Final Report: 

Falling Creek/ Southwest Creek BMPs for Low Impact Development (LID) 

A 319(h) project sponsored by NC DENR – Division of Water Quality

FY 04 – NC DENR Project # EW05082

Contract Period: 6/20/05 – 9/30/08
Total Project: $268,084
Requested 319 (h) funds: $165,273

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Report Submission Date: September 15, 2008
Acknowledgements
This project was funded under an EPA Section 319(h) grant administered by the North Carolina Department of the Environment and Natural Resources’ Division of Water Quality. Several agencies provided tremendous support during this project, most notably the City of Kinston. Other supporting entities were the County of Pitt, and the town of River Bend. The authors would like to particularly thank Mr. Scott Stevens, City Manager for the City of Kinston, Mr. Danny Lauderdale of Pitt County Cooperative Extension, and Mr. Charlie Humphrey of Craven County Cooperative Extension. Lastly, several students and faculty of Biological and Agricultural Engineering brought these projects to fruition: Ms. Kelly Collins, Mr. Jon Hathaway, Mr. Hayes Lenhart, Mr. Shawn Kennedy, and Ms. Gabrielle Skipper.

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Executive Summary

The original scope of this project was to install and evaluate two-three practices that were earlier identified by the Mid-Neuse NPS team as being likely installed in the coastal plain of North Carolina. The three practices that were particularly examined were permeable pavement, cisterns/water harvesting, and a green roof. The contract was later amended to deliver level spreader workshops and then again to monitor a stormwater wetland and deliver the Low Impact Development Summit in Asheville, NC.

The centerpiece of the grant was a 20 stall permeable pavement parking lot constructed in Kinston, NC. The lot demonstrated and evaluated four different types of permeable pavements (pervious concrete, concrete grid pavers filled with sand, and two types of permeable interlocking concrete pavement systems with two gap sizes). Results from the study showed that (1) all 4 pavement types performed very similarly and (2) they were substantially better than standard asphalt with respect to runoff reduction and for some pollutants. Per this research, NC State Biological and Agricultural Engineering does not recommend to NC DENR to treat any permeable pavement type with preference. There were two potential findings that do need further analysis: (1) the concrete grid pavement filled with sand, did seem to reduce nitrogen concentrations in the outflow; whereas, the other 4 pavements did not. (2) By inadvertently creating a sump in the bottom of one permeable pavement section, the amount of infiltration to the underlying soil dramatically increased. While designing a sump under the permeable layer is not currently part of the permeable pavement design standard, perhaps it should be. NC State recommends that this design feature be examined in more depth in the near future, as it may produce more infiltration from permeable pavement systems.

Several cisterns were installed (Kinston and Greenville). The cistern in Kinston was monitored for over 1 year to determine how much annual water could be captured. Two different water uses were employed: (1) vehicular washing in Kinston and (2) irrigation in Greenville. Unfortunately, at both sites the tanks often remained near capacity, meaning that most storm events bypassed the cisterns and directly entered the storm drainage network. The study demonstrated the requirement that cistern water have a required/dedicated – and not optional – use associated with it. This appears to be a major hurdle for widespread cistern approval by NC DENR. A second study is currently underway to evaluate 4 more cisterns with dedicated water uses; this study is also funded by NC DENR’s 319(h) program.

A green roof was installed at the Pitt County Arboretum and is now a focal point of that garden. The monitoring of an approximately 0.5 acre stormwater wetland installed in River Bend (Craven County) was partially supported by this project. The wetland released pollutant concentrations similar to those of nearby streams, but from a percent removal standpoint, there was little to no improvement. One major finding of the wetland examine was that it reduced outflow volumes substantially. Being that volume reduction is a tenant of Low Impact Development (LID), perhaps some stormwater wetlands should be considered an LID practice when used in Eastern North Carolina.

Several trainings were held in conjunction with this grant, with the highlight being the Low Impact Development Summit in Asheville, NC, on June 23-34, 2008. Nearly 300 people attended this event, with over ½ that number hailing from North Carolina. Several resources, notably a water harvesting model, were created as part of this project and are now available to the general public.
The model is available on the following website: www.bae.ncsu.edu/topic/waterharvesting. It continues to be amended thanks to the previously mentioned 319(h) grant.

**Project Deliverables**
The initial project was comprised of nine deliverables. Per an agreement with Ms. Kimberly Nimmer, administrator of the project with NC DENR, two more deliverables were added in December 2004. All eleven deliverables are listed below. Additionally, a brief description of how each was accomplished is given.

1. **Four Types of Permeable Pavement will be demonstrated and evaluated at the city of Kinston’s Public Works Department**

   A 20-stall parking lot was constructed at the Kinston, NC, Public Utilities Department in December 2005 and January 2006. Monitoring assembly was installed by April 2006, and reliable data collection began in June 2006. Data collection continued until July 2007.

2. **A Green Roof will be constructed at the Pitt County Arboretum**

   A pavilion green roof was constructed at the Pitt County Arboretum in March 2006.

