LONG ISLAND SOUND STUDY
EPA ASSISTANCE AWARD

FINAL REPORT

EPA Grant Number: LI96159301

Project Title: Bioretention-based stormwater practices for nitrogen removal: implementation and monitoring

Grant Project/Budget Period: October 1, 2012-December 30, 2013

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Project Abstract:
Nitrogen (N) has been shown to be a major driver of algal blooms that in turn cause hypoxia in Long Island Sound. Low Impact Development (LID) practices such as rain gardens or bioretention areas have been found to treat many pollutants, but N has been difficult to control. This project involved installation of a modified bioretention system designed to increase N retention in the system. A saturated zone was created to encourage denitrification. Inflow and outflow volumes were measured for one year (Dec. 2012-Dec. 2013). Flow-weighted samples were analyzed for TN concentrations. Inflow and outflow TN concentrations (n=29 and 31, respectively) were compared using an unpaired *t*-test. Outlet concentrations were significantly ($p<0.001$) lower than inlet concentrations, with a 59.8% reduction in the mean TN concentration. The total measured mass of TN that entered the bioretention was 4.93 kg, whereas the TN mass out was 1.92 kg, for a 61.6% reduction. Results indicate that this practice could be used in urban or agricultural areas to reduce N loading to receiving waters.

Methods

Shortly after receipt of funding in August 2013, a QAPP for monitoring was prepared, submitted to EPA, and approved. Site selection was occurring simultaneously. The bioretention was installed in November 2012 (Figure 1). The watershed of the bioretention area was approximately 18,840 ft^2. A PVC pondliner was installed to contain the media and allow for capture of all outflow water. Two 4-inch perforated underdrains were installed. Two 3-inch bulkhead fittings were installed in the liner and piped to the monitoring sump (Figure 2). Approximately 37 cubic yards of bioretention media was installed in the cell. The media was a 4:3:2 (sand:topsoil:compost) blend purchased from Read Custom Soils (http://admakepeace.com/read_custom_soils/soil_solutions). Plantings included chokeberry (*Aronia arbutifolia)*, switchgrass (*Panicum virgatum* Ruby Ribbons), and orange coneflower (*Rudbeckia fulgida* Goldsturm).

An elevated outlet pipe was used to create a saturated zone approximately 1 foot deep in the bottom of the bioretention unit. Pipe weirs were installed in the inlet and outlet pipes of the bioretention. Water level was measured using pressure transducers connected to a Campbell Scientific datalogger (Figure 2). Flow volumes were calculated in the datalogger and pulses were sent to ISCO samplers to perform flow-weighted composite sampling. Samples were collected weekly. Temperature was also measured at the

Figure 1. Installation of liner beneath bioretention unit, Storrs, CT.

Figure 2. Monitoring equipment and elevated outlet pipe, modified bioretention, Storrs, CT.

inlet and outlet. Oxidation-Reduction Potential (ORP) was measured in the saturated zone using a probe installed in the center of the bioretention. Monitoring occurred from December 2012 - December 2013.

Results

Quantitative results

TN analysis was performed on 29 and 31 samples from the inlet and outlet respectively (Table 1). An unpaired *t*-test analysis was performed on TN concentration data. Analysis indicated that outlet concentrations were significantly ($p<0.001$) lower than inlet concentrations, with a 59.8% reduction in mean TN concentrations (Table 1). A comparison of exceedance probabilities for inlet and outlet concentrations illustrates graphically the difference between the two (Figure 3).

Table 1. Summary of TN concentrations for the inlet and outlet of modified bioretention, Storrs, CT.

Location	n	Median TN (mg/L)	Mean TN (mg/L)	Std. dev.
Inlet	29	11.99	12.69	7.8
Outlet	31	4.02	5.11	3.5
% change		**66.5**	**59.8**	

The total measured mass of TN that entered the bioretention to date was 4.93 kg, whereas the TN mass out was 1.92 kg, for a 61.6% reduction in TN mass. Due to equipment malfunctions (sub-zero temperatures or large events), flow data for the inlet was not accurately recorded in a large number of instances (56% of sampling periods). For these instances, the mass balance of the system was used to compute a substitute value. Precipitation inputs were subtracted from outflow volume (which were highly reliable), and substituted for the inlet volume. This substitution is not expected to impact mass calculations in a meaningful way. Occasional overflows of the bioretention cell also occurred, impacting the volume estimate for the week. One major overflow occurred, along with several minor overflows. Overflow volumes were estimated to be approximately 10-15% of total inflow volume.

