Table 3: *E. coli* Concentration Efficiency for BMPs in Wilmington, NC.

BMP Type	*E. Coli* Concentrations (MPN/100ml)		
	Geometric Mean Influent	Geometric Mean Effluent	Concentration Reduction (%)
Bioretention - shallow cell	135	564	-318
Bioretention - deep cell	135	50	63
Wetland 1	482	543	-13
Wetland 2	945	1031	-9
Wet Pond 1	1559	73	95
Wet Pond 2	2477	74	97

Table 4: Enterococcus Concentration Efficiency for BMPs in Wilmington, NC.

BMP Type	Enterococci Concentrations (MPN/100ml)		
	Geometric Mean Influent	Geometric Mean Effluent	Concentration Reduction
Bioretention - shallow cell	337	376	-12
Bioretention - deep cell	337	43	87
Wetland 1	1040	495	52
Wetland 2	1208	483	60
Wet Pond 1	224	46	80
Wet Pond 2	2128	181	92

Analysis of the geometric mean effluent concentrations from all BMPs reveals that not every BMP was able to reach EPA target concentrations for surface waters, particularly for enterococcus. Only the deep Bioretention cell and Wet Pond 1 had geometric mean effluent concentration which approached EPA standards for enterococcus. For *E. coli*, the deep Bioretention cell and both wet ponds reached EPA standards.

Conclusions

This study suggests that some stormwater BMPs may effectively sequester and remove bacteria. Multiple stormwater BMPs in Wilmington, NC, were able to reduce indicator bacteria concentrations by over 50%. The deep Bioretention cell in Wilmington, NC, performed well; however, data from the shallow Bioretention cell indicates that some design features may impact the ability of bioretention areas to remove indicator bacteria. The substantial indicator bacteria removal in Wilmington wet ponds is not well understood, but indicates wet ponds as promising BMPs for indicator bacteria removal in coastal areas.

If the proper environment exists, it may be possible for stormwater BMPs to be sources of indicator bacteria. This may be due to both animal activity and to indicator bacteria persistence within BMPs. This was potentially the case for shallow Bioretention and wetlands studied in Wilmington, NC. This emphasizes the need for further study as to which environmental factors impact indicator bacteria sequestration, inactivation, and persistence in stormwater BMPs.

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Development of a Laboratory Based Stormwater Sampling and Test Facility Utilizing Natural Stormwater Runoff

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ABSTRACT

Field monitoring of stormwater treatment BMPs is needed to evaluate BMP effectiveness, however this approach is typically costly and takes a significant amount of time to collect qualified samples. Laboratory studies provide more experimental control but do not simulate actual storm conditions and ultimately are not representative.

A laboratory based pump and treat apparatus was constructed to capture natural stormwater runoff from a catch basin receiving runoff from an outside asphalt parking lot in Portland, Oregon. The catch basin was modified with a small lift station to pump runoff from the catch basin to the laboratory located adjacent to the parking lot.

The system uses a triplex pump system to capture flows up to three liters per second, while approximating the inflow hydrograph. Flow from all three pumps is combined into a mixing column and then discharged to a test tank which can be equipped with different types of treatment technologies.

Three samplers have been positioned to collect influent samples and effluent samples from two effluent sources which allow for side by side comparison of different treatment technologies. The system is configured to treat flow on a flow basis but can also be configured to treat flow on a volume basis as well.

The system has been in operation since the fall of 2009 and captured many different storm events. One of the challenges is that the parking lot pollutant load significantly reduces as successive storms wash off the accumulated pollutants. Tests are currently underway to develop a methodology to increase solids loading by taking sediment from nearby catch basins and "seeding" the parking lot.

INTRODUCTION

Field evaluation of stormwater treatment BMPs is the principal method to make a determination if the BMP meets the water quality treatment criteria established by different programs throughout the United States. Of particular note are the USEPA's

ETV program, the State of New Jersey's TARP program which is administered by the New Jersey Corporation for Advanced Technology (NJCAT) and the State of Washington's Technology Assessment Protocol – Ecology (TAPE) program.

These programs required detailed field studies of manufactured treatment devices (MTDs) which typically take two years of monitoring to collect from 12 to 15 qualified storms. These studies can in some cases be very costly and problematic.

In order to establish a good monitoring site the BMP must be first part of a development plan, go through a construction phase, and allow for the site to stabilize and build up enough pollutants in the runoff to provide meaningful results. If the period of study is two years, it can be in excess of four years from the time the site is identified to the end of the data collection period.

In addition, it may be discovered that despite all site vetting efforts, insurmountable issues with site hydraulics, pollutant loading (or lack thereof), safety, etc. may lead the site to be abandonned because the data quality objectives cannot be met.