3. **Rain Catchments such as cisterns and rain barrels will be installed at an institutional setting and at 2 residences/government operations**

   Two large above ground water harvesting systems were installed in Kinston and Greenville. The Kinston cistern was 5000 gallons and supplied water to wash the City’s motor fleet. It was located at the Public Utilities Complex. The Greenville cistern was 3000 gallons and supplied water for irrigating the grounds of the County Extension Center. A smaller, 500-gallon, cistern was installed to receive runoff from the green roof mentioned previously. Its primary purpose is for demonstration. Finally, a 500-gallon cistern was installed at a residence (the Riggs family) in Greenville.

4. **Evaluation of construction site runoff to determine nutrient loading at the Public Works Department**

   An attempt to monitor nutrient concentrations associated with construction was made during the Kinston parking lot construction. However, no samples were able to be collected due to lack of generated runoff. However, a second attempt to collect construction site runoff was made in Raleigh at the NC Art Museum in Winter 2008, and these data are presented herein.

5. **Instructional Guidelines for Citizen Use of Rain Catchments, including sizing and fertigation specifications. This will result in the printing and distribution of 2000 factsheets.**

   The water harvesting pump sizing factsheet was completed and posted on-line at www.bae.ncsu.edu/stormwater/PublicationFiles/Pumps4cisterns.pdf. It has been distributed as part of subsequent workshops to 100’s of design professionals.
6. The effectiveness of the permeable pavement types will be evaluated for water quality and water quantity. Design recommendations based upon this and other studies will be presented to NC DENR-DWQ to facilitate design standards of permeable pavement.

Four permeable types were evaluated and found to uniformly and substantially reduce runoff. Most of them positively impacted water quality, as well. However, one type of pavement system appeared to preferably remove total nitrogen: concrete grid pavers filled with sand. A journal article was written and is now in press (slated for publication in December 2008 in the *Journal of Hydrologic Engineering*). Recommendations have been made to NC DENR to ___ treat different permeable pavement systems differently.

7. The effectiveness of cisterns and rain barrels will be evaluated with respect to water quality and captured quantity.

Two cisterns were monitored (in Greenville and Kinston), with more effort dedicated to the latter project. Water was underutilized at this site. It is highlighted in the proceedings of the 11th International Conference on Urban Drainage and is attached in the appendix.

8. Six Field Days and/or Workshops to be held demonstrating the effectiveness of home water harvesting and/or permeable pavement.

This deliverable was met by the following activities:

- Data from the Kinston Cistern was presented at a Green Roof and Cistern Workshop in Raleigh on February 2, 2006.

- Another two detailed presentations on the Kinston and Pitt County Cisterns were made in Asheville at another Green Roof & Cistern Workshop on June 21, 2006.

- A BMP Ask the Researcher Training was held in Raleigh on December 6, 2006. Over 80 people attended. Data from the Kinston permeable pavement presentation was presented, as was information collected from the Pitt County Green Roof.

- The Pitt County green roof was also incorporated, as part of a the field tour in the Stormwater BMP Inspection and Maintenance Certification training held in Greenville on September 1, 2006. Approximately 55 people attended.

- A city of Kinston information workshop was held in March 2007. Ms. Collins presented the permeable pavement and Kinston cistern findings to city officials and community leaders.

- An “LID Technologies: Permeable Pavement and Water Harvesting System” workshop was conducted in Wilmington December 7, 2007

- An “LID Technologies: Permeable Pavement and Water Harvesting System” workshop was held in Raleigh December 17, 2007, extensively featuring results of this project.
• A permeable pavement design workshop and a cistern design workshop were held in Asheville in June 2008. A permeable pavement design workshop was held in Raleigh in August 2008. Among all 3, there were more than 150 attendees.

9. A stormwater wetland will be evaluated in River Bend, NC, for water quality and hydrology.

A stormwater wetland was evaluated for water quality and hydrology in River Bend from January – June 2008. Findings from this study are part of the following thesis:

A North Carolina field study to evaluate the effect of a coastal stormwater wetland on water quality and quantity and nitrogen accumulation in five wetland plants in two constructed stormwater wetlands, by Hayes A. Lenhart. It is available at the following website: http://www.lib.ncsu.edu/theses/available/etd-08132008-150224/

10. An LID training event, entitled the “Low Impact Development Summit” will be held in Asheville.

The Low Impact Development Summit was held in Asheville on June 23-24, 2008. Nearly 300 people (297) attended the Summit from 19 different states. Approximately 65% of attendees were from North Carolina. One-half day post conference workshops and field tours were held on June 24.

11. A final report will be submitted upon completion of the research project.

Presented herein.

Project Component Discussion
Several portions of the project are highlighted in the following section, including the Kinston permeable pavement study, the water harvesting analysis conducted on the cistern used to supply water to the vehicular wash, the construction nutrient runoff study, and the stormwater wetland study. Each is presented below.

Permeable Pavement Evaluation
Site description
A 20-stall employee parking lot was constructed in January 2006 at the City of Kinston Public Service Complex in eastern North Carolina. The lot was comprised of six 6 m by 18 m pavement sections: two standard asphalt sections each containing two parking stalls and four different permeable pavement sections each containing 4 parking stalls (Fig. 1). The four permeable sections were comprised of the following types of pavement:
- Pervious concrete (PC),
- Permeable interlocking concrete pavers with 12.9% open surface area and openings filled with No. 78 stone (PICP1)
- Concrete grid pavers with 28% surface open areas and opening filled with sand (CGP)
- Permeable interlocking concrete pavers with 8.5% surface open areas and openings filled with No. 78 stone (PICP2).
On the ends of both asphalt sections, 3 m x 6 m asphalt entranceways were hydraulically disconnected from the rest of the lot. The lot was surrounded by a concrete curb to prevent any run on from areas surrounding the lot.

