TreePod® Filter Research and Development

2010

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Prepared for Kristar, Inc.

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Final Report

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Executive Summary

The TreePod® Filter was tested for its hydraulic and treatment capabilities.

The hydraulics were tested by falling head and infiltrometer tests. Two media were tested. One was an 80/20 percent by volume blend of concrete sand and compost respectively. The other media was an 80/20 percent by volume blend of expanded slate and compost. For a particular media, the hydraulic performance of the TreePod® Filter varies depending on wetting and drying cycles. The maximum observed hydraulic capacity for both media was 450 in/hr, the minimum was 17 in/hr, and a typical capacity estimated throughout a 150-minute test is 40-60 in/hr, based on professional judgment.

Treatment was tested based on a protocol similar to the State of Washington's Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE). Changes were made to TAPE for testing the TreePod® Filter. Street dust particles, fine street sweeping particles less than 75 microns, were used in place of ground silica to better represent the composition and shape of actual stormwater particles. And though TAPE does not specify the duration of each test run or total hydraulic loading for all the runs, each TreePod® Filter test was 150 minutes long and the total hydraulic loading was equivalent to approximately 5 inches of runoff from a drainage area of about a third of an acre.

Treatment capabilities of the expanded slate and compost media were evaluated based on the reduction of total suspended solids (TSS), suspended solids concentration (SSC), turbidity, total phosphorus (TP), total copper (TCu), total lead (TPb), and total zinc (TZn) concentrations. Influent concentrations were representative of typical stormwater runoff.

Maximum percent removal, which occurred when there was no bypass, was highly dependent on influent concentrations relative to background concentration. Average influent concentrations for solids were 105 mg/L TSS, 103 mg/L SSC, and 28 Nephelometric Turbidity Units (NTU). Average influent for TP was 0.073 mg/L. The average influent concentrations for metals were 9.4 μg/L for TCu, 2.5 μg/L for TPb, and 16.9 μg/L for TZn. Initial background concentrations of constituents from a clean water flush prior to the treatment tests were 0.67 mg/L TSS, 0.53 mg/L SSC, 3.55 NTU, 0.94 mg/L TP, 4.3 μg/L TCu, 0.13 μg/L TPb, and 3.6 μg/L TZn.

Sediment was removed best, followed by metals; phosphorus increased due to low influent concentrations. The measured removals ranged from 65% to 99% for TSS, -1386% to -170% for TP, 42% to 77% for TCu, 52% to 95% for TPb, and 49% to 87% for TZn over flows that ranged from 6 to 30 gpm. Flow rate through the media had little impact on performance. When influent flow exceeded flow capacity, bypass caused the lower removal efficiencies. The decrease in performance was directly proportional to the amount of water bypassed.

Site-specific hydraulic performance will depend on local precipitation patterns, climate, dry-weather flows, and catchment characteristics. Percent reduction of constituent concentration will depend on influent concentrations.

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1 Introduction

Kristar's TreePod® Filter is a media filter intended to remove a wide array of pollutants of concern from stormwater runoff. This filter was tested by the Office of Water Programs (OWP) under contract 518251.

1.1 Background and Purpose

The TreePod® Filter consists of a tree box filled with engineered filter media and a pre-filtration inlet box with a litter screen. The TreePod® Filter tested has a manufacturer's design loading rate of 1 gpm/ft^2. OWP tested the hydraulic capacity of the filter, and also tested for treatment of total suspended solids (TSS), suspended solids concentration (SSC), turbidity, total phosphorus, total copper, total lead, and total zinc. The tests were performed to obtain results that would mimic the field performance of the TreePod® as closely as possible. This information is presented for consideration by BMP approval authorities across the country, though the protocol used here evolved from those specified by the State of Washington's Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE) (ECY 2002/2008, 4-5). However, the specifications and procedures were refined as discussed in Section 4 to better mimic field performance.

1.2 TreePod® Filter Description

The TreePod® Filter tested had an outside footprint of 5ft x 9ft and the internal dimensions of the media bed was 4ft x 6ft The filter was originally constructed without a bottom so the filter can infiltrate water below the vault. However, for testing purposes, the filter was constructed with a sealed 6-inch concrete bottom to prevent infiltration losses. The TreePod® has two weirs set into the sides of the inlet to allow for bypass if the flow exceeds the filter capacity. The TreePod® is designed to support vegetation, but the unit tested did not have vegetation. The media composition in the TreePod® was similar to the tree box filter tested by the University of New Hampshire (UNH 2007). Figure 1 is a schematic of the filter.

