CITY of CHARLOTTE
Pilot BMP Monitoring Program

Little Sugar Creek - Westfield Level Spreader

Final Monitoring Report

June 2007

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Submitted To:

Charlotte-Mecklenburg Storm Water Services

Purpose

The purpose of this report is to document monitoring and data analysis activities undertaken by the City of Charlotte, Mecklenburg County, N.C., and NC State University to determine the effectiveness and stormwater treatment capabilities of the Little Sugar Creek - Westfield Level Spreader.

Introduction

Level Spreaders are designed to spread stormwater out over a wide filter strip or riparian buffer. The filter strip (or riparian buffer) infiltrates and treats the stormwater as it passes through the system. Additionally, the water is slowed and sedimentation is encouraged. Simultaneously, subsurface soil processes (such as oxidation-reduction reactions) treat the stormwater for some pollutants. These systems are often installed to satisfy diffuse flow requirements in watershed protection areas such as the Neuse and Tar-Pamlico Basins in central and eastern North Carolina. In addition, properly designed level spreader – filter strip BMPs are given credit for the removal of total suspended solids (TSS), total nitrogen (TN), and total phosphorous (TP). North Carolina DENR gives filter strip - level spreader systems credit for 25 - 40% TSS removal (depending on vegetation type), 20% TN removal, and 35% TP removal (NCDENR, 2007).

Site Description

Located in Charlotte, N.C., the Westfield Level Spreader receives runoff from a residential area adjacent to Little Sugar Creek. The watershed draining to the level spreader was approximately 0.85 acres with nearly 45% of the watershed being impervious surfaces. The level spreader was a retrofit BMP project constructed on a parcel of land purchased by Mecklenburg County under the FEMA Flood Plain Buyout Program. As part of this retrofit, the drainage system was changed to allow diversion of stormwater to the level spreader.

Originally, three drop inlets serviced the watershed, sending stormwater directly to Little Sugar Creek. During the retrofit, water quality inlets were placed just before the original inlets in the stormwater flow path. With the new drainage configuration, most stormwater flows (water quality design flows from the first 1" of rainfall) enter the water quality inlets and are diverted to the level spreader. During large rain events as water quality flows are exceeded, the stormwater backs up, overtops the water quality inlet, enters the original inlet, and continues directly to the stream, thus bypassing the BMP. All three water quality inlets are tied together and enter the level spreader at a single inlet point.

The level spreader was originally constructed with rip rap, but was later reconstructed by Charlotte-Mecklenburg Stormwater Services to increase its effectiveness. The rock level spreader was replaced with concrete, resulting in a stable, erosion resistant lip for stormwater to pass over. A fore bay acts to reduce the influent stormwater velocity and allow some sedimentation. Upon entering the level spreader, stormwater flows in a thin sheet over the level spreader lip before entering a filter strip that is approximately 150 ft long with a slope of ~1.5%. The filter strip consisted mostly of well maintained grass (Figure 1). After passing through the vegetated filter strip, stormwater is recollected in a grass lined channel and routed to a pipe. The pipe conveys the stormwater to Little Sugar Creek.

Figure 1: Filter strip down slope of level spreader.

Monitoring Plan and Data Analysis

Area-velocity meters connected to ISCO 6712 samplers were used to monitor flow at both the inlet 15-inch reinforced concrete pipe (RCP) and the outlet 18-inch RCP (Figure 2). The inlet and outlet culverts showed some signs of submergence during the monitoring period. During large storm events, it is possible for Little Sugar Creek to rise and back water up into the outlet pipe.

Figure 2: Typical installation of area-velocity probe (left) and sampler intake (right) with expansion bracket

Monitoring efforts were initiated in October 2005 and continued until January 2007, with 27 storm events being, at least partially, collected and measured at the time these data were analyzed. However, due to sample collection failures, inflow samples were collected for only 26 of these storms. Furthermore, due to the infiltration capabilities of the filter strip, only 5 samples were collected at the outlet. During the majority of the storms monitored, no stormwater reached the outlet monitoring station. Manual grab samples, from which levels of fecal coliform, E. coli, and oil & grease were measured, were collected for 7 storm events at the inlet and for 1 event at the outlet. This made analysis of these parameters infeasible.

Average inflow and outflow event mean concentration (EMC) values for each pollutant were used to calculate a BMP efficiency ratio (ER):

$$ER = (EMC_{inflow} - EMC_{outflow}) / EMC_{inflow}$$

where EMC_{inflow} and $EMC_{outflow}$ represent the mean BMP inflow and outflow EMCs across all storm events for which inlet and outlet samples were collected. However, with only 4 events captured at both the inlet and outlet, and with the large amount of stormwater lost to infiltration in the filter strip (not a flow-through system), the ER is not the best representation of BMP performance. Thus, a summation of loads (SOL) analysis was also performed on the system, pairing flow data with water quality data to determine the pollutant loads entering and exiting the system. The SOL can be calculated as follows:

$$SOL = 1 – (\text{sum of outlet loads} / \text{sum of inlet loads})$$

It should be noted that some authors have suggested that reporting BMP effectiveness in terms of percent removal may not give a completely accurate picture of BMP performance in some situations (Urbonas, 2000; Winer, 2000; Strecker et al., 2001; US EPA, 2002). For example, if the influent concentration of a pollutant is extremely low, removal efficiencies will tend to be low due to the existence of an “irreducible concentration”, lower than which no BMP can achieve (Schueler, 1996). For these relatively “clean” storms, low removal efficiencies may lead to the erroneous conclusion that the BMP is performing poorly, when in fact pollutant targets may be achieved. Caution should be used when interpreting BMP efficiency results that rely on a measure of percent or proportion of a pollutant removed.

