington by the City of Wilmington shows a potential reduction in frequency of severe algal blooms in the creek in the last 3 years of monitoring compared to years 2007- 2012. Continued improvement of Burnt Mill Creek's watershed will be dependent on the ability and willingness of local stewards to support continuing efforts in the future.

2. List of figures and abbreviations

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Abbreviations:

Best management practices (BMPs)
Clean Water Management Trust Fund (CWMTF)
Copper (Cu)
Directly connected impervious area (DCIA)
lead (Pb)
Low impact development (LID)
North Carolina Division of Water Resources (NCDWR)
North Carolina Ecosystem Enhancement Program (EEP)
NC State University (NCSU) Department of Agricultural and Resource Economics (ARE
NC State University (NCSU) Department of Biological and Agricultural Engineering (BAE)
Nitrate-nitrite-nitrogen (NO_x-N)
Organic nitrogen (ON)
Ortho-phosphate (O-PO_4^{3-})
Polycyclic aromatic hydrocarbons (PAHs)
Runoff coefficient (ROC)
Stormwater Control Measures (SCMs)
total ammoniacal nitrogen (TAN)
Total suspend solids (TSS)
Total Kjeldahl nitrogen (TKN)
Total ammoniacal nitrogen (TAN),
total phosphorous (TP)
Water Resources Research Institute (WRRI)
Zinc (Zn

4. Introduction/Background

Burnt Mill Creek, in the lower Cape Fear River Basin, is listed as impaired for aquatic life and secondary recreation on the state's 303(d) list from impacts of urban stormwater runoff, including impacts from Chlorophyll *a*. In 2002, the NC Division of Mitigation Services (formerly NC Ecosystem Enhancement Program) completed a watershed plan for the creek. NC Division of Water Resources' Assessment Report of the Burnt Mill Creek Watershed (2004) identified toxic impacts from polycyclic aromatic hydrocarbons (PAHs) as a primary cause of biological impairment, with secondary and cumulative causes identified as sedimentation and nutrient enrichment. Stakeholders led by NC State University and City of Wilmington have been working together since then to implement watershed improvement projects such as those recommended in the NCDWQ Report:

- Feasible and cost-effective stormwater retrofit projects should be implemented throughout the watershed to mitigate the hydrologic effects of development.
- A strategy to address toxic inputs should be developed and implemented, including a variety of source reduction and stormwater treatment methods.

Figure 1: Burnt Mill Creek - lower portion

The team has installed several BMP retrofits so far with previous funding sources, including street retrofits with side and bumpout bioretention areas, tree treatment cells (Silva), and permeable parking lanes; large stormwater wetlands in Mary Bridgers Park and Stonesthrow Townhomes, parking lot bioretention at Port City Java, permeable pavement and bioretention at YMCA, bioretention and cisterns at schools, and 14 residential raingardens and 36 rainbarrels in the Bottom Neighborhood. Our team's previous monitoring of the Port City Java bioretention showed that bioretention provided significant reductions of PAHs from the parking lot, and additional research literature shows evidence of bioretention successfully reducing PAH loads. More recently, monitoring showed street retrofits to successfully reduce all pollutants in the runoff and reduced stormwater runoff volumes by 52% over the year-long monitoring period.

A literature search on PAHs by the PI (2012) found that commercial/industrial land uses, in particular parking lots, are likely the highest contributors of PAHs in urban runoff to streams. Research by NCSU on the watershed's first parking lot bioretention retrofit revealed a 76-91% reduction in PAHs leaving the bioretention area. This lot was observed to be sealed by some kind of asphalt sealant, likely the source of PAHs. As a result of the team's most recent research studying runoff reductions of street retrofits, they learned that while other pollutant removal was significant, PAHs in street runoff was negligible, illustrating that parking lots are a higher priority for stormwater treatment than streets if the goal is to reduce PAHs in the creek.

The ultimate goals for Burnt Mill Creek are to eventually remove it from the 303(d) list, and increase the safety for human and animal secondary contact with the creek. To achieve this will require the cumulative impact of many retrofit projects and redevelopment projects incorporating stormwater management. The work is happening, with each retrofit project and redevelopment cumulatively reducing the stormwater runoff and pollutants from 2004 levels.

Specifically, this grant project sought to construct two high priority parking lot retrofits that will provide stormwater runoff amelioration and treatment where none is occurring today, while engaging youth and educators in hands-on learning about watershed restoration through stormwater management.

5. Purpose and Goals

Goals of the project were to:

- Implement high priority parking lot stormwater retrofits at New Hanover High School and DREAMS of Wilmington (an after school arts center for at-risk and underserved youth) that will reduce stormwater runoff and associated pollutants (including PAHs) to Burnt Mill Creek.
- To leverage retrofit design and construction as a means to educate youth and adults about watershed protection and stormwater management through their involvement in helping design, construct, and maintain the stormwater retrofits at two educational facilities in the watershed.
- To better quantify pollutant reductions possible from parking lot retrofits so future parking lot retrofits can be designed to maximize pollutant reductions.

6. Deliverables

Finalized New Hanover High School retrofit designs

Project team staff met with New Hanover High School and New Hanover County Schools Facilities staff to review and finalize the parking lot retrofit designs, taking into considerations including retaining space in the parking lot for high school band practice, and low maintenance. New Hanover Schools staff were all supportive of the resulting retrofit project design.

