An Evaluation of the Dye Branch Wetlands

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Site Description
The Dye Branch Wetlands were located in the Piedmont of North Carolina in the Town of Mooresville and were constructed between the Fall of 2005 and the Spring of 2006. The wetlands serviced a watershed with an estimated area of 31 acres, 60% of which was impervious. The composite curve number for the watershed was estimated to be 87.5. Soils in the watershed were primarily Cecil fine sandy loam. Due to topographical and space limitations, the Best Management Practice (BMP) was designed as a treatment train of three wetland cells. The cells had a combined area of approximately 0.81 acres.

Monitoring Description
Flow monitoring
The cells were designed to be hydraulically separate to allow individualized flow monitoring. Flow was measured at the inlet of cell 1 and the outlet of all three wetland cells. Stormwater runoff entering the system was routed into a large concrete structure outfitted with a 120 degree v-notch weir, and each wetland cell outlet was a flashboard riser with a weir/orifice combination used to control flow. ISCO model 730 bubblers were installed at the inlet and at each outlet. Stage measured via the bubbler was converted to flow via standard weir and orifice equations. During some rain events, slight submergence was noticed at the cell 3 outlet, resulting in some error in flow calculations. Additional errors in flow measurements made evaluation of volume reductions, and thus load, unreasonable.

Water Quality Monitoring
Flow measurements were considered adequate for facilitating flow-paced water quality samples, collected with ISCO Avalanche automated samplers. Water quality samples were taken at each flow monitoring point. Samples were normally collected within 24 hours of a rain event and preserved as necessary. Samples were analyzed for turbidity, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), total ammoniacal nitrogen (TAN), nitrate – nitrite (NO_2-NO_3), and

total phosphorus (TP). Estimations of total nitrogen (TN) were determined by adding the concentrations of TKN and NO_2-NO_3. Estimations of organic nitrogen (ON) were determined by subtracting TAN from TKN.   Table describes the minimum detectable levels associated with each for each parameter (Table 1).

Data Analysis

Overall, 27 storm events were monitored at the site. However sampler power failures and inadequate volumes for analyzing all constituents were sometimes experienced. Further, to provide balanced analysis of the system, only storms where samples were collected from each monitoring point were used for data analysis. Thus, between 10 and 15 paired samples were collected for each pollutant (Table 1). At least 5 aliquots had to be taken during a given event for a storm to be considered for analysis.

Table 1: Description and Methods of Chemical Parameter Analysis

Parameter	Minimum Detectable Level	Number of Paired Samples
Turbidity	1 NTU	12
TSS	6.2 mg/L	10
TKN	0.20 mg/L	14
TAN	0.02 mg/L	15
NO_2-NO_3	0.02 mg/L	15
TP	0.02 mg/L	15
TN	n/a	14
ON	n/a	14

Exploratory analysis was performed on the data, including a calculation of the mean, median, and standard deviation for each monitoring point and each pollutant (Appendix A). Prior to more in-depth statistical analysis, the data were check for normality using the Kolmogorov-Smirnov test. The results of this analysis were checked using box plots and histograms of the data. Data were found to have various distributions. Most data were found to be normal; however, some required log transformation and some could not be matched to any distribution. To maintain consistency in the analyses, and due to the small number of paired samples taken for each pollutant, a non-parametric Wilcoxon signed-rank test (WSR) was chosen to determine the statistical significance of the comparisons made between data. Using this non-parametric analysis allowed comparisons to be made without concerns over the assumption of normality. Efficiency ratios (ER) were generated to document the amount of pollutant removal provided by each wetland cell. Since flow paced samples were collected, each pollutant measurement from a given sample event was considered to be an event mean concentration (EMC). The following equation was used to determine the efficiency ratio:

Equation 1: $$ER = 1 - \left(\frac{Average\_Outlet\_EMC}{Average\_Inlet\_EMC}\right)$$

Results and Discussion

Overall Effectiveness of the System

The effectiveness of the system was evaluated, in part, by comparing influent EMCs to those at the outlet of wetland cell 3, effectively the outlet of the system. Inlet EMCS were higher than outlet EMCs for all pollutants, indicating that the wetland is performing well with regard to pollutant removal. Table 2 shows the wetland ER for each pollutant, a further indication of the system's performance. All pollutants were removed with an ER of at least 0.36, and the results of a Wilcoxon signed rank test indicate that significant removal of each pollutant occurs as it passes through the system of wetlands (Table 2). The efficiency ratios are lowest for ON and TKN. TKN is the nitrogen species which represents the combination of ON and TAN, thus the ER for ON is likely associated with the low ER for TKN. Organic nitrogen can be present in plant and animal debris, and is likely added to the flow stream as stormwater passes through the wetland. Thus, there may be a limit to how much reduction in ON concentration can occur in wetlands. Parameters associated with solids such as TSS, turbidity, and TP were all removed with a high efficiency. TAN and NO_2-NO_3 are also readily removed in the wetlands. This indicates that both aerobic and anaerobic environments are being produced in the wetlands to facilitate nitrification and denitrification. Overall, the system seems to perform well for a variety of dissolved and particulate species of pollutants.