Figure 1. Permeable pavement parking lot design (plan view).

All permeable sections overlaid a washed ASTM No. 78 stone aggregate bedding layer and a washed ASTM No. 5 stone base course layer, the depths of which varied slightly based on the product specifications of the overlying pavement types. For ease of installation, the excavation depth beneath permeable pavements was kept consistent. Each pavement section was designed to be hydraulically separate from the other sections. Thirty mil thick (0.75 mm) LLDPE plastic sheeting was trenched between each pavement section to prevent any subsurface flow from one pavement section to the next. 6.5 cm high asphalt berms were placed to prevent surface flow migration from one pavement section to another.

Due to the low permeability of the in situ soils, perforated corrugated plastic pipe (CPP) underdrains (d=10cm) were installed at the bottom of the each permeable pavement aggregate base course layer to drain water from the system, thereby creating separate “cells.” The aggregate subbase of each permeable pavement section sloped to the corrugated underdrains in the center of each pavement section at a 30:1 side slope. The pavement cells were unlined, to allow for some potential exfiltration of water into the subsoil.

The entire parking lot, excluding the entrance ways, was designed with a 0.42% surface and sub-grade slope to provide drainage and allow for monitoring. Surface runoff from each of the six pavement sections drained to a partitioned gutter and then to a monitoring vault, where flow was measured over 30 degree, galvanized steel v-notch weirs. The underdrains from the four permeable
sections also flowed to the monitoring vault where four additional weir boxes measured subsurface drainage flow rates.

Results and Discussion
Fig. 2 illustrates the typical response of a permeable pavement section following a rainfall event. The majority of the stormwater left the permeable pavement cells as subsurface drainage from the underdrains. This is also where permeable pavement peak outflows were observed. Total permeable pavement outflow was defined as the sum of surface runoff and cell subsurface drainage for a particular section. Exfiltrate, which was not monitored, referred to water that entered the soil underlying the permeable sections.

![Figure 2. Asphalt runoff and CGP runoff and drainage for 32.8 mm event on 7/3/2006.](image)

Surface Runoff
Between 40 and 44 events were examined for runoff reduction. When compared to asphalt, all four permeable pavement sections dramatically reduced surface runoff volumes. The marked reductions in permeable pavement surface runoff were similar to results found by Bean et al. (2007b) and Brattebo and Booth (2003) on unclogged pavement sites. Mean runoff reductions from rainfall depth were 34.7, 99.9, 99.3, 98.2, and 99.5% for asphalt, PC, PICP1, CGP, and PICP2, respectively (Table 1).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Asphalt (n=44)</th>
<th>PC (n=40)</th>
<th>PICP1 (n=41)</th>
<th>CGP (n=40)</th>
<th>PICP2 (n=40)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MEAN</strong></td>
<td>34.65</td>
<td>99.86</td>
<td>99.33</td>
<td>98.17</td>
<td>99.51</td>
</tr>
<tr>
<td><strong>MEDIAN</strong></td>
<td>29.43</td>
<td>99.94</td>
<td>99.37</td>
<td>98.67</td>
<td>99.68</td>
</tr>
<tr>
<td><strong>MIN</strong></td>
<td>-2.73</td>
<td>99.03</td>
<td>97.76</td>
<td>91.11</td>
<td>96.94</td>
</tr>
<tr>
<td><strong>MAX</strong></td>
<td>84.80</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>STDEV</strong></td>
<td>18.71</td>
<td>0.22</td>
<td>0.58</td>
<td>1.83</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Surface runoff volumes of all pavements were statistically different from one another (p<0.01). Expressed in order of highest runoff generation, pavements performed as follows: Asphalt>>CGP>PICP1>PICP2>PC. All pavement surface runoff volumes were positively correlated to rainfall depth and intensity (p<0.05). Asphalt, PC and PICP2 were more strongly
correlated to rainfall depth, whereas stronger correlations to intensity were observed for PICP1 and CGP. PICP2 runoff was positively correlated to the age of the parking lot, although not significantly (p=0.059), reflecting potential clogging of this pavement surface during the study.

Water Quality
Table 2 summarizes mean and median concentrations from the four permeable pavement types, asphalt, and atmospheric deposition. The pavements behaved very similarly with respect to each other, with one notable exception being CGP’s performance with respect to nitrogen removal.

**pH**
All pavements buffered the pH of the influent acidic rainfall. On average, all permeable pavement drainage had a higher pH than asphalt runoff (p<0.001). The PC cell had higher pH values than all other permeable pavement cells (p<0.001), probably due to greater contact time with cementitious materials. Atmospheric deposition pH was lower than asphalt and all permeable pavement sections (p<0.01). No correlations were observed between atmospheric deposition pH and any pavement pH. Similar buffering capacities of permeable pavements have been observed by James and Shahin (1998) and Pratt *et al.* (1995).