One or more community and/or student workshop or charettes held to develop the concept plan for DREAMS site design

The American Society of Landscape Architects (ASLA) Cape Fear Region group offered to provide pro bono services to DREAMS and the City of Wilmington to develop an overall concept sketch plan for the entire site. They consulted with us in planning a charette for students to see pictures of various landscape elements (including stormwater control measures) and to share their preferences for the elements. NCSU/WRRI staff participated in the charette. The resulting concept sketch plan illustrates a parking area that includes bioretention and permeable paved parking spaces. We used this concept plan to inform the creation of a stormwater retrofit site plan.

Collaboration with DREAMS teachers and classes that results in students educated about watershed science

A project goal has been to foster a strong connection between DREAMS' students and their immediate environment, in particular increasing their understanding of stormwater and associated environmental issues, and deepening their interest in and concern for our natural world. The following activities engaged the DREAMS community throughout the entire span of the project, in leading towards that goal. The continued engagement of staff even during turnover of leadership ensures institutional memory going forward.

- A planning charrette was facilitated by the American Society of Landscape Architects Cape Fear Region group where students were involved with looking at various landscaping elements including stormwater BMPS.
- DREAMS staff, City of Wilmington, Cape Fear River Watch, NC Coastal Federation, New Hanover Cooperative Extension, and NCSU partners Water Resources Research Institute and Dept. Biological and Agricultural Engineering held a session to create on educational program plan to accompany the retrofit project.
- A presentation on creative stormwater retrofitting was shared with DREAMS teaching artists.
- Interactive watershed model presentations (using an Enviroscape) were provided to two arts classes in April 2015.
- Eleven middle school students participated in the field trip on March 31, 2015. They first visited Archie Blue Community Park on Burnt Mill Creek, where they learned how to look at and evaluate a stream. Their second site was Gregory Elementary School, where they learned about stormwater and rain gardens, and helped install plants to uplift the school's rain garden. Their third and last stop was Wrightsville Beach, where they participated in a stormwater BMP scavenger hunt at the NC Coastal Federation facility and waded in tidal creeks to look at aquatic animals and learn where stormwater ends up.
- A service event was held for high school DREAMS students and staff to learn about rain gardens and install mulch to uplift a school rain garden in April 2015.
- In spring 2016, two interactive presentations on stormwater problems and solutions were provided to an arts class, with a session held at the Ann McCrary Stormwater Park.

- A horticulture teaching artist is engaging a class in propagating perennials to supplement the plantings in the bioretention area.
- Two educational signs were created and installed on site about bioretention/rain gardens and permeable surfaces.

Concept plan and finalized DREAMS retrofit designs

Finalizing the DREAMS retrofit designs involved the following activities:

- DREAMS, NCSU/WRRI, City of Wilmington met to determine information needs, including City requirements, and how to coordinate with renovations to the DREAMS building
- NCSU project engineer surveyed the site and created a concept plan with permeable pavement and bioretention. He revised the concept plan based on DREAMS and City feedback.
- Changes to DREAMS' building renovation plans required revising the concept plan based on DREAMS desire to retain an existing drive-up canopy.
- An engineered design was provided to City of Wilmington Planning Department for a required review. After several comments were provided, the design was revised and re-submitted.
- The City approved the design.
- A pre-construction meeting with City of Wilmington staff and all partners.

New Hanover High School parking lot bioretention retrofit installation

The parking lot was retrofitted with four bioswales and three bioretention cells. Sod was planted in the bioretention cells and muhly grass was planted in the swales. Cape Fear River Watch volunteers installed the plants, which included muhly grass (muhlenbergia capillaris) in the bioswales and four river birches (Betula nigra) in the bioretention cells. An educational sign was installed.

Figure 2: Bioretention and bioswale at NHHS

Location: Latitude 34°14'09.69" North, Longitude 77°55'53.65" West

Size of treatment area: 48,969 square feet of parking lot

Size of bioretention cells/bioswales: 2,744 square feet total

Pollutant removal: See section of this document entitled: "Summary of Retrofit Monitoring Results" for details. The bioretention/bioswales reduced the runoff coefficient from 0.45 to 0.28, meaning that before SCM was built, 45% of a rainfall event became runoff, while 28% of a rainfall event became runoff after the SCM was built. Stormwater runoff volumes are reduced by 36%.

Yearly pollutant load reductions were not easily ascertained due to issues in the paired watershed research design, so expected pollutant load removals were calculated here using the Jordan/Falls Lake Stormwater Load Accounting Tool.

Table 1: Expected pollutant removals from NHHS retrofits

TN (lbs/yr)	TP (lbs/yr)	TSS (tn/yr)
8.9	1.0	0.36

DREAMS site retrofitted with bioretention, cistern, and permeable pavement

Figure 3:DREAMS parking lot before retrofit

The parking lot was retrofitted with a 2,540 square foot bioretention area in the middle of the parking lot, surrounded by an asphalt driving lane, and 16 permeable paved parking stalls (out of 24 required stalls) that total 2,400 square feet. The permeable pavement and bioretention were sized to detain and treat runoff from the 1.5-inch storm. The City of Wilmington Planning Department required following their parking lot landscaping ordinance, with landscaping areas surrounding the periphery of 3 sides of the parking lot. The bioretention was planted with cypress trees, and the landscaped areas were planted with muhly grass, Dianella grass, and Crape Myrtles. Additional plantings of lance-leaf coreopsis and gaillardia (blanket flowers) are planned from propagations by DREAMS students in spring 2017.