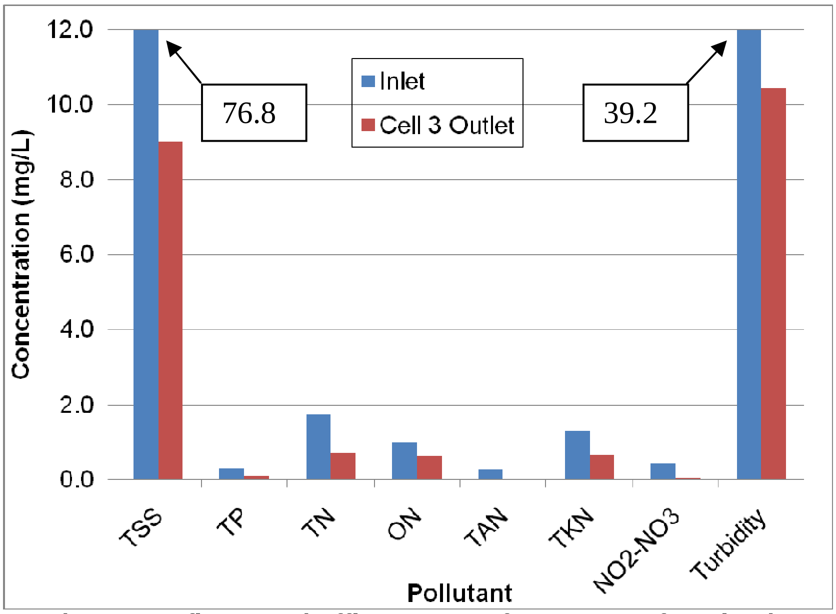


Figure 1: Influent and Effluent EMCs for System of Wetlands
(Note: Turbidity Concentration in NTU)

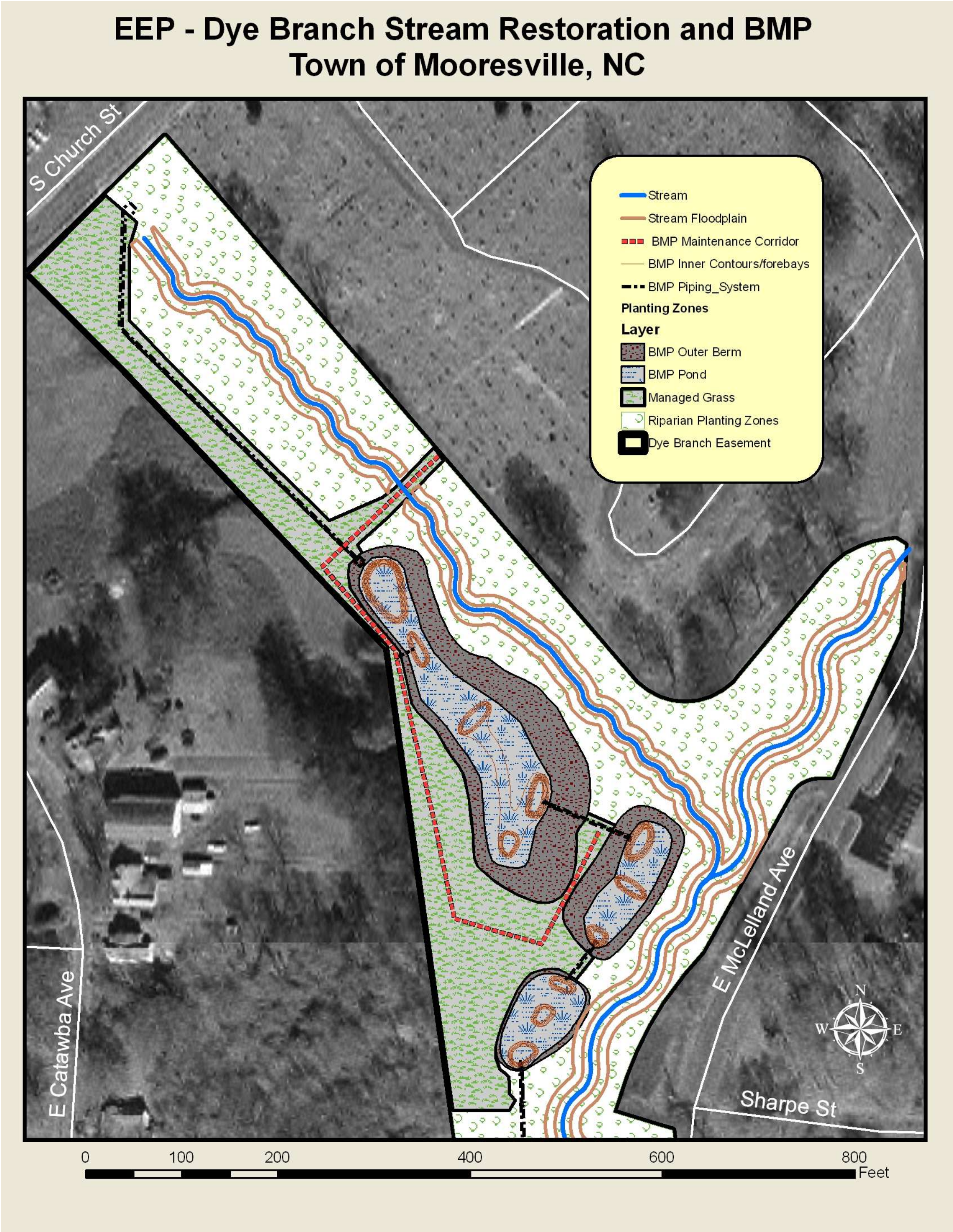
Table 2: Efficiency Ratios and Statistical Significance of Pollutant Removal in System