Nitrogen
Generally, permeable pavement subsurface drainage tended to have lower NH$_4$-N and TKN concentrations than asphalt runoff and atmospheric deposition. With the exception of the CGP cell, permeable pavement subsurface drainage had higher NO$_{2,3}$-N concentrations. The CGP cell produced the lowest TN concentrations. Nitrogen loads leaving the PICPI cell were generally low due to the outflow volume reductions provided by this section. The possible N removal is similar to that found in sand filter research (Barrett 2003), not surprising considering the composition of CGP; CGP in essence is a shallow depth sand filter.

<table>
<thead>
<tr>
<th>Pollutant Concentrations (mg/l)</th>
<th>Atm. Dep.</th>
<th>Asphalt 1</th>
<th>Asphalt 2</th>
<th>PC</th>
<th>PICP1</th>
<th>CGP</th>
<th>PICP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.7 (6.9)</td>
<td>7.2 (7.2)</td>
<td>7.3 (7.4)</td>
<td>9.2 (9.1)</td>
<td>8.1 (8.0)</td>
<td>7.9 (8.0)</td>
<td>7.9 (7.9)</td>
</tr>
<tr>
<td>TN</td>
<td>1.30 (1.20)</td>
<td>1.24 (1.20)</td>
<td>1.27 (1.16)</td>
<td>1.27 (1.14)</td>
<td>1.73 (1.28)</td>
<td>0.95 (0.83)</td>
<td>1.38 (1.22)</td>
</tr>
<tr>
<td>NO$_{2,3}$-N</td>
<td>0.35 (0.32)</td>
<td>0.29 (0.28)</td>
<td>0.31 (0.33)</td>
<td>0.73 (0.63)</td>
<td>1.25 (0.78)</td>
<td>0.46 (0.42)</td>
<td>0.90 (0.83)</td>
</tr>
<tr>
<td>NH$_4$-N</td>
<td>0.59 (0.41)</td>
<td>0.34 (0.22)</td>
<td>0.39 (0.33)</td>
<td>0.05 (0.05)</td>
<td>0.05 (0.04)</td>
<td>0.04 (0.03)</td>
<td>0.05 (0.04)</td>
</tr>
<tr>
<td>TKN</td>
<td>0.96 (0.81)</td>
<td>0.95 (0.89)</td>
<td>0.96 (0.81)</td>
<td>0.55 (0.50)</td>
<td>0.48 (0.48)</td>
<td>0.48 (0.47)</td>
<td>0.48 (0.40)</td>
</tr>
<tr>
<td>ON</td>
<td>0.29 (0.30)</td>
<td>0.56 (0.46)</td>
<td>0.50 (0.44)</td>
<td>0.52 (0.44)</td>
<td>0.43 (0.37)</td>
<td>0.44 (0.41)</td>
<td>0.43 (0.38)</td>
</tr>
<tr>
<td>TP</td>
<td>0.16 (0.08)</td>
<td>0.14 (0.09)</td>
<td>0.08 (0.06)</td>
<td>0.15 (0.14)</td>
<td>0.12 (0.12)</td>
<td>0.20 (0.13)</td>
<td>0.11 (0.10)</td>
</tr>
<tr>
<td>OPO$_4$</td>
<td>0.09 (0.04)</td>
<td>0.09 (0.04)</td>
<td>0.03 (0.02)</td>
<td>0.05 (0.03)</td>
<td>0.05 (0.05)</td>
<td>0.07 (0.03)</td>
<td>0.04 (0.03)</td>
</tr>
<tr>
<td>TSS</td>
<td>9.8 (8.2)</td>
<td>19.4 (18.6)</td>
<td>14.5 (12.3)</td>
<td>15.2 (13.4)</td>
<td>15.2 (12.6)</td>
<td>12.5 (10.4)</td>
<td>13.8 (9.9)</td>
</tr>
</tbody>
</table>

Orthophosphate, Total Phosphorus, and Total Suspended Solids
No significant differences in OPO$_4$, TP, and TSS concentrations were observed among sampling sites. The TSS concentrations from the PC, PICP1, and PICP2 cells were positively correlated to asphalt TSS concentrations (p<0.05), but no other correlations between similar parameters were observed. For many storms, TP concentrations for the permeable sections were higher than those from asphalt or atmospheric deposition. On three occasions in the winter and early spring months, CGP cell drainage yielded very high concentrations of TP.
Conclusions

The following conclusions can be made from the research presented herein:

1. With respect to runoff reduction, all pavements performed substantially and statistically significantly better than asphalt (p<0.001). Although hydrologic differences among the pavements did exist, they were small in comparison to the overall improvements from asphalt.

2. One year after lot construction, permeable pavement drainage tended to have lower NH$_4$-N and TKN concentrations than asphalt runoff and atmospheric deposition. With the exception of CGP cell drainage, permeable pavements had higher NO$_{2,3}$-N concentrations, a probable result of nitrification. The CGP cell had lower NO$_{2,3}$-N concentrations than other permeable pavements (p<0.01). CGP also had the lowest mean TN concentrations, although results were not significantly lower than those of asphalt.