Data Analysis Results

Flow Results

The flow data collected from this site were important in determining BMP pollutant removal efficiency. Due to the large amount of stormwater lost in the filter strip through infiltration, the summation of loads analysis was the most reasonable indicator of BMP effectiveness. There were some questionable flow data that were collected during this study, so some assumptions were made to glean out potential inaccuracies. Among the errors were instances where backwater (negative flow) was detected in either the inlet or outlet pipes. It is unknown if these occurrences were errors, actual backwater conditions, or the receiving stream backing water up into the system. For the sake of this study, the event runoff volumes were calculated including the negative flow values indicated by the data. Data analysis showed that excluding the negative flow values would likely not significantly change the results of this study, thus, a judgment was made to include them in the remainder of the analyses.

To verify that the monitoring equipment was providing a reasonable estimation of influent stormwater volumes, runoff volume was modeled using the Simple Method for each rain event (Figure 3). Since the theoretical performance of the filter strip is unknown, effluent flows could not be compared to another data source and were considered to be reasonably accurate for the sake of this study.

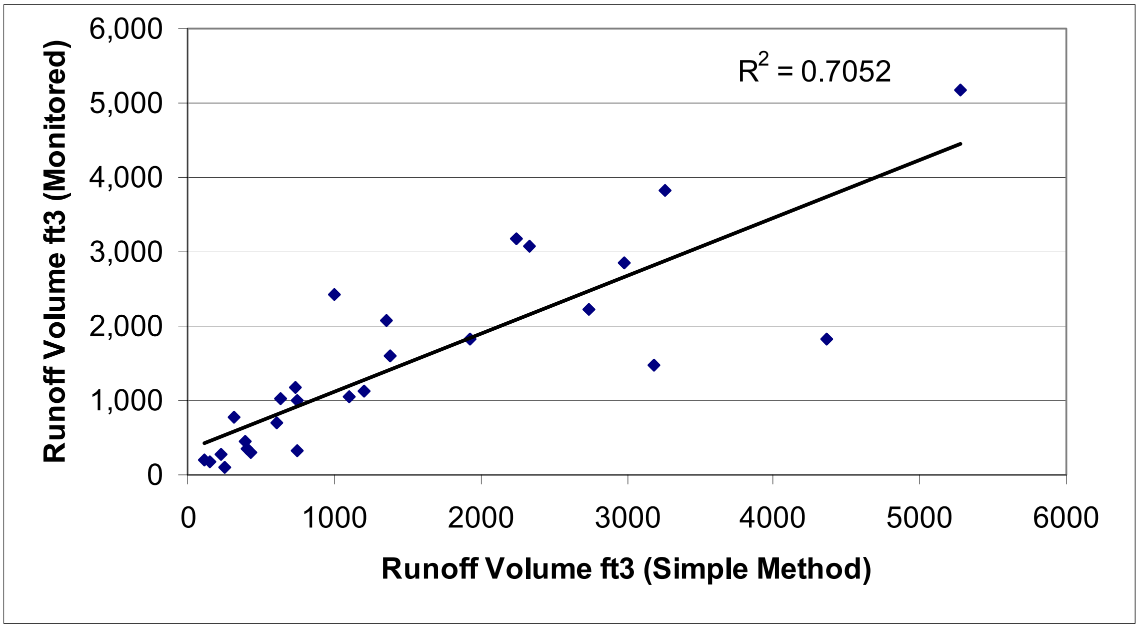

Figure 3: Modeled runoff volume vs. monitored runoff volume for each event

The relationship between the model and the monitoring data was found to be a relatively good fit ($R^2 = 0.7$); however, some potential outliers within the data set were examined. Two large events (10/7/2005 and 11/21/2005) at the onset of monitoring had substantially lower monitored runoff than would be expected given the model results. The events were 3.07 inches and 2.24 inches, respectively, but monitoring results showed runoff volumes less than 2000 cf, far less than expected. Additional support for the conclusion that the monitoring data was in error for these two events is that the effluent flows monitored for these two events are larger than the influent flows, an unlikely scenario.

Likewise, at least two small events (8/7/2006 and 1/2/2007) produced substantially more runoff than would be expected given the watershed model. The events were 0.22 inches and 0.71 inches, respectively. When an error calculation is performed between the model and monitored runoff volume for these two small events, the values are -151% and -217%, respectively.

These 4 storm events were flagged as potential outliers and removed from the data set. An additional plot was created to show the model and monitored data without the potential outliers, which resulted in a much better fit ($R^2 = 0.93$) (Figure 4). These 4 storm events were removed from flow and load analyses based upon these assumptions.

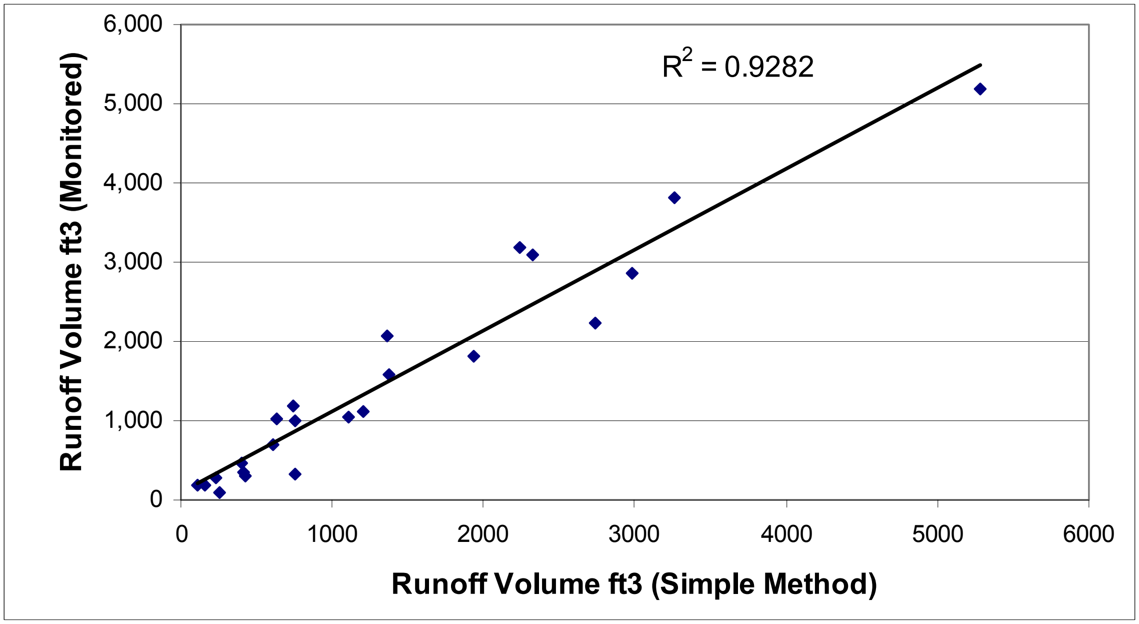

Figure 4: Modeled runoff volume vs. monitored runoff volume for each event – potential outliers removed.