The rate of TN reduction appeared to increase (Figure 4) since the practice was installed in early winter 2012. This trend was statistically significant ($p<0.001$), with $R^2=0.39$. This is perhaps not surprising as biological activity in the soil media would likely be higher in the warmer months. Oxidation Reduction Potential (ORP) levels were in the range where denitrification reactions would take place (Figure 5), indicating good potential for lowering TN concentrations.

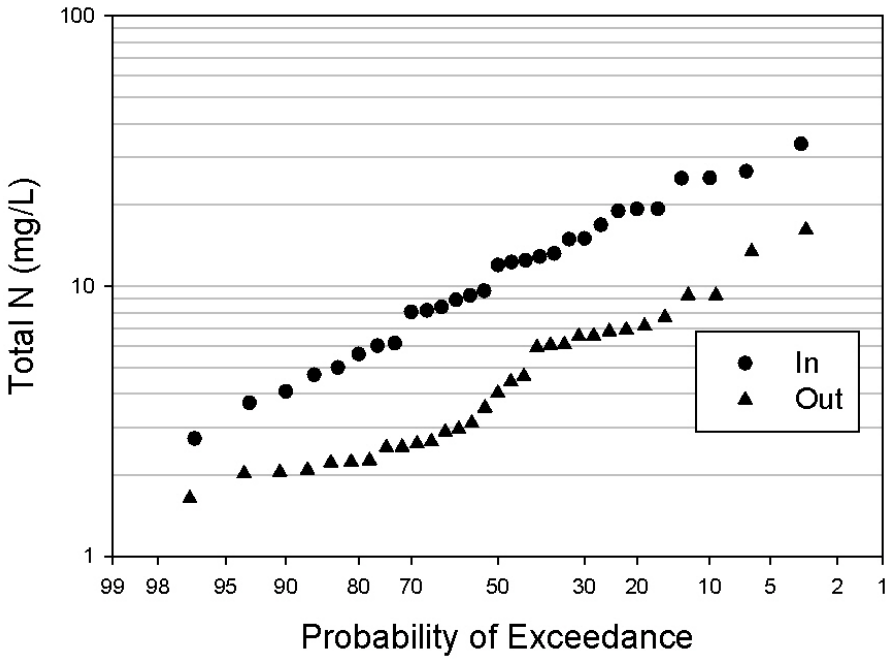

Figure 3. Probability of exceedance of TN concentrations, in vs. out, for modified bioretention.

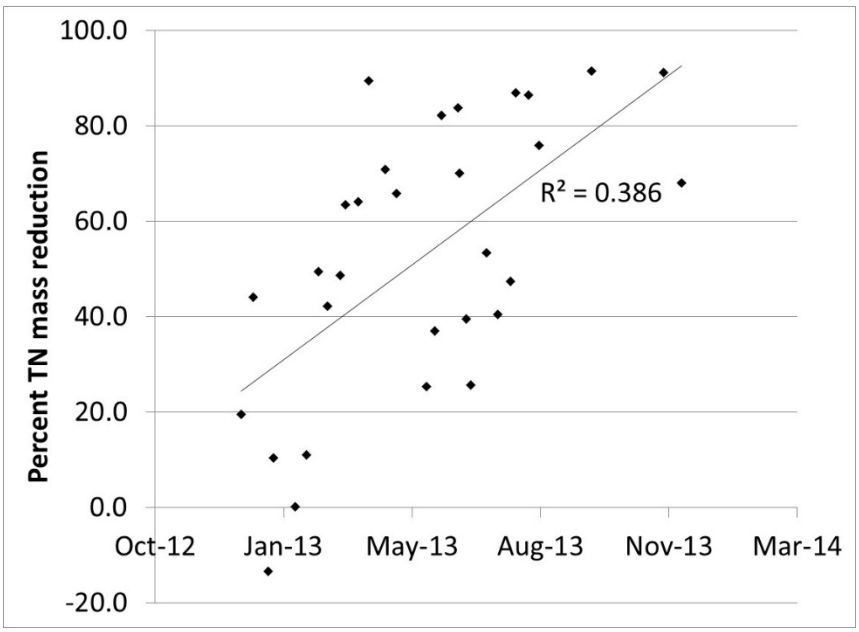

Figure 4. Weekly TN load reductions for modified bioretention.