3. TP and TSS concentrations were not different among various pavement sections. No liner separated the permeable pavements’ subbase from phosphorus laden in situ soils, allowing water to interact with in situ soils while it drained from the cells. This caused suspected TP leaching from the underlying soils into the underdrains. It is unlikely that TP leached from the pavement materials. Further, it is possible that the disturbance of the underlying soils during site construction resulted in sediments washing from the cells during rainfall events.

Water Harvesting

A 5000 gallon cistern in Kinston, NC, (35°13'44.97"N, 77°36'49.97"W) collected water from an approximately 4000 ft$^2$ section of rooftop, with the collected water used to wash vehicles. The harvested rainwater was pumped to a faucet at a vehicle washing station where signs clearly indicated that the faucet was supplied by rainwater. Within the same vehicle washing station, there were several faucets connected to the municipal water supply. Typically, pressure washers were used at the washing station to clean large commercial vehicles. The Kinston rainwater harvesting system was monitored from June of 2005 through August of 2006.

![Graph](image_url)

Figure 3. Percentage of cistern capacity filled by runoff storage at the Kinston location
At the Kinston location, rainwater usage was minimal, with the cistern maintaining at least 80% of its capacity for the duration of the study (Figure 3). Observations at the site confirmed that water demand intended for the rainwater harvesting system was being supplied by municipal water. Vehicles were primarily washed with handheld pressure washers attached to the municipal water supply with water from the rainwater harvesting system used to meet small water demands. After better educating the facility workers on the use of the rainwater harvesting system in early 2006, rainwater usage increased. Even with this increased usage, the cistern remained near capacity, since municipal water was still used for much of the vehicle washing.

Results of the monitoring study indicate the presence of major hurdles in effectively implementing rainwater harvesting systems in the southeastern United States. When installing rainwater harvesting systems, knowledge of the anticipated water usage is imperative to ensure that an appropriately sized cistern is used. Even when a reasonable estimate of water usage is available, logistical problems such as cistern location, changes in facility use, and public perception can have substantial impacts on actual rainwater usage volumes. In fact, public perception may be one of the greatest hurdles to overcome, since observations suggest that city of Kinston workers chose to use municipal water over harvested rainwater in many cases, despite more than adequate volumes stored within the rainwater cisterns. With increased planning, public awareness, and education, rainwater harvesting systems should serve as valuable tools in reducing the demand on municipal water supplies and the negative impacts associated with urban stormwater runoff at the same time. It seems imperative that forcing the cistern water as a “first choice” for water use is needed for this practice to reach its full water quality potential.

**Construction Nutrient Study**

Three monitoring stations were located at the North Carolina Museum of Art during a construction period this spring on that campus. ART-1 monitored the pond outlet, while ART-2 monitored the stormwater pipe draining the developed/construction part of the site and ART-3 monitored the natural/undisturbed part of the site. Figure 4 is a schematic of the Art Museum monitoring stations.

![Art Museum Monitoring Schematic](image.jpg)

**Figure 4.** Art Museum Monitoring Schematic
Starting in February 2008, ART-1, ART-2 and ART-3 were in simultaneous operation for four months. The goal of this brief monitoring period was to investigate the difference between the undisturbed part of the property (ART-3) and the construction part of the property (ART-2), as well as the effect of the pond (ART-1). A total of 6, 9, and 4 events were collected at ART-1, ART-2, and ART-3, respectively. There was a substantial amount of infiltration in ART-3’s undisturbed watershed.

Results and Discussion

Table 3 shows the differences in mean EMCs when all three ART stations were operational and the pond was being used as a sediment trap. The last line of the table shows ART-3 values when one storm was excluded.

**Table 3.** Mean EMC’s for ART-1 (downslope of pond), ART-2 (construction watershed), and ART-3 (undisturbed natural)

<table>
<thead>
<tr>
<th>Art Museum Sample Sites</th>
<th>TKN (mg/L)</th>
<th>NO₃&amp;NO₂ (mg/L)</th>
<th>TN (mg/L)</th>
<th>NH₃-N (mg/L)</th>
<th>TP (mg/L)</th>
<th>Ortho-P (mg/L)</th>
<th>TSS (mg/L)</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>ART-1</td>
<td>0.93</td>
<td>0.40</td>
<td>1.33</td>
<td>0.19</td>
<td>0.16</td>
<td>0.01</td>
<td>118</td>
<td>6</td>
</tr>
<tr>
<td>ART-2</td>
<td>1.52</td>
<td>0.32</td>
<td>1.85</td>
<td>0.172</td>
<td>0.34</td>
<td>0.01</td>
<td>397</td>
<td>9</td>
</tr>
<tr>
<td>ART-3</td>
<td>1.93</td>
<td>0.77</td>
<td>2.71</td>
<td>0.132</td>
<td>0.39</td>
<td>0.01</td>
<td>466</td>
<td>4</td>
</tr>
<tr>
<td>ART-3 (excl.)</td>
<td>1.07</td>
<td>0.96</td>
<td>2.03</td>
<td>0.14</td>
<td>0.12</td>
<td>0.01</td>
<td>57</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 5 shows the mean TSS concentrations at the Art Museum stations. Construction occurred during part of this time; however, the sediment accumulated in the pond and the pond was not pumped out. As the construction increased and the pond was regularly pumped out, the mean TSS concentration at ART-1 increased nearly fivefold, from 26 mg/L to 118 mg/L in the spring of 2008. The mean TSS concentration at ART-2 was substantially higher, at 397 mg/L, clearly showing the impacts of the land disturbance.