During the 27 storms monitored as part of this study, 40,600 ft^3 of runoff entered the level spreader – filter strip system as determined by the area-velocity meter (not including rain that fell on the system). Of the total inflow, only 11,150 ft^3 reached the outlet, for a total reduction of 72.5% (Figure 5). When the 4 potential outliers were removed from the data set, the volume reduction increased to 84.6%. Even during events where stormwater reached the outlet of the filter strip, the system still provided good volume reduction, ranging from 36% to 66% for the three storms for which there was good inlet and outlet flow data.

A study performed by Line (2006) on a level spreader – grassed filter strip (5.2% slope) receiving highway runoff from a 0.86 acre, 49% impervious watershed showed a volume reduction of 49%. The Westfield Level Spreader received stormwater from a 0.85 acre, 45% impervious watershed. The high volume reduction observed at the Westfield system (estimated between 73 and 85%) is potentially impacted by the presence of the water quality bypass, but also may be due to the smaller slope at the site (approximately 1.5%). It is logical that passing water over a very flat grassed area will result in a low velocity flow and will allow ample time for infiltration.

Accurately determining the volume of runoff that bypassed the system is not feasible for this study; however, a rough estimation was made based on the differences in the modeled and monitored data. If the modeled data is considered to be a reasonable estimation of the volume of runoff produced during a given event, any storm event that resulted in less stormwater entering the system (as determined by the area-velocity meter) than the model amount produced in the watershed could be considered bypass. This is a rough approximation as errors in the area-velocity meter likely impact the flow results, and the modeled data likely contains additional error. However, this approximation indicates that only 1766 ft3 of runoff potentially bypassed the system during the storms that were monitored (not including outliers). This is only 5.6% of the total volume of runoff produced by the storm events monitored as determined by the simple method. When outliers are included, the potential bypass percentage increases to 18%, indicating that at least 80% of the storm runoff produced during the monitoring events entered the level spreader / filter strip system as determined by this rough approximation.

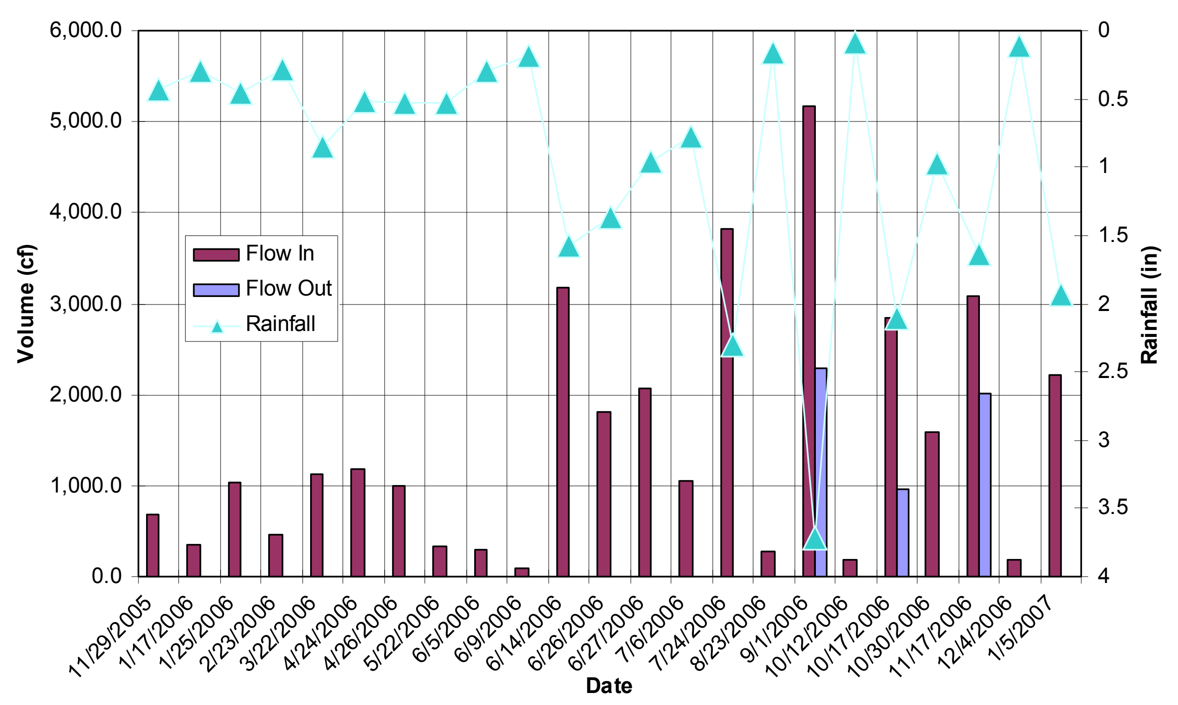

Figure 5: Rainfall – Runoff illustration excluding outliers.

Water Quality Results

Figure 6 and Table 1 illustrate the performance of Westfield Level Spreader with regard to pollutant removal. The pollutant removal efficiency is described by the summation of loads (SOL) which is discussed above. A positive SOL indicates that the pollutant, which entered the basin as stormwater runoff, was retained by the basin. A negative ER represents a surplus of pollutant leaving the BMP, suggesting either internal production of pollutants, or loss of stored pollutants from previous storm events.