Figure 4: DREAMS parking lot bioretention area and sign

Location: Latitude 34°14'42.37" North, Longitude 77°56’14.28”" West

Size of treatment area: 19,204 square feet of parking lot (reduced by 530 square feet from 19,733)

Size of bioretention cell: 2,540 square feet

Size of permeable pavement: 2,400 square feet

Pollutant removal: The bioretention cell and permeable pavement were designed to capture and treat 1.5” of runoff. The bioretention cell removes 2,400 cu ft of stormwater runoff, while the permeable pavement removes 300 cu ft. of stormwater runoff. The following expected pollutant load reductions were calculated using the Jordan/Falls Lake Stormwater Load Accounting Tool

Table 2: Expected pollutant removals from DREAMS retrofits

Practice	TN (lbs/yr)	TP (lbs/yr)	TSS (tn/yr)
Bioretention cell	4.4	0.5	0.14
Permeable pavement	0.5	0.1	0.02
Totals	4.9	0.6	0.16

Educational signs installed at New Hanover High School and DREAMS site

An educational sign was created and installed at New Hanover High School. Two signs were created for the DREAMS parking lot based on City of Wilmington's required sign template. These are shown below.

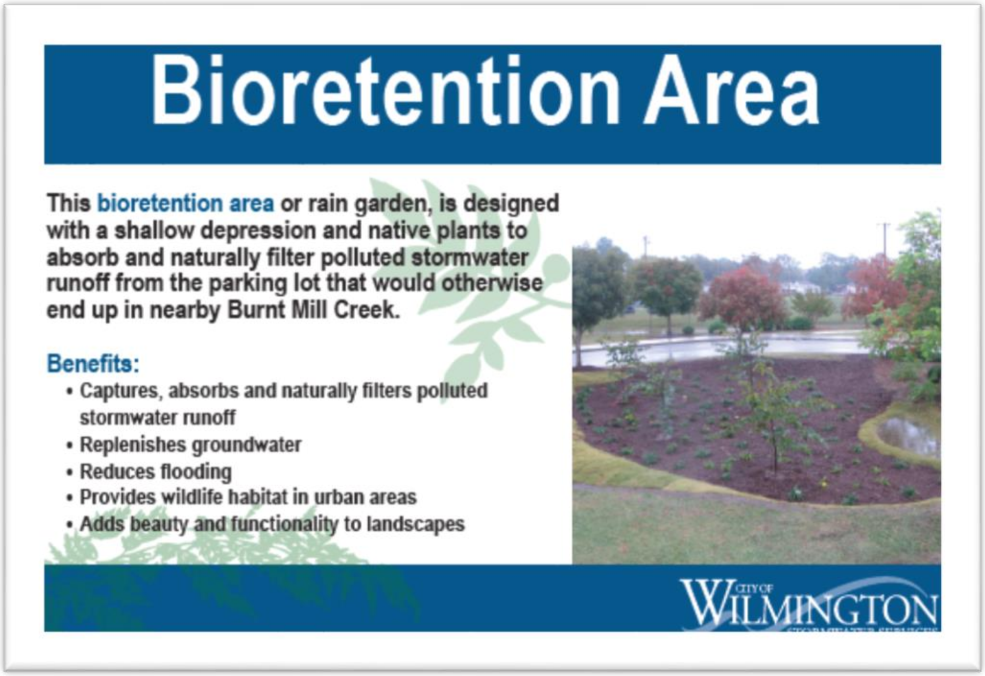

Figure 5: DREAMS parking lot bioretention sign

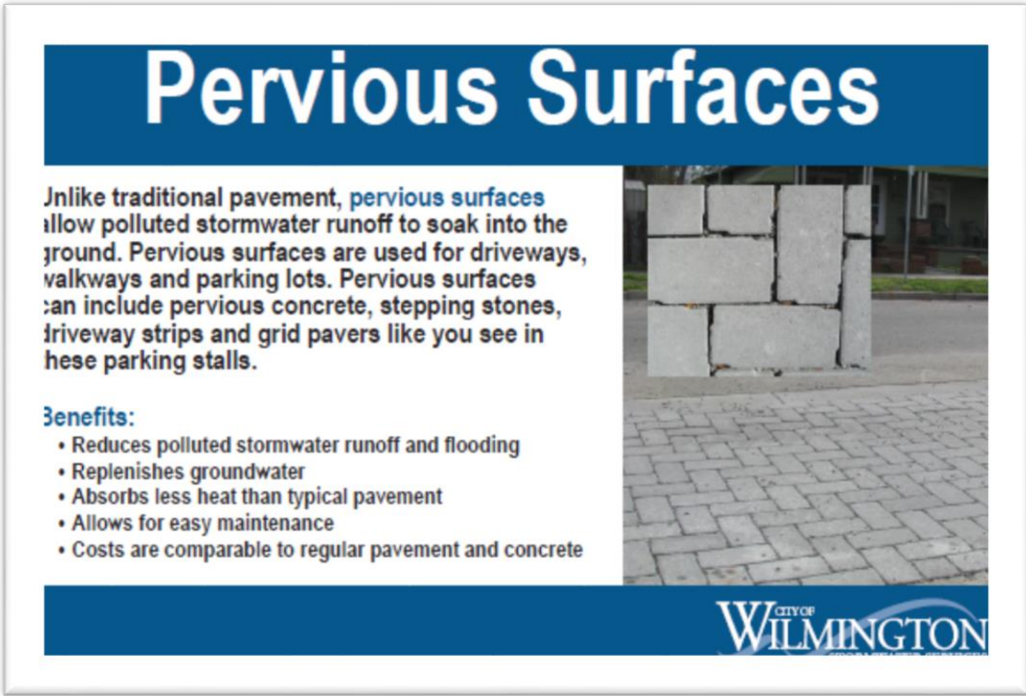

Figure 7: DREAMS parking lot permeable pavement sign

Figure 6: New Hanover High School sign

Maintenance event held at DREAMS with staff and students to teach maintenance of retrofits

A meeting between City of Wilmington stormwater staff and DREAMS staff was held in November 2016. Function and maintenance of the bioretention and permeable pavement was discussed. City of Wilmington staff will inspect and maintain the bioretention area infrastructure. DREAMS staff will maintain the plantings, mulch, and keep the permeable pavers from clogging. Maintenance supplies were provided to DREAMS staff to ensure they had the tools necessary to water the plantings and keep the permeable pavers free of materials that may clog them.

Monitoring report summarizing pollutant removal and stormwater volume reductions from New Hanover High School parking lot retrofits

From Bree TIllet, NCSU Department of Biological and Agricultural Engineering Masters graduate (2016)

Methods

The initial monitoring scheme for this project was a paired watershed design to evaluate hydrology and water quality of the parking lot. This approach requires two watersheds (Control and Retrofit) in a close vicinity and two monitoring periods (calibration and treatment). During the calibration period conditions within the watersheds remain unchanged. After the calibration period, a treatment is applied to one of the watersheds. In