At first glance, it would appear that the mean TSS concentration was highest at ART-3, with 466 mg/L, however this value was misleading. Only four samples were obtained at ART-3, and three of those samples had concentrations less than 100 mg/L. One of the samples, on 4 March 2008, was based on only four aliquots, and had an extremely high concentration of 1690 mg/L. It is possible that construction workers used flexible piping to re-route stormwater flow during this storm from the construction area which would normally flow through ART-2, however this was not actually observed. The potential for mixing of ART-3 sample with ART-2 runoff, as well as the limited number of aliquots made this sample suspect. Excluding this high TSS value, the mean TSS
concentration at ART-3 was 57 mg/L. This matched what was typically observed at the undisturbed/natural site; namely, relatively clean samples with minimal sediment.

Figure 6 compares the mean nutrient concentrations at ART-1, ART-2 and ART-3 during the spring of 2008. Two nutrient exports for each pollutant are shown for the ART-3 station in 2008; the second set of values was denoted with “excl”. TKN, TN and TP concentrations were lower when the 5 March 2008 storm was excluded, while NO₃ and NH₃ concentrations were slightly higher after excluding the storm. Overall the highest mean TKN and TP concentrations occurred at ART-2 (the construction site). The highest mean NH₃ concentration occurred at ART-1, while the highest mean NO₃ and TN concentrations occurred at ART-3.

![Figure 6. Mean Nutrient Concentrations at Art Museum Stations During 2008](image)

Although not definitive given the limited number of samples at ART-2 and ART-3, the foregoing discussion provides evidence that the disturbed portion of the Art Museum property monitored at ART-2 had substantially poorer water quality concentrations, particularly for TSS, as compared to the natural area monitored at ART-3. The lower concentrations of the unmonitored parts of the museum property, as well as the successful functioning of the pond as a sediment trap served to mitigate some of the negative impacts from ART-2.

**Stormwater Wetland Study**

**Background**

The research site was a 0.14 hectare (0.34 acre) stormwater treatment wetland constructed in River Bend, NC, located in Craven County (Table 4). The wetland was sized to capture runoff from the 3.3 cm (1.3 in) rainfall event and store approximately 122 m³ (4300 ft³) of water.
Built in March 2007, the wetland treats stormwater from a 46.5 hectare (115 acre) watershed consisting of 0.2 ha (0.5 acre) residential lots, a small industrial area and a golf course. The relative permeability of the watershed, as described by the Natural Resources Conservation Service (NRCS) curve number (CN) method, was calculated to be 54, indicating a moderately to very permeable watershed. The NRCS Web Soil Survey (WSS) reported five different soil series within the watershed: the Conetoe, Goldsboro, Masontown, Tarboro and Udorthents series. The primary series, Conetoe, present in 75 percent of the watershed, is a well drained loamy sand with slopes ranging from 0 to 10 percent, and an elevation range from 10 to 70 feet (NRCS 2002).

The River Bend wetland was first constructed in 1998. At that time the watershed was 30.4 ha (75 ac) consisting of 0.2 ha (0.5 ac) residential lots. Between 1998 and 2006 the town of River Bend expanded the watershed by approximately 16.1 ha (40 ac). This occurred as a result of ditch digging beside roads along the perimeter of the original watershed that caused more land area to drain into the River Bend wetland. As a result the wetland was undersized.

To remedy the situation, the wetland was resized in March 2007 to meet the standard design recommendations for a stormwater wetland, such as a shallow water normal pool depth from 2 to 4 inches (Hunt et al. 2007). At this time the wetland’s surface area was expanded from 0.07 ha to 0.14 ha, and approximately 3200 plants of different species were planted in the wetland (Table Y). Soon afterward, a surprising late season freeze occurred in April which killed virtually all the plants in the wetland. As a result the wetland had to be replanted in June, with approximately 1000 plants of the same variety as the original planting plan.
Results & Discussion
Peak inflow and outflow rates from 24 rain events varied in size from 0.001 cms (0.04 cfs) to 0.22 cms (7.65 cfs). The wetland reduced outflow peaks by an average of 80%. The wetland reduced runoff volumes by an average of 54%.

Based on mean pollutant concentrations the wetland is exporting or not reducing TKN, NH₄-N, TN, TP and TSS; however, concentrations of NO₂⁻⁻-N and Ortho P are being modestly reduced (Table Z). Based on loading, the wetland is reducing all pollutant loads (Table 5). This load reduction is a direct result of the significant reduction between inflow and outflow volumes.

To better relate the water quality results from this wetland, the influent and effluent concentrations have been compared with water quality concentrations from three NCDENR stream and river monitoring sites in the same watershed as the River Bend wetland (the Trent River). The stations were all within 10 miles of the River Bend site and are listed below:
- Station number J8690000 (N 35.06364, W 77.46107)
- Station number J8730000 (N 35.00993, W 77.21891)
- Station number J8770000 (N 35.07502, W 77.11627)

Comparing these concentrations will help put the results of this study into context with natural or typical background pollutant concentrations in the area. In short, how did wetland influent and effluent water quality compare to these background concentrations.