According to statistical tests, Westfield Level Spreader significantly (*p*<0.05) reduced every pollutant evaluated byway of a loads analysis. The dominant pollutant removal mechanism in this system was infiltration of the influent stormwater. This system retained large amounts of stormwater runoff, thus also retaining the pollutants associated with that runoff. It should be noted that only 3 storm events in the data set (potential outliers removed) resulted in stormwater reaching the outlet of the system. This had a large impact on the load analysis results, thus, if more large storms were captured (where stormwater reached the outlet of the system) the results would likely vary from those presented.

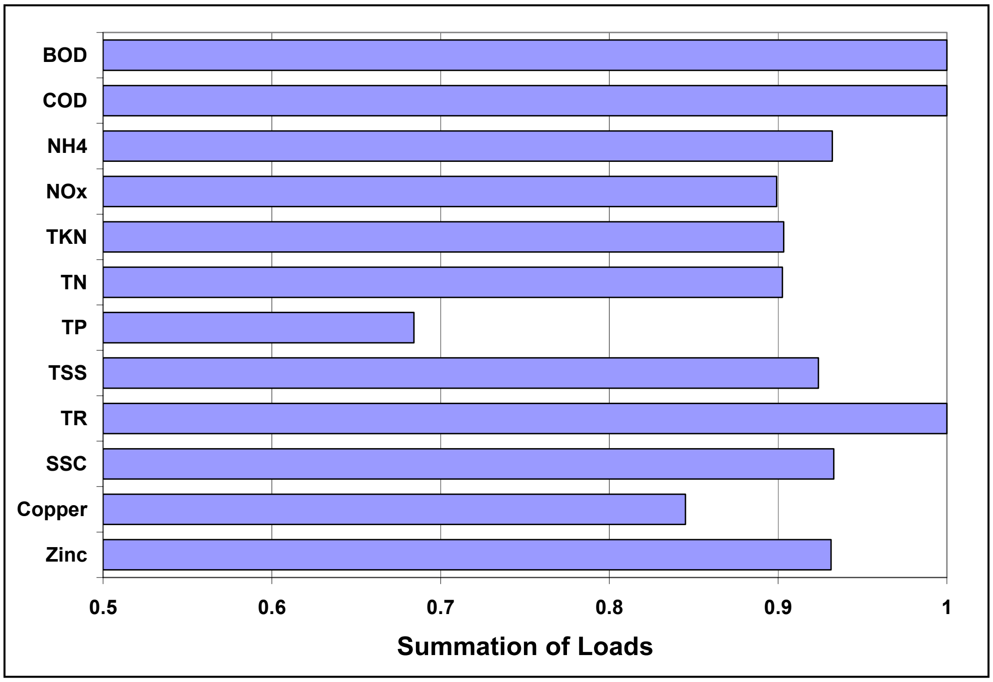

Figure 6: SOL of selected pollutants based on pre- and post-BMP mean concentrations (EMCs) at Westfield Level Spreader.

Summation of Loads (SOL) = 1 – (sum of outlet loads / sum of inlet loads)

Table 1: Summary of Water Quality Load Analysis

Parameter	# of Samples	SOL	p-value	Significant ($p < 0.05$)
Flow	22	0.83	<.0001	yes
BOD	13	1.000	0.0002	yes
COD	14	1.000	0.0001	yes
NH4	22	0.932	<0.001	yes
NOx	22	0.899	<0.001	yes
TKN	22	0.903	<0.001	yes
TN	22	0.903	<0.001	yes
TP	22	0.684	<0.001	yes
TSS	22	0.924	<0.0001	yes
TR	14	1.000	0.0001	yes
SSC	18	0.933	<0.0001	yes
Copper	22	0.845	<0.0001	yes
Zinc	22	0.931	<0.0001	yes

Due, in large part, to the substantial amount of infiltration that occurred within the filter strip, only 4 water quality samples were captured at both the inlet and outlet. These water quality samples indicate that the level spreader – filter strip system removes a high load of pollutants, but does not decrease pollutant concentrations in all cases. Table 2 shows the pollutant concentration removal provided by the system.

Table 2: Summary of Water Quality Concentration Analysis

Parameter	Units	# of Samples	Influent EMC	Effluent EMC	ER
NH4	ppm	4	0.3	0.5	-0.68
NOx	ppm	4	0.4	0.3	0.23
TKN	ppm	4	1.6	1.5	0.07
TN	ppm	4	2.0	1.8	0.10
TP	ppm	4	0.6	1.2	-1.11
TSS	ppm	4	74.8	116.3	-0.56
SSC	ppm	3	105.3	27.3	0.74
Turbidity	ppm	4	37.8	58.5	-0.55
Copper	ppb	4	6.1	7.8	-0.27
Zinc	ppb	4	34.0	18.3	0.46

It should be noted that the first storm monitored at the site (10/7/2005) was included in the concentration analysis but not the loads analysis due to poor influent data. This sample contained large amounts of TSS, TR, NH_4, and had a high turbidity. This sample contained higher amounts of these pollutants than other samples collected later in the study. The soil on the filter strip may have been unstable, leading to these higher values. When the first storm is removed from the data set (Table 3), the analysis shows greater removal of TSS, TR, and NH_4. Note that TP removal is poor in both table 2 and 3.