At the other end of this spectrum, arguments for laboratory studies instead of field monitoring studies are based upon lower costs, shorter time lines, and control of variables. For example, laboratory based tests for solids removal utilizing silica materials with known particle size distributions, concentrations, and flow rates are relatively easily accomplished. Protocols for laboratory based evaluations have been (or in the process of being) developed by the ASCE Manufactured Treatment Devices subcommittee (Bannerman et al, 2009) and the American Society of Testing and Materials (ASTM) committee ASTM C27.70 on Precast Stormwater Treatment Units.

Though attractive for those reasons, laboratory testing does not simulate actual stormwater and runoff conditions found in the field. For example, laboratory testing of BMPs for TSS and SSC removal utilizes silica particles as a surrogate for TSS and SSC pollutants and evaluates removal at constant flow rates. Though this may allow for a controlled variable evaluation or comparison, the results are difficult to translate into field conditions with variable particle properties, fluctuating flow rates, and a variety of BMP loading scenarios.

In the desire to develop a BMP testing approach that had both the simplicity of the laboratory based methods while providing the complexity and reality of natural storms and runoff pollutants, a laboratory-based, pump-and-treat stormwater collection system (PNT) was constructed in Portland, Oregon. The apparatus was constructed specifically to test the Stormwater Management StormFilter® (StormFilter), a filtration BMP.

APPARATUS

The PNT system, schematically illustrated in Figure 1, was developed to provide side by side comparison of StormFilter cartridges containing different media types for the reduction of pollutants such as suspended solids (SS), total phosphorus (TP), total copper (Cu), and total zinc (Zn) from real stormwater runoff.

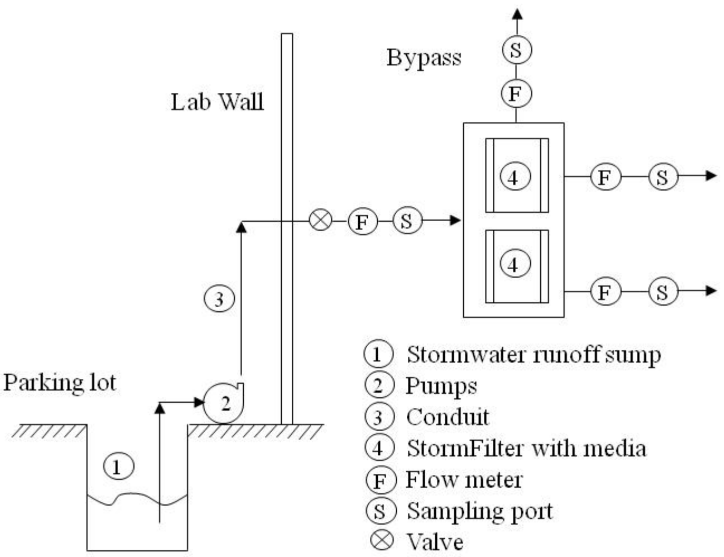

Figure 1. Illustration of pump & treat system.

The PNT system is located at a testing lab in Portland, Oregon and involves stormwater runoff from a well-established asphalt parking lot drained by a single catch-basin. The catch-basin was fitted with three pump intakes and a depth sensor. Runoff is sensed and pumped from the catch basin to the laboratory where it is directed into a container with two StormFilter cartridges via an influent mixing, measurement, and sampling manifold. Outflow from the cartridges is routed through individual flow measurement and sampling manifolds. The treated effluent is then discharged to the sanitary sewer. The system was meticulously designed to minimize the influence of the stormwater delivery and effluent conveyance systems on the characteristics of the stormwater.

Catchment Characteristics

The parking lot area shown in Figure 2 contributes stormwater runoff to the PNT system and is about 0.2 acres in size, 90% impervious, with a calculated Washington State Department of Ecology water quality design flow rate of 0.032 cfs (14.4 gpm). The parking lot, is located within a light industry area, is subject to light traffic, and lies beneath the flight path of the Portland International Airport. The slope is mild with some seasonal sources of organic matter from vegetation. A tipping bucket rain gage is located near the center of the catchment area as shown in Figure 2.