this case the retrofit stormwater control measures (SCMs) were installed in the Retrofit watershed. Overall 250 m^2 of infiltrating area was installed to treat a 4485 m^2 area. The Treatment period continues monitoring post-retrofit. The paired watershed method benefits from the removal of climatic variables affecting end results. Any change in the Retrofit watershed should be directly attributable to the retrofit treatment.

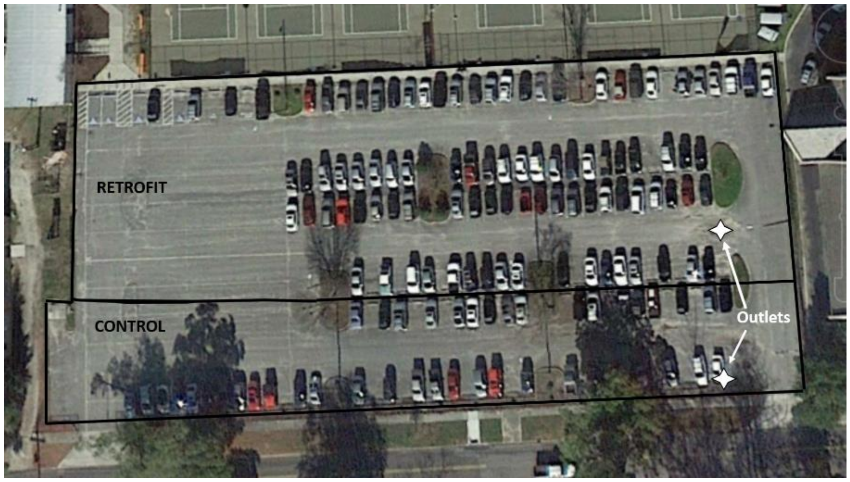

Figure 8: Planned NHHS parking lot monitoring treatment areas, before retrofit

The main challenge with this project was not discovered until the end of the monitoring period. As part of the southern system, two curb cuts were placed in one location to allow runoff to enter from either side. Storms of certain depth and intensity caused ponding within the cell to a height of the inlets. Any additional rain caused runoff to flow from the Retrofit watershed through the inlets and into the Control watershed and catch basin. After observing cross-over occur several times, it was determined that this was a very frequent occurrence. In effect, a new watershed was created during the Treatment period breaking the paired watershed assumptions.

Figure 9: Actual NHHS parking lot monitoring treatment areas, after retrofit

Table 3: Control & retrofit watershed parameters

Parameter	Watershed	
	Control	Retrofit
Drainage Area (m^2)	2015	4485
Length (m)	122	122
Width (m)	18	40
Impervious Fraction	0.97	0.95
Slope (%)	2	2
Soil Series	Leon Urban Land Complex	Leon Urban Land Complex
USDA Soil Class	Sand	Sand
Outlet Location	34.235754, -77.931037	34.235972, -77.931064
Receiving Water Body	Burnt Mill Creek	Burnt Mill Creek
River Basin	Cape Fear	Cape Fear

Monitoring equipment was installed in the Control and Retrofit watershed catch basins in February 2014. ISCO 6712™ portable automated samplers were installed near the catch basins. Ninety-degree V-notch weirs and weir boxes were mounted within the catch basins to accurately measure discharge and volume from the parking lot. ISCO 730™ bubbler flow modules were used in concert with the ISCO 6712™ to measure stage above the weirs at two minute intervals. Bubbler and sampler tubing were run under protective plastic speed bumps across the drive aisles into the catch basins. Samplers were powered by 12-volt batteries and an attached solar panel. Rainfall was monitored utilizing an automated gauge and manual gauge. A HOBO™ tipping bucket rain gauge was installed alongside a cylinder gauge on a wooden post in a clear area. The tipping bucket gauge was connected to the Retrofit ISCO 6712™ sampler and recorded rainfall in 0.25 mm increments on two-minute intervals.