Table 3: Summary of Water Quality Concentration Analysis – First Storm Removed

Parameter	Units	# of Samples	Influent EMC	Effluent EMC	ER
NH4	ppm	3	0.11	0.10	0.12
NOx	ppm	3	0.34	0.31	0.11
TKN	ppm	3	1.24	0.96	0.22
TN	ppm	3	1.58	1.27	0.20
TP	ppm	3	0.37	0.96	-1.59
TSS	ppm	3	89.33	30.33	0.66
SSC	ppm	3	105.33	27.33	0.74
Turbidity	ppm	3	42.00	24.67	0.41
Copper	ppb	3	6.57	6.03	0.08
Zinc	ppb	3	36.00	15.33	0.57

Sediment

The SOL for TSS removal in Westfield Level Spreader was 0.92 (significant at $p<0.05$). This indicates that a substantial amount of treatment for TSS is occurring in the filter strip, likely through sedimentation, filtration, and infiltration. State regulations give filter strips with level spreaders 25% to 40% TSS removal credit depending on vegetation type. Under these regulations, the Westfield Level Spreader would only receive 25% TSS removal, far below the monitored value. The SSC load reduction was found to be relatively the same as the TSS removal.

A study performed by Line (2006) on highway runoff entering a level spreader – filter strip system showed similar removal as the Westfield Level Spreader. Load reductions of 83% were determined by the Line (2006) study, with TSS concentration reductions being similar to those shown in Table 3 (analysis excluding first storm event). Line (2006) does show a lower effluent TSS concentration, but the level spreader evaluated in the study received stormwater with a lower TSS concentration than that received by the Westfield Level Spreader. Inflow and outflow TSS loads for each storm can be seen in Appendix A – Figure A1.

Table 4: Level Spreader – Filter Strip Reference: Line (2006)

Parameter	# of Data Points	Mean Influent	Mean Effluent	Concentration Reduction (%)	Load Reduction (%)
NH4	14	0.8	0.5	36	**75**
NOx	14	0.6	0.5	11	49
TKN	13	2	1.6	17	66
TN	13	2.5	2.1	14	62
TP	14	0.2	0.2	-11	48
TSS	14	36	10	70	83
Copper	3	31	31	ND	ND
Zinc	3	190	66.7	74	82

Nutrients and Organic Material

The removal rates for most major nutrient pollutants were consistent with those found by Line (2006) (Table 4). The major pollutant removal mechanism in the Westfield Level Spreader is infiltration, thus, pollutant removal was high across all nutrient and organic species.

Oxygen Demand:

Biological oxygen demand (BOD_5) and COD are typical measurements of the amount of organic matter in stormwater runoff. Any process that contributes to the decomposition of organic matter will cause a reduction of BOD_5 and COD. Physically, this can occur by adsorption onto particles and subsequent filtration and sedimentation. Westfield Level Spreader removed both BOD and COD with an efficiency of 100% (both significant at $p<0.05$). There was a lack of literature pertaining to the function of level spreader – filter strips in the removal of BOD; however, a 70% COD removal was observed by Line (2006). Because BOD and COD were not analyzed for in any of the effluent samples (BOD and COD analyses ceased after the 16th storm), the 100% removal is based solely on the 100% stormwater volume reduction.

Nitrogen:

Soluble pollutants can be removed by chemical adsorption to suspended particles followed by sedimentation of those particles, by plant uptake and microbial transformations, and through infiltration. In stormwater treatment practices (such as wet ponds and wetlands) which rely on biogeochemical reactions, a major removal mechanism of the various forms of nitrogen is bacterial transformation. However, Westfield Level Spreader removes pollutants primarily through infiltration, making it difficult to evaluate which other nutrient removal mechanisms are being employed. TKN, NOx, NH_4, and TN removal in the system was 90%, 90%, 93%, and 90% respectively. Line (2006) reports lower load reduction of nitrogen species; however, Westfield Level Spreader removed a higher percentage of the stormwater flow it received than did the level spreader evaluated by Line (2006). This is likely a major cause of the differences in values reported in the two studies. NCDENR (2006) gives a 20% TN removal credit to grassed filter strips, much lower than that observed at Westfield. Inflow and outflow TN loads for each storm can be seen in Appendix A – Figure A2.

The concentrations of the various nitrogen species that were monitored slightly decreased based on the data collected. When the first storm event is removed, reductions are seen in each of the 4 nitrogen species. These reductions are substantially lower than the load reductions measured at the site. The same pattern was observed in the study by Line (2006), where the TN load reduction was 62%, but the concentration reduction was only 14%. In the Westfield Level Spreader study, the TN load reduction was 90%, and the TN concentration reduction was only 10% (Tables 1 and 2).

Phosphorous:

TP load removal in Westfield Level Spreader was 68%. Adsorption onto iron-oxide and aluminum-oxide surfaces and complexation with organic acids accounts for a large portion of phosphorus removal from the water column. In some natural systems, these particles can fall out of solution and be stored on the bottom of the treatment system. Under some conditions, phosphorous can be released from the sediment, adding to the effluent mass of TP. In a flat, grassed filter strip, TP is likely removed primarily through infiltration. The removal determined for the Westfield system is slightly higher than the 48% reported by Line (2006).

TP concentration reductions at the Westfield Level Spreader were poor. The concentration reduction was -111%, indicating an increase in TP during storms which reached the system outlet. It is possible that fertilization of this grassed area or grass clippings are resulting in an accumulation of exportable phosphorous. An increase was also seen in Line (2006), indicating that these natural systems may export TP if not for the substantial infiltration they facilitate.

NCDENR (2006) gives 35% TP removal credit to grassed filter strips. This value is lower than that observed in the Westfield study and in the study by Line (2006). Inflow and outflow TP loads for each storm can be seen in Appendix A – Figure A3.

Pathogens

There were not enough grab samples collected at the Westfield Spreader to make any judgments on pathogen removal. It is likely that on a load basis, they perform well. This is based on the high infiltration provided by the filter strip.

Metals

As for most of the other pollutants, trace metals can be removed from the water column through physical filtering and settling/sedimentation. Although these removal mechanisms were likely acting at the Westfield Level Spreader, infiltration of influent stormwater was the dominant mechanism for metal removal, as was the case for every other pollutant.

The level spreader performed well in regard to metal removal. Statistically significant reductions were found for copper and zinc. Chromium and lead were also analyzed, but too many samples were at or below the minimum detectable level to perform analysis. Copper and zinc removal in the system was 85% and 93% respectively. Compared to the study performed by Line (2006), the removal of zinc at the Westfield site is similar (copper removal not reported).