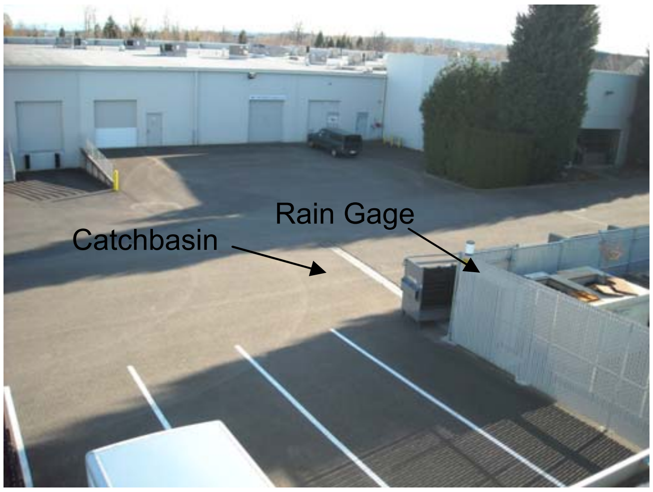

Figure 2. Catchment area.

Catch Basin Modification

The existing catch basin was a 36x36 inch steel catch basin with a sump and steel grate. Discharge from the catch basin was directed to a main which ultimately discharges to the Columbia Slough.

The catch basin shown in Figure 3 was modified with a concave floor and three pump intake pipes terminating just off the bottom of the invert to capture all solids in the runoff and ensure complete capture of all the fine solids. A small recirculation line was also installed to constantly stir the bottom of the catch basin during pump operation to prevent settling and promote movement of solids towards the invert.

Figure 3. Pump intake cluster, the EnviroPod® insert, and the completed system with grate.

The sump was fitted with a pressure transducer to communicate the water surface elevation to the central controller located inside the building. Lastly, a catch basin insert (EnviroPod®) was installed to trap bulk solids greater than 2000um such as gravel, leaves and trash. This mass is measured and removed after each storm.

Pump Station

The pump station shown in Figure 4 is located outside with the intake lines running underground to the catch basin sump. The pumps operate at approximately 5, 10, and 25 gpm each, for a total of 40 gpm collectively. The pumps are programmed to track the influent hydrograph by turning on and off based upon the fluctuation of the water level in the catch basin. Flows in excess of the pump capacity simple overflow into the original catch basin outlet so as to not flood the catchment. The pumps are also designed to drain back to the catch basin between pump cycles, though a small volume of water (<5-L) remains in the pump heads and priming pots for priming purposes.

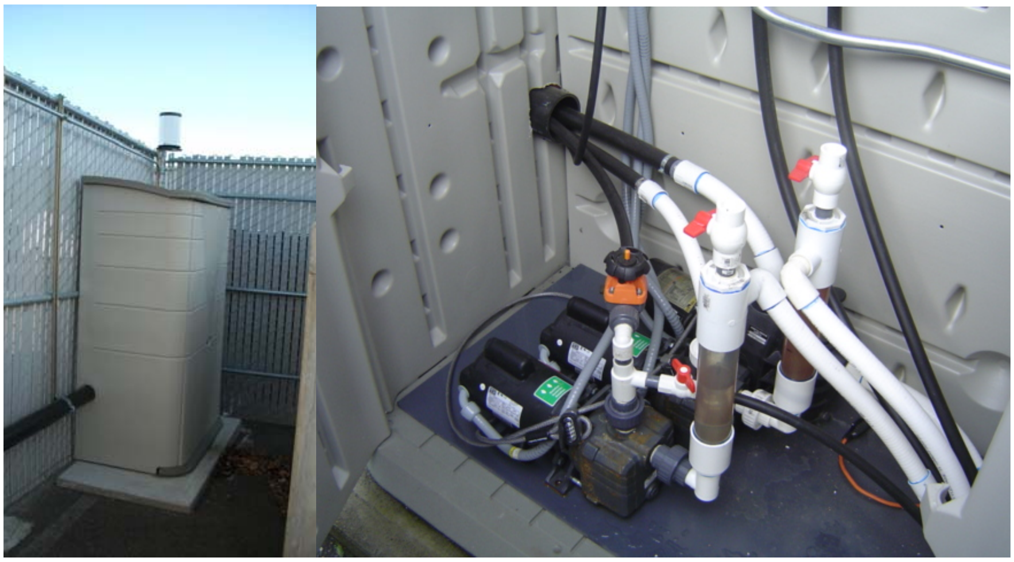

Figure 4. Pump station and the 3 pumps within.

The lines used for each pump were carefully designed to provide flow velocities greater than two feet per second. Too small of a line diameter results in excessive head loss and consequently flow reduction, whereas line diameters that are to large result in lower velocities that allow solids to settle, which affects the representativeness of the influent delivered to the test apparatus.