The ISCO 6712™ samplers collected flow-weighted samples (200 mL) during storm events that were deposited in 1 of 24 1-L bottles. Flow weighting was adjusted based on expected rainfall amounts of incoming storms in order to capture at least 70% of the hydrograph. Samples were suctioned from the bottom of the weir box in an area of well-mixed flow. Water quality samples were tested for Total suspend solids (TSS), total Kjeldahl nitrogen (TKN), total ammoniacal nitrogen (TAN), nitrate-nitrite-nitrogen (NO_x-N), organic nitrogen (ON) total phosphorous (TP), ortho-phosphate (O-PO_4^{3-}), copper (Cu), lead (Pb), zinc (Zn), and polycyclic aromatic hydrocarbons (PAHs). TSS and nutrient species were analyzed by the North Carolina Center for Applied Aquatic Ecology (CAAE) at NCSU in Raleigh, NC. PAHs and metals were analyzed by NCDEQ Environmental Chemistry Lab in Raleigh, NC. The labs are located 210 km from the study site. Water quality samples were collected within 24 hours of a rain event. Only storms producing 2.5 mm to 51 mm of rain were sampled as long as 70% of the hydrograph was accounted for. Additionally, both samplers were required to produce collectable samples in order to maintain the paired watershed design. Gloves were worn while sampling and the samples were immediately placed on ice.

Hydrologic data were first reviewed within FLOWLINK Version 5.12 for any abnormalities. Rainfall amounts were adjusted by a scaling factor calculated by comparing the tipping bucket totals to manual gauge totals. Rainfall events were separated for storms with at least 2.54 mm of rain and a six hour antecedent dry period. The data were then exported from FLOWLINK for further analysis and transformation. Five-minute and hourly intensities were calculated from transformed two-minute rainfall data. For the missing rainfall events in the Calibration period only hourly intensities could be computed. Flow was calculated from the recorded two-minute stage data using the stage-discharge weir equation from ISCO. Metric conversions were made after computation. From the two-minute flow data cumulative volume, runoff coefficient (ROC), and peak discharge could be calculated for each storm. The ROC represents the fraction of rainfall that becomes runoff.

Water quality data from the labs came in the form of event mean concentrations (EMCs). Sampling for PAHs was ended several months into the Treatment period because all concentrations were below detection limits. For other constituents, any concentrations less than the reporting limit were assigned a concentration one half the reporting limit. Concentrations were converted to pollutant loads for each storm. SAS Version 9.3™ was used for all statistical analyses. Hydrology and water quality datasets were first tested for normality both visually and diagnostically. Inspection of histograms and quintile-quintile plots in combination with three goodness of fit tests (Shapiro-Wilk, Anderson-Darling, and Lilliefors) was used to make the decision. Data that were not normal were log-transformed and retested for normality. Any data that remained not normal were tested with non-parametric methods.

Due to the failure of the paired watershed design, simple tests were used to evaluate the Retrofit watershed pre- and post-SCM. If data were normal, a two-sample t-test was performed. Otherwise, a Wilcoxon rank-sum test was done. Comparisons were made between runoff depth, runoff coefficient, peak discharge, and all water quality variables. Data were analyzed for significance with 95% confidence (α=0.05). Additionally, runoff pollutant concentrations were compared to ambient water quality standards from various sources.

Results

Monitoring of the Calibration period occurred February 26, 2014 through July 3, 2014. In this time 16 hydrologic events were recorded, but three were eliminated due to technical difficulties. Rainfall for remaining storms to be analyzed ranged from 4.06 mm to 91.69 mm. The Treatment period lasted from September 6, 2014 to December 21, 2015. Seventy-seven events were recorded and 12 were removed due to equipment error. Rainfall for the events used in analyses for the Treatment period ranged from 2.54 mm to 64.01 mm. A "same season" comparison was made between Calibration events and Treatment events (March-June 2014-15). In the "Like-Season" Treatment period 17 events were recorded. During the Calibration period, 58% of rainfall was captured and used in analyses. In the Treatment period this number was 81%.

Three hydrologic variables were used as a metric in retrofit analysis: runoff depth, runoff coefficient (ROC), and peak discharge. Due to watershed area changes, runoff volume was normalized by area to be tested as runoff depth and peak discharge was normalized by area as well (L/s·ha). The Treatment period was much longer than the Calibration period, so the metrics were compared for the Like-Season Treatment events as well.

Means of the hydrologic variables during the Calibration and Treatment period are presented in Tables 2 and 3. Differences in medians and means for runoff depth and peak discharge point to the need for transformation of the data. ROC data were normal for both periods. Statistical testing using two-sample t-tests shows that the reduction in ROC is significant (table 2). The addition of the SCMs decreases the fraction of rainfall that becomes runoff.