Table 5. Mean water quality concentrations, loads and reductions.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Mean Inflow Concentration (mg/L)</th>
<th>Mean Outflow Concentration (mg/L)</th>
<th>Mean Reduction (%)</th>
<th>Mean Inflow Load (kg)</th>
<th>Mean Outflow Load (kg)</th>
<th>Mean Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TKN</td>
<td>0.55</td>
<td>0.94</td>
<td>-70</td>
<td>0.51</td>
<td>0.33</td>
<td>34.9</td>
</tr>
<tr>
<td>NO₂⁻⁻-N</td>
<td>0.18</td>
<td>0.17</td>
<td>9</td>
<td>0.08</td>
<td>0.05</td>
<td>40.7</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>0.05</td>
<td>0.08</td>
<td>-53</td>
<td>0.06</td>
<td>0.03</td>
<td>41.6</td>
</tr>
<tr>
<td>TN[1]</td>
<td>0.73</td>
<td>1.11</td>
<td>-51</td>
<td>0.60</td>
<td>0.38</td>
<td>35.7</td>
</tr>
<tr>
<td>TP</td>
<td>0.23</td>
<td>0.23</td>
<td>0</td>
<td>0.18</td>
<td>0.09</td>
<td>47.2</td>
</tr>
<tr>
<td>Ortho P</td>
<td>0.15</td>
<td>0.09</td>
<td>39</td>
<td>0.12</td>
<td>0.05</td>
<td>60.9</td>
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<tr>
<td>TSS</td>
<td>31.2</td>
<td>40.5</td>
<td>-30</td>
<td>24.8</td>
<td>12.6</td>
<td>49.2</td>
</tr>
</tbody>
</table>

[1] TN – Calculated by adding TKN and NO₂⁻⁻-N

River Bend inflow and outflow concentrations for NO₂⁻⁻-N were 0.18 and 0.16 mg/L, respectively, much lower than the neighboring stream concentrations of 0.64, 0.61, and 0.34 mg/L. River Bend NH₄-N concentrations were similar to these streams. Concentrations of TKN appear to be similar when comparing inflow concentrations; however, outflow TKN concentrations from River Bend are greater than those of background streams. River Bend inflow and outflow TN concentrations were 0.73 and 1.11 mg/L, which compared similarly to concentrations in the neighboring streams of 1.30, 1.18 and 0.95 mg/L, respectively. The mean River Bend inflow concentration was lower than all three other streams, while the average outflow concentration is only greater than NCDENR J8770000. From this comparison it appeared as though River Bend is both receiving and exporting low concentrations of TN, evidence to support the possibility of irreducible concentrations. The
River Bend wetland tended to receive and release higher concentrations of TP and TSS when compared to streams in the surrounding watershed. Mean TP concentrations to and from River Bend were greater than the 90% high concentrations in these streams. The minimum TSS concentrations to and from River Bend were approximately equal to the 90th percentile background concentrations.

Conclusions
1. Depending upon method of evaluation, this wetland either removed or added pollution to the Trent River. Only utilizing changes in concentration (for percent removal efficiency) could produce a different (and negative) understanding of how the wetland performs. Mass removal and/or relating the wetland to local water conditions provides a different assessment.
2. A major role of this wetland was to reduce the volume of water leaving the system. This is a major tenant of Low Impact Development.

Low Impact Development Summit
The Low Impact Development Summit was held in Asheville on June 23-24, 2008. Nearly 300 people (297) attended the Summit from 19 different states. Approximately 65% of attendees were from North Carolina. The Summit was held at the Renaissance Hotel in Asheville, NC. The Summit consisted of 1.5 days of presentations focusing on planning, research, and implementation of Low Impact Development and its associated practices. Invited presenters included faculty, regulators, designers, and developers from the following institutions: NCSU Biological and Agricultural Engineering, NCSU Soil Science, NCSU School of Design, the Center for Watershed Protection, the Low Impact Development Center, Villanova University, University of Maryland, Utah State University, UNC-Chapel Hill School of Government, Clemson University, University of Georgia, City of Charlotte, New Castle County Delaware, Stocks Engineering, Woodsong Development, and the US Environmental Protection Agency.

One-half day post conference workshops and field tours were held on June 24. They included a permeable pavement training, a water harvesting workshop, an LID site planning workshop, a tour of LID technologies at the NC Arboretum south of Asheville, and stream restoration projects in Buncombe County. Overall, the evaluations for the Summit were excellent. The full agenda and the website for the event is located at the following: http://www.bae.ncsu.edu/workshops/lid_summit/
**Pictorial Retrofit Descriptions**
A pictorial view of the construction of each project follows.

**Kinston Permeable Pavement Lot**

(a) Looking west at the Kinston, NC, Public Utility center prior to construction of the permeable lot.

(b) During the construction process, the gravel layer for all the permeable sections has been placed.

(c) The four permeable pavement types (& asphalt) separated by asphalt berms.

(d) The monitoring vault to which all underdrain flow and runoff was delivered.
Water Harvesting

(e) 5000 gallon cistern installed at the City of Kinston Public Works Facility.

(e) Using the cistern’s water to wash vehicles is the intended use of this cistern as shown in late December 2005.