CONCLUSIONS

- Westfield Level Spreader exceeded the performance expected by NCDENR for TSS, TN, and TP removal. For vegetated filter strips, NCDENR gives 25-40% TSS, 20% TN, and 35% TP removal credit. The Westfield system had a pollutant removal efficiency of 92% for TSS, 90% for TN, and 68% for TP. Based on these results, level spreader – filter strip systems should be considered viable BMPs for flow reduction and pollutant removal.
- Infiltration is considered the dominant pollutant removal mechanism in the Westfield Level Spreader based on the 83% flow reduction observed at the site. This is likely due to the well maintained grass and the slight slope (1.5%) that are present in the filter strip. Line (2006) reported a volume reduction of 50% on a level spreader with a steeper slope.
- The Westfield Level Spreader removed substantially more sediment, nutrients, and metals on a load basis than on a concentration basis. This exemplifies the benefit of the infiltration this system provides.
- Out of 27 storms monitored (regardless of the data quality), outflow from the level spreader only was measured for 5 storm events. The smallest of these events was 1.6 inches, and the largest of which was 3.7 inches. This indicates that the system can treat larger events than the 1-inch event it was designed to treat.
- The Westfield Level Spreader performed relatively consistently with what was found by Line (2006) in a study performed on a level spreader – filter strip receiving highway drainage. The Westfield system provided better removal for many pollutants (on a load basis) than the system studied by Line (2006), likely do to the larger percentage of the influent stormwater that was infiltrated at this site.

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APPENDIX A

Additional Graphs and Tables

Table A1: Results of statistical between inlet and outlet BMP concentrations of selected pollutants at the Westfield Level Spreader

Parameter	Assumed Distribution	Reject Based on KS Test	Paired *t*-Test	Wilcoxian Signed - Rank Test	Significant ?
			p - value		
Flow	Normal	no	0.0005	<.0001	**yes**
BOD	Log	no	<0.0001	0.0002	**yes**
COD	Log	no	<0.001	0.0001	**yes**
NH4	Normal	**Yes**	<0.001	<0.001	**yes**
NOx	Normal	**Yes**	<0.001	<0.001	**yes**
TKN	Normal	no	<0.001	<0.001	**yes**
TN	Normal	no	<0.001	<0.001	**yes**
TP	Normal	**Yes**	0.0016	<0.001	**yes**
TSS	Normal	**Yes**	0.0046	<0.0001	**yes**
TR	Log	no	<0.0001	0.0001	**yes**
SSC	Normal	**Yes**	0.0041	<0.0001	**yes**
Copper	Normal	**Yes**	<0.0001	<0.0001	**yes**
Zinc	Normal	**Yes**	<0.0001	<0.0001	**yes**

1. Rejection (α=0.05) of Kolmogorov-Smirnov goodness-of-fit test statistic implies that the assumed distribution is not a good fit of these data.

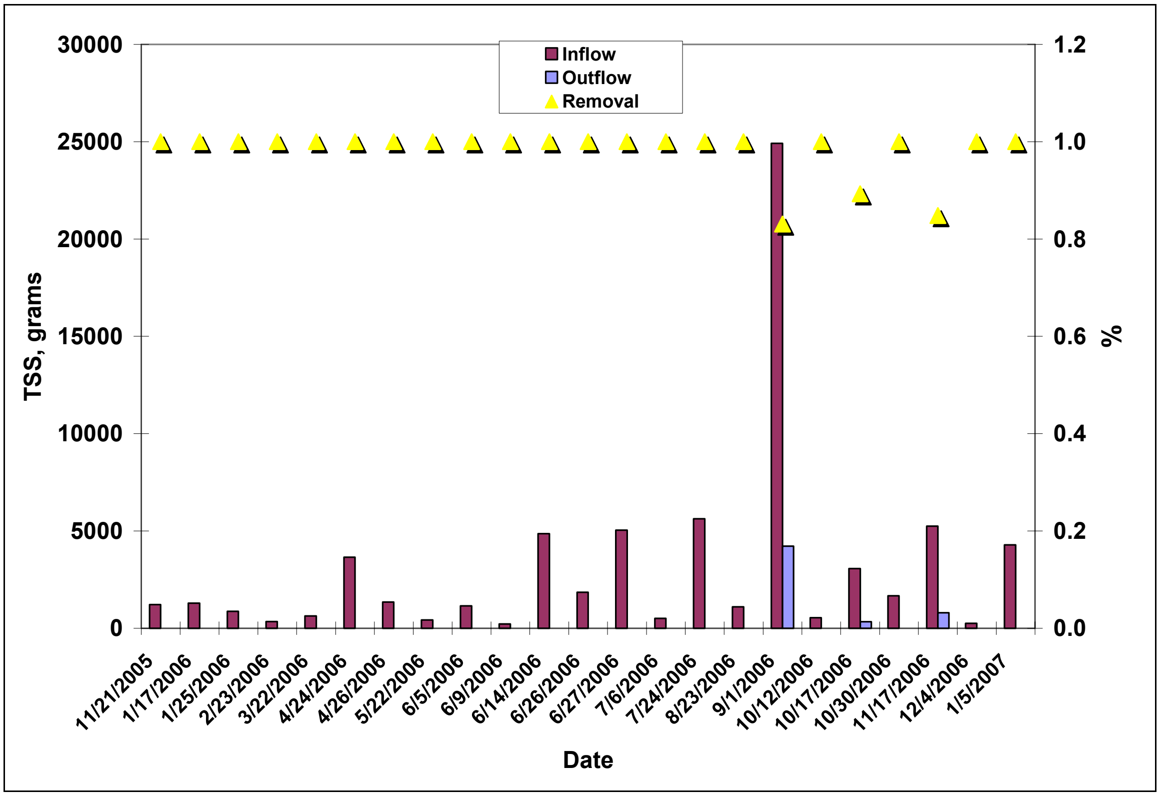

Figure A1: Change in TSS load due to BMP treatment by storm event.