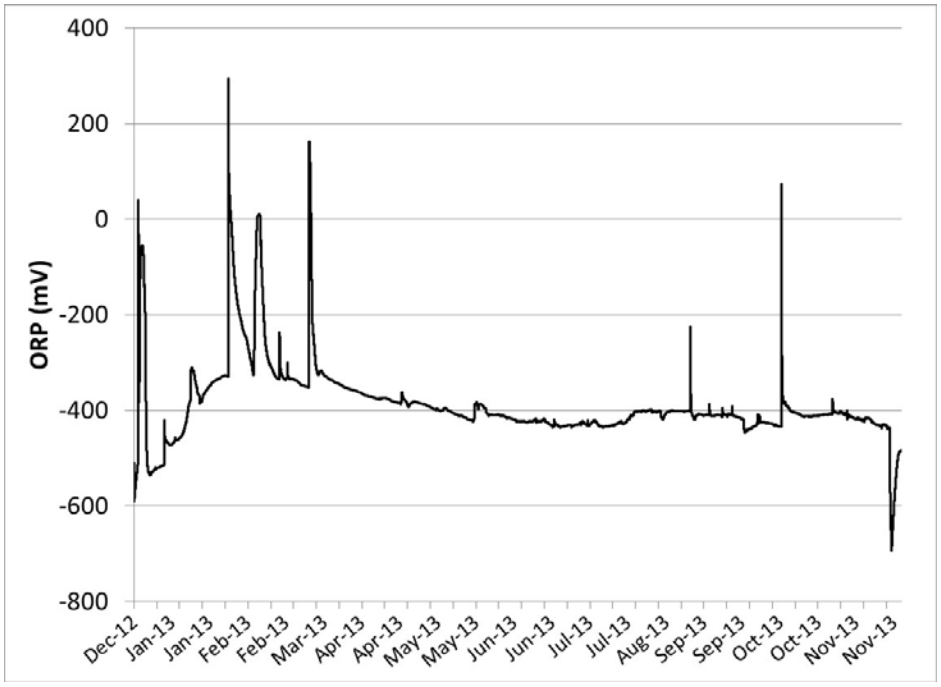

Figure 5. Oxidation-Reduction Potential inside modified bioretention, Storrs, CT.

Qualitative results

Although the red chokeberry and switchgrass thrived in the bioretention area (Figure 6), heavy deer browse on the orange coneflower killed all plantings of that variety.

Figure 6. Chokeberry plantings in modified bioretention, Storrs, CT.

Due to the agricultural activity (primarily grass and corn silage storage and loading) occurring in the watershed of the bioretention unit, there was heavy loading of particulate matter to the system. The trench drain that collected runoff from the asphalt area often became clogged with debris, which caused water to bypass the system completely (Figure 7).

Figure 7. Trench drain clogged with silage debris.

The runoff that did enter the system carried coarse sand (used to hold down plastic covers on silage piles) and pieces of corn and grass silage that spilled during the loading process. These materials built up on the surface of the bioretention, reducing the infiltration capacity of the soil. Surface pooling of water after storms occurred for longer periods of time as more of this material built up (Figure 8). In practical terms, if this practice were to be used in agricultural settings, some sort of pre-treatment settling pool would be beneficial to help prolong the life of the practice itself. In more urban settings, this pretreatment would most likely not be necessary unless large amounts of sand are being applied in the winter.

The design for this modified practice included an impermeable liner. This allowed for the creation of the saturated zone to encourage denitrification, and it also allowed for full measurement and sampling of water that passed through the system. This results in the system essentially acting as a water quality filter, without infiltrating water into the ground. One of the main goals of low impact development is to increase groundwater recharge, so if this system were to be used in real-world settings, the design would

need to be modified in some way to allow for infiltration of the treated water. This could be as simple as sending effluent from the system to sub-surface infiltration chambers.