(g) 500 gallon cistern capturing runoff from green roof pavilion at Pitt County Arboretum

(h) 3000 gallon cistern at Pitt County Agricultural Building was used for irrigation
Pitt County Arboretum Green Roof

(g) Green roof at Pitt County Arboretum under construction.

(h) A unique way of transporting media to the green roof: a mulch blowing truck.

(i) The media is placed and vegetation is on the verge of planting.

(j) Some vegetation in place with more waiting in containers. Ag center in background.
Outcomes and Conclusions
The main outcomes and conclusions are segregated by theme: permeable pavement, cisterns/water harvesting, construction pollutant, stormwater wetlands, and LID Summit. Recommendations regarding each practice are emphasized with italics.

Permeable pavement:
- All 4 permeable pavement systems performed similarly with respect to runoff reduction. On average they reduced peak flows by at least 98% when compared to rainfall intensity.
- Outflow (drainage + runoff) from the permeable pavement systems was substantial in part because (1) the systems were designed to drain and (2) the underlying soil was relatively tight. The majority of the water leaving permeable pavement did so via the underdrains.
- The 4 permeable pavement types, in general improved water quality, with the notable exceptions of NO2-3-N, TN, and TP. Only concrete grid pavers filled with sand provided a (non-significant) improvement in the nitrogen species. All phosphorus concentrations increased due to contact with an underlying, high P-Index soil.
- There was an outflow reduction (and consequent increase in infiltration) in one pavement system that had an inadvertent sump. Perhaps a sump should be a design requirement for future permeable pavement systems overlying low plasticity soils. Future research on this is recommended.
- All four permeable pavement systems performed similarly enough that NCSU-BAE does not recommend they should be treated differently from each other by NC DENR.

Water Harvesting
- The water harvesting systems examined were near full capacity for the entire monitoring period, despite repeated attempts to coax the use of the water. These particular water harvesting systems should get little to no credit for runoff reduction and nutrient removal.
• Water harvesting systems need a dedicated/required use for them to be successful from a water quality perspective. In both cases having the cistern as an optional source of water was not sufficient.

Construction Sediment & Nutrients
• A site receiving runoff from the NC Museum of Art construction site had much higher TSS, TP, and TKN counts than a site that had an undisturbed watershed. However, there was no apparent difference with NO2-3-N and TN. Because the monitoring did not occur at the edge of the construction site there probably was some pollutant mitigation that occurred before the runoff reached the monitoring station.

Stormwater Wetland
• The stormwater wetland reduced outflow by approximately 50%. This is a hallmark of Low Impact Development. Perhaps certain wetlands in eastern North Carolina that have a reasonable expectation of exfiltration from the wetland should be considered by NC DENR as an LID practice.
• The wetland released concentrations of nutrients that were often higher than inflow. However, the wetland did provide load removal for every pollutant studied.
• The effluent concentrations were similar to those in nearby waterways that served as a background (the Trent River). The pollutant treatment effectiveness is different per the method used to assess the system.

LID Summit
• A major educational event was held in North Carolina in June 2008, as nearly 300 people from across the USA attended, bringing great focus to work ongoing in this state. The majority of attendees were North Carolinians, which will hopefully encourage the adoption of more innovative treatment systems.
## Budget

### Actual Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Descriptions</th>
<th>319 (h) Funds Requested*</th>
<th>Non-federal Match</th>
<th>Total</th>
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</table>
| Salary/fringe Grant Supported:  
  Mr. Jon Hathaway (Kinston + Greenville project design and management)  
  Ms. Kelly Collins (Kinston data collection and analysis)  
  Mr. Hayes Lenhart (River Bend data collection and analysis)  
  Ms. Gabrielle Skipper (Construction study)  
  Mr. Shawn Kennedy (project technician on all projects)  
  Match:  
  William F. Hunt (overall project management)  
  Dwane L. Jones (local project management)  
  Mitchell Woodward (Level Spreader Workshops)  
  Andrea Olevano (Level Spreader Workshops) | $76,596 | $42,568 | $119,164 |
| Travel Travel to/from project sites (Kinston, Greenville, River Bend). Speaker travel (in form of honoraria) to LID Summit | $10,075 | $10,075 | |
| Supplies & Materials Gravel, pavement, cisterns, green roof materials (wood, media, plants) | $40,504 | $40,504 | |
| Contract/Construction Grant Supported:  
  Contractors for Parking Lot  
  Pitt County green roof structure  
  Match:  
  City of Kinston Parking lot construction | $13,624 | $30,000 | $43,624 |
<p>| Student Aid Tuition for Collins (mostly) with minor support for Lenhart and Skipper | $5,008 | $5,008 | |
| Laboratory Analysis Water quality sample analysis for projects in Kinston and River Bend | $4,441 | $4,441 | |
| Direct charges | $150,248 | $72,568 | $222,816 |
| Match indirect (10%)*NCS U portion | | $4257 | $4257 |
| Indirect charges (10%) | $15,018 | $15,018 | |
| Under | | $25,993 | $25,993 |</p>
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<th>recovered indirect (17.3%)</th>
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<td>Total</td>
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Appendices:


Factsheet: Choosing a Pump for Rainwater Harvesting, by M.P. Jones and W.F. Hunt, NCSU Cooperative Extension (8 pages)