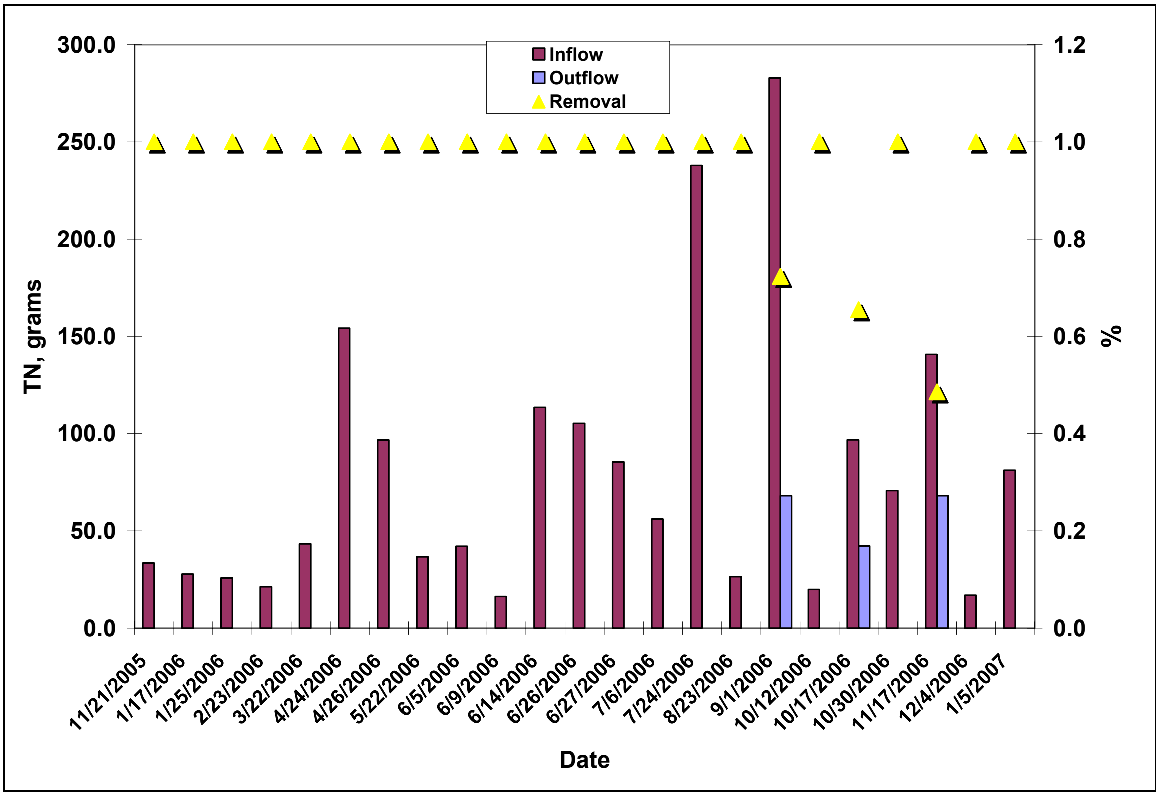

Figure A2: Change in TN load due to BMP treatment by storm event.

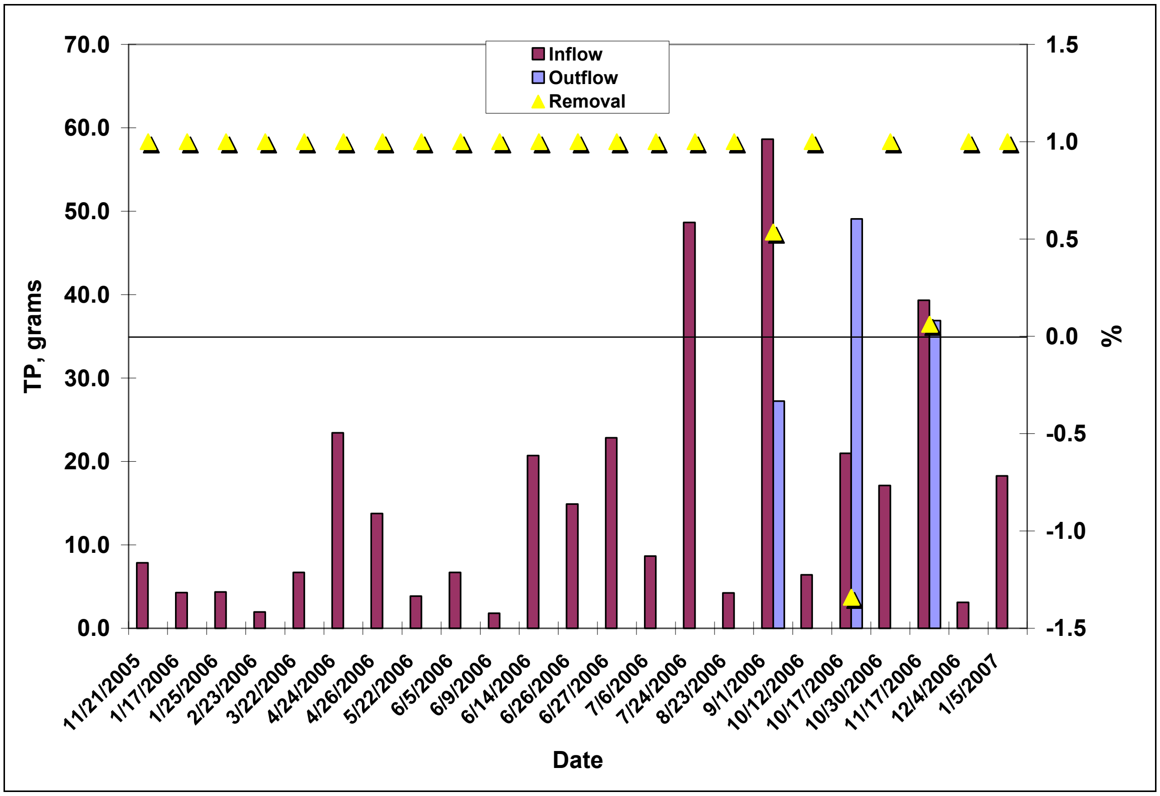

Figure A3: Change in TP concentration due to BMP treatment by storm event.