Table 4 Means of hydrologic variables during calibration (CAL) and treatment (TREAT)

Variable	Mean		Reduction (%)	p-value	Significant Difference
	CAL	TREAT			
Runoff Depth (mm)	8.8	7.5	15	0.2528	No
Runoff Coefficient	0.45	0.29	36	0.0011	Yes
Peak Discharge (L/s/ha)	54.7	83.5	-53	0.8325	No

Summary statistics for the Calibration and Like-Season Treatment data resulted in similar distributions as for the full Treatment period (table 3) Normality testing of the Like-Season Treatment data showed that ROC was normal while runoff depth and peak discharge were log-normal. Two sample t-tests proved that the differences in ROC pre- and post-retrofit are significant (table 3) Scaling down to the smaller dataset did not improve results for hydrologic metrics.

Table 5: Summary statistics for Calibration (CAL) and Like Season (LIKE) treatment

Variable	Mean		Reduction	p-value	Significant
	CAL	LIKE	(%)		Difference
Runoff Depth (mm)	8.8	3.4	61	0.2300	No
Runoff Coefficient	0.45	0.28	38	0.0060	Yes
Peak Discharge (L/s/ha)	54.7	76.4	-40	0.7695	No

During the Calibration period, six water quality samples were collected, however one was discarded due to equipment malfunction. Rainfall for these events ranged from 9.40 mm to 91.69 mm with an average antecedent dry period of 90.9 hours. Seventeen water quality samples were collected during the Treatment period. Sampling events for this period ranged from 4.83 mm to 35.31 mm with an average antecedent dry period of 109.7 hours. The Like-Season rainfall ranged 4.8 to 31 mm and mean antecedent dry period of 99.67 hours. At least three storms per season were sampled for water quality.

Pollutant concentrations were not significantly different during either the Treatment period or Like-Season period. ON and TSS loads were significantly reduced (30% and 23%, respectively) by the SCMs for the full Treatment period. When the Calibration dataset is compared to the Like-Season data all pollutants but NOx-N and TAN are significantly reduced by the SCMs (48-84%) (table 4).

Table 6 Pollutant concentrations during calibration and Like season

Pollutant	Mean (g/ha)		Reduction	p-value	Significant
	CAL	LIKE	(%)		Difference
TKN	78.54	27.80	65	0.0061	Yes
NO_x-N	8.20	7.55	8	0.7517	No
TAN	5.87	2.44	58	0.0929	No
TN	86.74	35.35	59	0.0119	Yes
ON	72.66	25.35	65	0.0049	Yes
TP	9.86	3.60	63	0.0116	Yes
O-PO_4^{3-}	1.50	0.24	84	0.0072	Yes
TSS	4770	1717	64	0.0047	Yes
Cu	0.41	0.21	48	0.0165	Yes
Pb	0.31	0.10	67	0.0042	Yes
Zn	2.90	1.25	57	0.0222	Yes

Pollutant concentrations were also compared to ambient water quality thresholds as another means of determining SCM effects. McNett et al. (2010) determined the TP threshold for "Good" macroinvertebrate health in the Coastal Plain. NCDEQ set the TSS threshold for high quality waters in the state. Heavy metals thresholds, also from NCDEQ, are for acute aquatic toxicity.

Table 7 Pollutant concentrations compared to ambient water quality thresholds

Pollutant	Mean Concentration			Threshold	Exceedance Probability (%)		
	Calibration	Treatment	Like-Season		Calibration	Treatment	Like-Season
TP[1]	0.12	0.10	0.12	0.09	60	65	63
TSS[1]	67.8	51.9	64.8	20	80	88	88
Cu[2]	5.6	5.6	5.7	3.6	80	82	75
Pb[2]	4	4.4	3.3	14	0	0	0
Zn[2]	36	38	37	36	40	53	50

1: (mg/L) 2: (µg/L)

Additional analyses were conducted to characterize the parking lot's runoff in comparison to other asphalt parking lots. Overall, this parking lot has a larger average sediment concentration than other lots, which may be attributed to the age of the lot and erosional processes taking place at the surface. Copper and zinc average concentrations were lower than those found in other lots. This may be due to traffic patterns within the lot. As a school, cars only move in and out of the lot twice a day rather than continual overturn. Less traffic leads to lower metals concentrations. Nutrient concentrations in this lot were similar to other parking lots, including ones in the NC Coastal Plain.

A first flush analysis was also conducted for the parking lot. The pollutant load per millimeter of runoff was compared over several rainfall intervals to determine if the first portions of a storm contain the greatest amounts of pollutants. This analysis showed that for TN, TP, TSS, Cu, and Zn the load per millimeter of runoff was greatest in the first 12.7 mm (.5 inch) of rainfall. The Pb load per millimeter of runoff was greatest in the first 25.4 mm (1 inch) of rainfall. An example of the plot created is below.