Flow Measurement and Influent Sample Collection

Once a storm occurs, incipient runoff begins to fill the sump of the catch basin. When the water surface elevation reaches the low set point, the first pump initiates and pumps the runoff to a mixing manifold. If the capacity of the first pump is exceeded then the water surface elevation in the catch basin continues to rise to the low set point for the second pump, and so on. All three pumps discharge to the mixing manifold shown in Figure 5.

Figure 5. Vertical mixing manifold showing pump inlet pipes dropping in from the left.

The mixing manifold was also designed and calibrated to serve as a precision flow meter. A pressure transducer precisely records the driving head on the manifold and is converted to flow in the main controller. A sampling tube inserted in the vertical portion of the effluent manifold effluent line faces directly into the flow and permits sample collection by an ISCO 6712 autosampler.

Effluent from the mixing manifold is then discharged to a chamber containing two StormFilter cartridges shown in Figure 6. The entire system is elevated to allow for gravity drainage of the system to mimic how the actual systems operate in the field.

In this configuration the two cartridges can be configured with different types or gradations of media to allow for performance evaluation or comparison using natural stormwater.

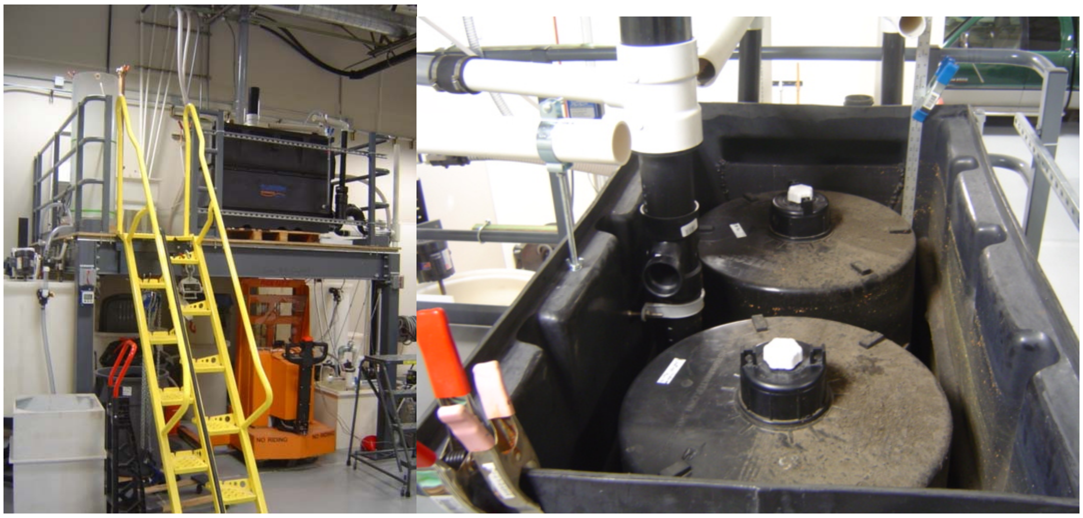

Figure 6. View of the elevated treatment system. In this configuration the outlet from the mixing manifold discharges to a vessel with two StormFilter, each configured with different filter media.

Effluent Sampling

Once the treated water is discharged from the StormFilters it is conveyed to individual manifolds similar to the influent manifold that is fitted with pressure transducers, sampling ports, and are designed and calibrated for flow measurement. These columns are also connected to ISCO 6712 autosamplers as shown in Figure 7.

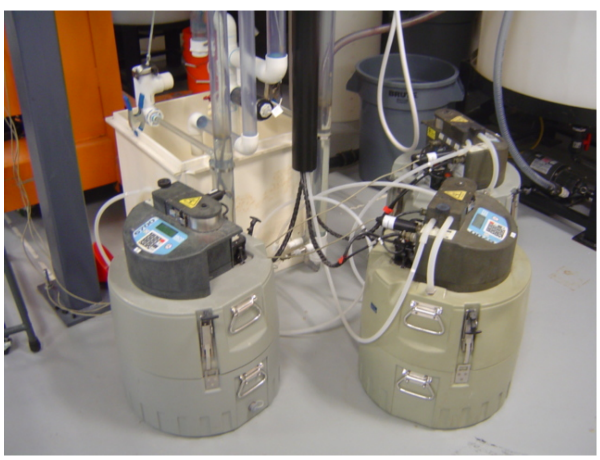

Figure 7. Effluent samples are taken by two ISCO samplers, one for each cartridge. The middle sampler is connected to the influent manifold for influent sample collection.

Once the samples are collected the aliquots are composited and sent to an analytical laboratory for analysis. The remainder of the effluent is collected in a sump and discharged to the sanitary sewer. After a storm is captured, the system is cleaned and set up for the next storm event.