Pollutant	ER	WSR	Significant ?
TSS	0.88	0.002	yes
TP	0.67	<0.0001	yes
TN	0.58	0.0001	yes
ON	0.36	0.0004	yes
TAN	0.90	0.0001	yes
TKN	0.48	0.0001	yes
NO_2-NO_3	0.85	<0.0001	yes
Turbidity	0.73	0.0005	yes

Conclusion

The objective of this report was to evaluate the overall function of a system of 3 wetland cells receiving urban stormwater. This system emphasized the efficiency with which stormwater wetlands can remove pollutants from urban runoff. Efficiency ratios and statistical analysis indicated that they wetland system was significantly ($p < 0.05$) removing pollutants with a high efficiency. Only organic nitrogen was removed with a ER less than 0.48, and it was likely that the wetlands were both removing and adding organic matter to the stormwater as it passed through, thus, the low ER for this pollutant is expected. Such behavior is normal in wetland systems. As total maximum daily loads (TMDLs) are established for surface waters on the 303(d) list, stormwater wetlands can be considered a viable option for reducing pollutant loads.

Appendix A: Maintenance Agreement / Easement



Appendix B: Summary Statistics of Dye Branch Wetland Data

Table B.1: Mean, Median, and Standard Deviation for Each Pollutant at Each Monitoring Point

Pollutant	**Function**	**Inlet**	**Cell 1 Outlet**	**Cell 2 Outlet**	**Cell 3 Outlet**
TSS	*Mean*	76.8	12.3	11.0	9.0
	Median	80.5	13.5	10.2	7.8
	St. Dev.	13.1	4.6	4.0	3.7
TP	*Mean*	0.31	0.12	0.12	0.10
	Median	0.26	0.11	0.11	0.09
	St. Dev.	37.11	6.48	5.29	4.33
TN	*Mean*	1.74	0.84	0.74	0.72
	Median	1.68	0.87	0.72	0.73
	St. Dev.	32.37	5.89	4.94	4.13
ON	*Mean*	1.00	0.68	0.63	0.64
	Median	0.98	0.71	0.64	0.66
	St. Dev.	31.75	5.67	4.76	3.98
TAN	*Mean*	0.28	0.04	0.03	0.03
	Median	0.21	0.02	0.02	0.02
	St. Dev.	30.80	4.91	4.01	3.18
TKN	*Mean*	1.30	0.73	0.66	0.67
	Median	1.25	0.77	0.67	0.69
	St. Dev.	28.38	4.59	3.76	3.00
NO_2-NO_3	*Mean*	0.44	0.14	0.08	0.07
	Median	0.40	0.14	0.05	0.03
	St. Dev.	14.59	2.50	2.07	1.71
Turbidity	*Mean*	39.2	15.0	13.7	10.5
	Median	35.5	12.5	11.0	10.0
	St. Dev.	14.85	2.43	2.02	1.64