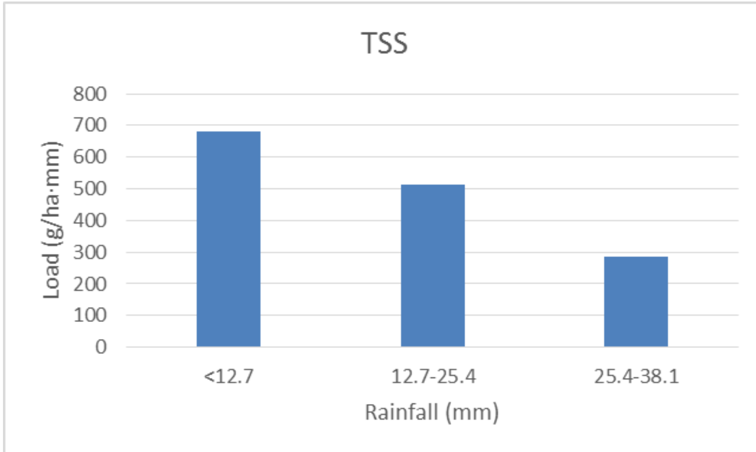

Figure 10 First flush analysis for TSS

Conclusions

Statistical analyses were limited by the disparities in sample size between the Calibration and Treatment periods. Future studies should ensure the pre- and post-retrofit datasets are of similar duration. Due to the failure of the paired watershed design, statistical analyses could not discount the effects of climatic variation between monitoring periods. However, the SCMs did decrease the runoff coefficient. Although there was not significant difference in pollutant concentrations, sediment was observed to accumulate within the SCMs. However, greater than 50% of TP, TSS, Cu, and Zn concentrations were above water quality thresholds set by the state and literature for aquatic health. The reduction of pollutant loads during the Like-Season analysis shows that the SCMs did have an impact on the parking lot when sample sizes were similar and climatic variation reduced. The age and condition of the parking lot affected the capacity of the SCMs to treat runoff. The eroding surface continually added sediment. Additionally, preferential flow patterns created by erosional features were sometimes contrary to expectations.

Future SCM retrofit designers should take the age and condition of a parking lot into consideration. More detailed topographic surveys may be needed to fully characterize existing flow patterns. Sediment may be the pollutant of concern in older lots, so SCM design should focus on sediment capture. Due to the apparent first flush effect, it may be more efficient for retrofit SCMs to be designed to capture the first 12.7 mm (.5 inch) of rainfall.

7. Methodology and Execution

See the preceding section for information about methods/execution of the New Hanover High School parking lot monitoring project.

Both project sites, New Hanover High School and DREAMS of Wilmington, were identified before the project started. Project designs were completed by Andrew Anderson, PE and Jonathan Page, EI. For the New Hanover High School parking lot retrofit, a draft design was created and provided to the principal, a science teacher who had expressed interest in engaging students, and New Hanover Public Schools Facilities director for review and feedback. Attempts were made but not fruitful in engaging students actively in the project as we had intended. Engaging high school students can be challenging given the existing workloads that teachers have, and this project was not an exception. We did provide passive education with a sign that provided information, photos, and a plea to students to prevent trashing of the bioretention areas.

Figure 11 NHHS BIoretention and bioswale

The DREAMS of Wilmington retrofit was the more comprehensive and holistic of the two projects. The project team initially included WRRI, NCSU BAE engineers, City of Wilmington Stormwater and Streets divisions, DREAMS of Wilmington staff and volunteers, then expanded for the educational efforts.

The design of the retrofit began with a planning charettte organized by the American Society of Landscape Architects (ASLA) Cape Fear region. The charrette engaged DREAMS of Wilmington students and staff, and was attended by NCSU staff. With feedback from the charrette, the ASLA group created a concept plan that was used to inform our design of the parking lot retrofit.

The design of the DREAMS parking lot retrofit had to meet the desired functions of DREAMS for parking, water quality improvement, and the City of Wilmington's development code for parking lots. Meeting the multiple goals and requirements took many months of review, feedback and changes that came during the City's development review process, and revisions of the design. The changes required an extension of the grant by 6 months to complete the construction.

As the City of Wilmington had committed to conducting demolition of the existing parking lot and construction of most of the DREAMS parking lot retrofits, there were several meetings and discussions to coordinate who bought which supplies, and who conducted which activities. While NCSU BAE engineers completed the surveying, engineering designs, and changes in design, City of Wilmington Stormwater and Streets crews demolished the old parking lot, conducted the site grading and excavation, excavated and constructed the bioretention, laid stone for the permeable pavement, and installed the curbs and asphalt driving lanes. Only the laying of permeable pavers and the installation of parking stops and drawing of parking stalls were contracted out. In the end, the City spent much more time and funding on the project than was originally anticipated.

Figure 12 DREAMS students spreading mulch

The process of engaging students happened at points throughout the project. Our project team was supplemented with a partnership with NC Coastal Federation, Cape Fear River Watch, and New Hanover Cooperative Extension, who helped plan and implement the educational involvement of DREAMS of Wilmington students. The team met and developed a plan for engaging students at the start of the project. A field trip was coordinated with the different partners to bring students to various points of the watershed down to the coast, to teach about stormwater and how our actions impact streams and the ocean. A service event involved older students to learn about bioretention and maintenance, while uplifting an older bioretention area in the watershed that was located at a school. Interactive presentations were provided to classes at different times during the project- at the beginning and during construction of the retrofit. Students were able to learn about stormwater and watersheds, then see how DREAMS was getting involved with helping reduce stormwater on-site. To help build institutional capacity for ongoing maintenance, DREAMS staff and volunteers were involved with installing the plants and mulch, and learning about site maintenance with City of Wilmington Stormwater staff. Staff were also engaged with selecting and purchasing equipment to help

Figure 13 DREAMS students learn maintenance while uplifting a school rain garden

them successfully establish and maintain the plants and permeable pavers. Finally, signs were created and installed to provide ongoing passive education about the parking lot features.

