Filterra® Bioretention System Water Quality and Hydrologic Field-Scale Performance Evaluation

Fayetteville Amtrak Station
472 Hay Street
Fayetteville, NC

Prepared for:

Contech Engineered Solutions
9025 Centre Pointe Drive
West Chester, OH 45069

Prepared by:

Andrew Anderson, *Extension Associate*
Alessandra Smolek, *Graduate Research Assistant*

North Carolina State University
Department of Biological and Agricultural Engineering
D.S. Weaver Labs, Campus Box 7625
Raleigh, NC 27695

August 23, 2015

Executive Summary

Filterra® Bioretention Systems are biofilters offering a unique version of the typical flow-through filter by coupling high volume treatment with an engineered bioretention media (140 in/hr design infiltration rate) (Lenth et al. 2010). The systems are viable options for retrofitting stormwater infrastructure in ultra-urban areas where space is of concern. The purpose of this study was to quantify the hydrologic and water quality treatment capabilities of a standalone Filterra® device to obtain performance data that supports approval by the North Carolina Department of Environmental and Natural Resources (NCDENR). This monitoring was performed in accordance with Preliminary Evaluation Period (PEP) guidelines described in the 2007 NCDENR Stormwater BMP Manual and the Quality Assurance Project Plan (NC State 2013) previously submitted to NCDENR.

North Carolina State University conducted a third-party analysis of the sediment, nutrient, and metals removal performance and hydrologic mitigation of a Filterra® Bioretention System ("Filterra"). The NCDENR total suspended sediment (TSS) design criterion is 85% removal. Another widely-implemented protocol for approval of emergent stormwater technologies is the state of Washington's Technology Assessment Protocol – Ecology (WSDE, 2011). TAPE designates a basic treatment target of (a) TSS removal greater than 80% when influent TSS range: > 200 mg/L, (b) TSS removal greater than or equal to 80% when influent TSS range is 100-200 mg/L or (c) effluent TSS concentration of less than 20 mg/L when influent TSS range: 20 – 100 mg/L. Once this basic criterion is met, additional treatment for total phosphorus may be awarded if removal of TP is greater than or equal to 50% for influent concentrations between 0.1 and 0.5 mg/L. Comparisons to both these protocols were made.

Results show the monitored Filterra® system reduced median peak flow by 56% for storms monitored in the study (0.10 to nearly 5 inches in depth). During the study period (2013-2014), statistically-significant bypass did not occur before 0.69 inches (Figure 5 and Table 15). When plotting the observed rainfall intensity vs. site peak outflow against the theoretical peak flows from the Rational equation's pre- and post-development conditions, the Filterra® device nearly mimics the pre-development site peak (Figure 10 and Figure 7). Additionally 72% of inflow volume was treated by the Filterra®, while the remainder was either bypass flow (22%) or a combination of soil storage and/or instrument error (6%) (see Hydrology

section). Data from Smolek et al. (2015) show that the expected overflow from a traditional stormwater BMP following NCDENR design guidance during an average year, such as a wetland or wet pond, is consistent with the overflow percent seen by the Filterra® in our study, suggesting that the Filterra® behaved similarly to widely-used and approved BMPs in North Carolina (Figure 4).

Over a 22-month monitoring period, the Filterra® significantly reduced total suspended solids concentrations with an efficiency ratio of 96%, a cumulative load reduction of 76%, and a median storm-by-storm TSS load reduction of 80%. Another sediment metric, Suspended Sediment Concentration (SSC), was measured, resulting in a 97% significant efficiency ratio, a 77% cumulative load reduction, and a 77% median storm-by-storm load reduction. The 95% confidence interval of the mean TSS removal on a per storm event basis was determined to be 90% - 94%, satisfying both NCDENR and TAPE criteria.

Total phosphorus concentrations were significantly reduced with an efficiency ratio of 64%, a cumulative load reduction of 54% and a 63% median storm-by-storm load reduction. TAPE criteria for accreditation of TP removal require 50% TP removal when influent concentrations are between 0.1-0.5 mg/L in order to account for irreducible concentrations. The mean storm-by-storm event mean concentration reduction of the 16 TAPE-qualified events was 66% with the 95% confidence interval of the mean TP removal ranging from 57% - 75%, satisfying the TAPE criteria. Overall cumulative percent loading reduction was 54%, indicating excellent removal of phosphorus that is on par and/or above the 45% pollutant removal credit awarded by NCDENR for bioretention without internal water storage (NCDENR 2009). Concentrations of both total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) were very low both entering and leaving the system (below what is expected on an urban watershed).

While total nitrogen is not a pollutant targeted for TAPE approval, total nitrogen concentrations were significantly reduced with an efficiency ratio of 39%, a cumulative load reduction of 39% and a 45% median storm-by-storm load reduction. Although total nitrogen was reduced, likely due to filtration of particulate-bound N, nitrate export was witnessed. This finding was expected, and is typical in systems that do not have apparent mechanisms for denitrification. Total zinc concentrations were also significantly reduced with an

efficiency ratio of 69%. For the Filterra® system as a whole, cumulative percent load reductions for TSS, TP and TN were 76%, 54% and 39%, respectively. When only storms that did not produce bypass were considered, the cumulative percent load reduction increased to 96%, 75%, and 45% for TSS, TP and TN, respectively.

When looking at effluent concentrations as a benchmark, water quality of discharged and treated stormwater was generally lower than "good" and "excellent" water quality thresholds in the literature. The median effluent TP concentration of 0.038 mg/L met the 0.06 mg/L "excellent" threshold for over 80% of all measured events. The 0.53 mg/L TN median effluent concentration meant that the "excellent" benthic threshold of 0.69 mg/L determined for this specific eco-region was met or exceeded for 65% of measured events.

Future studies with higher nutrient concentrations entering the Filterra® (perhaps from watersheds with a high gross solids and leaf litter loading) will provide a better assessment of soluble phosphorus species, since nutrient influent concentrations for this site were below what is typically seen on urbanized watersheds.