APPENDIX B

Monitoring Protocol

Stormwater BMP performance Monitoring Protocol for:

Westfield Level Spreader

Description of Site:

The Westfield Level Spreader is located near Little Sugar Creek and treats a 0.85 acre residential area in the Westfield neighborhood of Charlotte. Runoff from the watershed routes to a diversion drop inlet where the first 1 inch of a given storm event is diverted to the level spreader while the remainder goes straight to Little Sugar Creek. The level spreader discharges onto approximately 150 feet of grassed filter strip before recollecting in a vegetated swale. The swale routes the treated stormwater to an 18 inch RCP where it is discharged into the creek.

Watershed Characteristics (estimated)

The watershed consists of approximately 0.85 acres of ¼ acre residential land use with ~ 45% impervious area in the Westfield neighborhood of Charlotte.

Sampling equipment

Inlet monitoring should take place in the 15” RCP pipe leading into the level spreader. An Area-Velocity meter should be used at this location. The outlet pipe (18 inch RCP) should be equipped with an Area-Velocity meter. Using Area Velocity meters in these locations will allow some degree of flow monitoring during submerged conditions, should they occur. Expansion brackets should be used to install the Area-Velocity meters in both locations.

<u>Inlet Sampler</u>

Primary device:	15” diameter RCP
Secondary Device:	ISCO model 750 area-velocity meter
Bottle Configuration	single 18.9L polypropylene bottle

<u>Outlet Sampler</u>

Primary Device:	18” diameter RCP
Secondary Device:	ISCO Model 750 area- velocity meter
Bottle Configuration	single 18.9L polypropylene bottle
Rain gage:	Nearby USGS gage

Sampler settings

Inlet Sampler

Sample Volume	200 mL
Pacing	20 - 100 Cu Ft. (dependent on storm size)
Set point enable	None

Outlet Sampler

Sample Volume	200 mL
Pacing	0.25 - 1 Cu Ft. (dependent on storm size)
Set point enable	none

The outlet sampler is likely to experience very low flows, as a large amount of stormwater will infiltrate into the grassed filter strip. As monitoring efforts continue it is very likely that the user will need to adjust the sampler settings based on monitoring results. The user should keep detailed records of all changes to the sampler settings. One easy way to accomplish this is to printout the settings once data has been transferred to a PC.

Sample Collection and Analysis

Samples should be collected and analyzed in accordance with the *Stormwater Best Management Practice (BMP) Monitoring Protocol* for the City of Charlotte and Mecklenburg County Stormwater Services.

General Monitoring Protocol

Introduction

The protocols discussed here are for use by City of Charlotte and Mecklenburg County Water Quality personnel in setting up and operating the stormwater BMP monitoring program. The monitoring program is detailed in the parent document "Stormwater Best Management Practice (BMP) Monitoring Plan for the City of Charlotte"

Equipment Set-up

For this study, 1-2 events per month will be monitored at each site. As a result, equipment may be left on site between sampling events or transported to laboratory or storage areas between events for security purposes. Monitoring personnel should regularly check weather forecasts to determine when to plan for a monitoring event. When a precipitation event is expected, sampling equipment should be installed at the monitoring stations according to the individual site monitoring protocols provided. It is imperative that the sampling equipment be installed and started prior to the beginning of the storm event. Failure to measure and capture the initial stages of the storm hydrograph may cause the "first flush" to be missed.

The use of ISCO refrigerated single bottle samplers may be used later in the study if future budgets allow. All samplers used for this study will be configured with 24 1000ml pro-pak containers. New pro-pak containers should be used for each sampling event. Two different types of flow measurement modules will be used depending on the type of primary structure available for monitoring

Programming

Each sampler station will be programmed to collect up to 96 individual aliquots during a storm event. Each aliquot will be 200 mL. in volume. Where flow measurement is possible, each sampling aliquot will be triggered by a known volume of water passing the primary device. The volume of flow to trigger sample collection will vary by site depending on watershed size and characteristic.

Sample and data collection

Due to sample hold time requirements of some chemical analysis, it is important that monitoring personnel collect samples and transport them to the laboratory in a timely manner. For the analysis recommended in the study plan, samples should be delivered to the lab no more than 48 hours after sample collection by the automatic sampler if no refrigeration or cooling of samples is done. Additionally, samples should not be collected/retrieved from the sampler until the runoff hydrograph has ceased or flow has resumed to base flow levels. It may take a couple of sampling events for the monitoring personnel to get a good "feel" for how each BMP responds to storm events. Until that time the progress of the sampling may need to be checked frequently. Inflow sampling may be completed just after cessation of the precipitation event while outflow samples may take 24-48 hours after rain has stopped to complete. As a result it may be convenient to collect the inflow samples then collect the outflow samples several hours or a couple of days later.

As described above, samples are collected in 24 1,000mL containers. In order for samples to be flow weighted these individual samples will need to be composited in a large clean container; however, future use of single bottle samplers will likely reduce the need for this step. The mixing container should be large enough to contain 24,000mL plus some extra room to avoid spills. Once the composited sample has been well mixed, samples for analysis should be placed in the appropriate container as supplied by the analysis laboratory.

Chain of custody forms should be filled in accordance with Mecklenburg County Laboratory requirements.

Collection of rainfall and flow data is not as time dependent as sample collection. However it is advised that data be transferred to the appropriate PC or storage media as soon as possible.

Data Transfer

Sample analysis results as well as flow and rainfall data should be transferred to NCSU personnel on a quarterly basis or when requested. Transfer may be completed electronically via email or by file transfer.