8. Outputs and results

See section 4 “Deliverables” for a complete and detailed explanation of all results. One minor change in deliverable #8 was seen, but everything else was completed as indicated.

1. Finalized New Hanover High School retrofit designs
2. One or more community and/or student workshop or charettes held to develop the concept plan for DREAMS site design
3. Collaboration with DREAMS teachers and classes that results in students educated about watershed science
4. Concept plan and finalized DREAMS retrofit designs
5. New Hanover High School parking lot bioretention retrofit installation.
6. DREAMS site retrofitted with bioretention, cistern, and permeable pavement.
7. Educational signs installed at New Hanover High School and DREAMS site.
8. Maintenance event held at DREAMS with staff and students to teach maintenance of retrofits. (A maintenance meeting was held at DREAMS with staff, but not students.)
9. Monitoring report summarizing pollutant removal and stormwater volume reductions from New Hanover High School parking lot retrofits.
10. Quarterly reports
11. Final report.

9. Outcomes and Conclusions

The methods described above allowed for the following outcomes to be reached:

- Resulted in 1.70 acres of impervious parking lot surface treated with stormwater control measures that was previously untreated.
- The two parking lot retrofits contribute to a total of ~40 acres of watershed retrofitted for stormwater treatment since restoration efforts began.
- Provided a sustainable parking lot that DREAMS of Wilmington can use to engage and educate both students and the parents and community members who park in the lot to pick up their children and attend events at the facility.

Figure 14 DREAMS parking lot permeable pavement

- Built the capacity of DREAMS of Wilmington staff to maintain the parking lot BMPs.
- Middle school students were engaged in interactive activities to learn about watershed science, stormwater management, and ways they could contribute to their local waterways' well-being.
- The DREAMS of Wilmington site/team will be presented with an Outstanding Stewardship Award for the project from the Lower Cape Fear Stewardship Development Association at the February 24, 2017 Awards Banquet.
- The New Hanover County Schools parking lot reduced stormwater runoff effectively, but had less than optimal pollutant removals, possibly because the uphill area was abrading.
- Monitoring of 3 in-stream sites by UNC-Wilmington in 2014-15 through a contract with the City of Wilmington showed one yearly large algal bloom that exceeded state standards for chlorophyll a of 40 ug/L and some minor algal blooms, low dissolved oxygen in the lower portion of the creek, and fecal coliform exceeding human contact standards in >80% samples at two of the three monitored sites. Fecal coliform can be attributed to non-point source runoff, illegal discharges or sanitary sewage leaks. TSS levels were below levels considered by UNC-W to be of concern for the lower Coastal Plain. PAHs were not sampled. Overall monitoring results across several years (2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015) were briefly compared. Year 2008 was not included as the data for that year was consolidated with three other years' data and not available for individual comparison. It is interesting to note that while an average of 4 major algal blooms exceeding state chlorophyll standards were reported annually in the five reports 2007 through 2012, in the three most recent 2013- 2015 reports only one major algal bloom per year were reported. It will be interesting to see if the reduced severity of algal blooms is a continuing trend.

In conclusion,

- Retrofitting stormwater control measures at youth educational facilities can yield additional benefits in addition to stormwater and pollutant reductions. Benefits include educating and empowering youth and staff to take actions to reduce stormwater pollution.
- Achieving educational benefits appears to require two or more staff members at the facility to be actively engaged throughout the planning and implementation, and to hand off that enthusiasm and responsibility when staff changes.
- PAH levels in the New Hanover High School parking lot were not detectable. Parking lot sealants were not observed to be used on this particular parking lot, lending evidence to the benefits of not sealing parking lots in this watershed as a strategy to control PAH pollution.
- The dedication of DREAMS of Wilmington and City of Wilmington partners to the goals of the project was very apparent and led to the successful completion of the project, despite complete turnover of leadership during the project (at DREAMS), and an overrun of budgeted cost sharing time and expenses (by City of Wilmington).
- Each additional retrofit completed in Burnt Mill Creek watershed is contributing to a slow but cumulative reduction of runoff and associated pollutants that reach the creek and enter into downstream Smith Creek. Potential improvements in the creek may be evidenced by a reduced number of observed annual algal blooms in exceedance of state standards within the last few years. More investigation is needed to determine if any improvement has actually occurred, and whether any improvement is due to retrofitting, and/or other activities in the watershed such as behavioral changes.

10. Budget

Table 8 Actual and budgeted expenditures

	Federal request	Matching funds
Budgeted in contract	$198,938	$132,626
Actual expenditures	$198,557	$173,566
Difference	$381	($40,940)

11. References

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Watershed Education for Communities and Officials and NC Wetlands Restoration Program. 2002 Watershed Plan Summary for the Hydrologic Unit Containing Burnt Mill, Upper and Lower Smith, Prince George.

12. Appendices

Map of watershed with BMPs located
Retrofit engineer plan sheets for DREAMS
NHHS Hob Nob Wilmington story
NC ASLA Concept Plan for DREAMS site