Figure 6. Clogging of bioretention media with silage and sediment.

Table 2 contains the tasks, deliverables, outputs and outcomes that were initially proposed for this project, along with actual outcomes. All proposed tasks were met within the timeframe of the project.

Table 2. Comparison of actual accomplishments with anticipated outputs/outcomes

Work Plan Activity	Deliverable(s)	Timeline or % Time	Expected Output	Actual Output	Expected Outcome	Actual Outcome
Task: **Site and design anaerobic bioretention cell**						
	•	Oct-Nov 2012	• Site design specifications, UConn approvals	• Site design specifications, UConn approvals	• Implementation of IC-TMDL and N-TMDL	• Implementation of IC-TMDL and N-TMDL
Task: **Build bioretention cell, with monitoring system**						
	•	Nov 2012 – Dec 2013	• Nitrogen removing stormwater practice, 500 ft^2	• Nitrogen removing stormwater practice, 500 ft^2	• Reduction of N loading from ~79,000 gallons of urban runoff, annually	• 116,650 gallons treated
Task: **Technical and qualitative monitoring of bioretention**						
	• Write QAPP/get approval	Sep. 2012	• Approved QAPP	• Approved QAPP	•	•

Work Plan Activity	Deliverable(s)	Timeline or % Time	Expected Output	Actual Output	Expected Outcome	Actual Outcome
	before					
	• Monitoring data on N input and output	Nov. 2012-Dec 2013	• Data on N input and output	• Data on N input and output	• Scientific support for use of innovative stormwater practice	• Scientific support for use of innovative stormwater practice

Challenges/Changes:

The initial proposal for this project included some travel funds to bring Rob Roseen (UNH) down to UConn to consult on project design. Dr. Roseen left UNH prior to the start of this project, so James Houle was consulted in his place for design collaboration at the beginning of the project.

The initial site proposed for this project was found to be unsuitable due to large underground utilities present. An alternative site was selected where an erosion problem was occurring. The new site was a large paved area where corn and grass silage were stored and loaded.

The initial proposal included the use of wood shavings in the media. These were not included in the media mixture for two reasons: the new site is in an agricultural watershed where silage would likely be part of the runoff. The silage would provide the necessary carbon to be the electron donor in the denitrification reactions. Also, a new media was selected that had a substantial portion of compost, which would also be a source of carbon.

Once the site was selected, the project proceeded as scheduled. Challenges included winter sampling with excessively cold temperatures. This impacted sampling as measurement instruments were frozen in ice in the inlet and outlet pipes at various times, resulting in loss of flow data for 2 weeks. Also, the lack of significant rainfall in October-November 2013 resulted in fewer samples than we were expecting during this time period. However, the number of samples was sufficient to show statistically significant differences between inlet and outlet concentrations. Other problems have been outlined in the results section.

Quality Assurance:

The monitoring program followed QAPP requirements. Data were collected according to requirements listed, and sensors have been calibrated according to the schedules listed in the QAPP. All of this information is recorded in field sheets and field log for the project. The sample analysis at UConn's Center for Environmental Sciences and Engineering (CESE) was performed according to the laboratory QAPP in place at that location.

Presentations/Publications/Outreach:

Preliminary results of this project were presented at the Connecticut Conference on Natural Resources at UConn on March 18, 2013. The audience for this conference consists of state regulators and professionals in the state of Connecticut.

Preliminary results of this project were also presented at the NEIWPCC conference in Burlington VT in May 2013. The audience for this conference is regulators from the northeast region, academics, and professionals.

Preliminary results from the project were presented at the LISS Nonpoint Source and Watersheds work group on 11/20/13.

The results of this project will continue to be disseminated through our extension outreach activities in the State of Connecticut. Our typical audiences include municipalities, engineers, landscape architects, and other professionals. Outreach topics occasionally include designs to target specific pollutants such as N. Additionally, the CT NEMO program is the hub of the National NEMO network, which has a distribution list of professionals providing similar outreach in 32 states around the country.