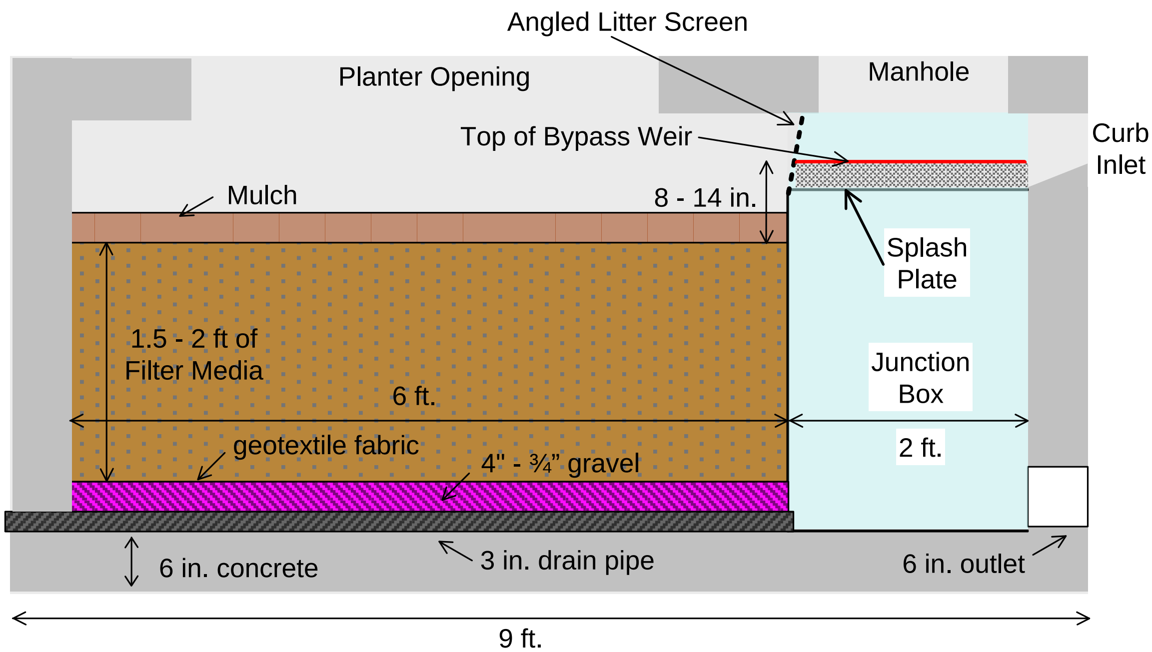


Figure 1 TreePod® Filter Schematic

1.3 Media Descriptions

Two media blends were tested: a blend of sand and compost (SC), and a blend of expanded slate and compost (ESC). The composition and physical characteristics of the media were not performed by OWP; they are reported as provided by Kristar. Hydraulic capacity tests were performed on SC and ESC. Treatment tests were only performed on ESC. The compost used in both blends met the specifications established by the US Compost Council.

1.3.1 Sand and Compost (SC) Blend

The SC blend (see sample KE 15b in Appendix A) was chosen by Kristar because it is similar to the blend used in a tree box filter tested by University of New Hampshire (UNH). The SC blend is composed of 80 percent sand and 20 percent compost. Previous laboratory results of the SC (see Appendix A) report the hydraulic conductivity of SC to be approximately 50 in/hr (0.035 cm/s) at the end of a 10-minute test (ASTM D2434). Two feet of SC were installed in the TreePod® Filter and tested for hydraulic performance.

1.3.2 Expanded Slate and Compost (ESC) Blend

The ESC blend (see sample KE 13b in Appendix A) is composed of 80 percent expanded slate and 20 percent compost. For treatment tests, the SC blend was removed and replaced with the ESC blend. The ESC blend was expected to have a higher hydraulic conductivity based on prior analysis. Previous laboratory results of the ESC (see Appendix A) report the hydraulic conductivity of ESC to be approximately 43 in/hr (0.03

cm/s) at the end of a 10-minute test (ASTM D2434). This blend was well mixed compared to the SC blend, which contained clumps of compost. 1.5 feet of the ESC blend were installed.

2 Setup

Hydraulic and treatment tests were performed at the Stormwater and Erosion Research Facility (SERF) at California State University, Sacramento. The setup for the hydraulic and treatment tests and a discussion of the sediment source used for the treatment tests, are discussed in this section.

2.1 Influent

The influent setup for both hydraulic and treatment tests is essentially the same, except that when performing the treatment tests a sediment slurry, discussed in Section 2.1.2, is injected into the main water supply. A schematic of the water flow path is shown in Figure 2.

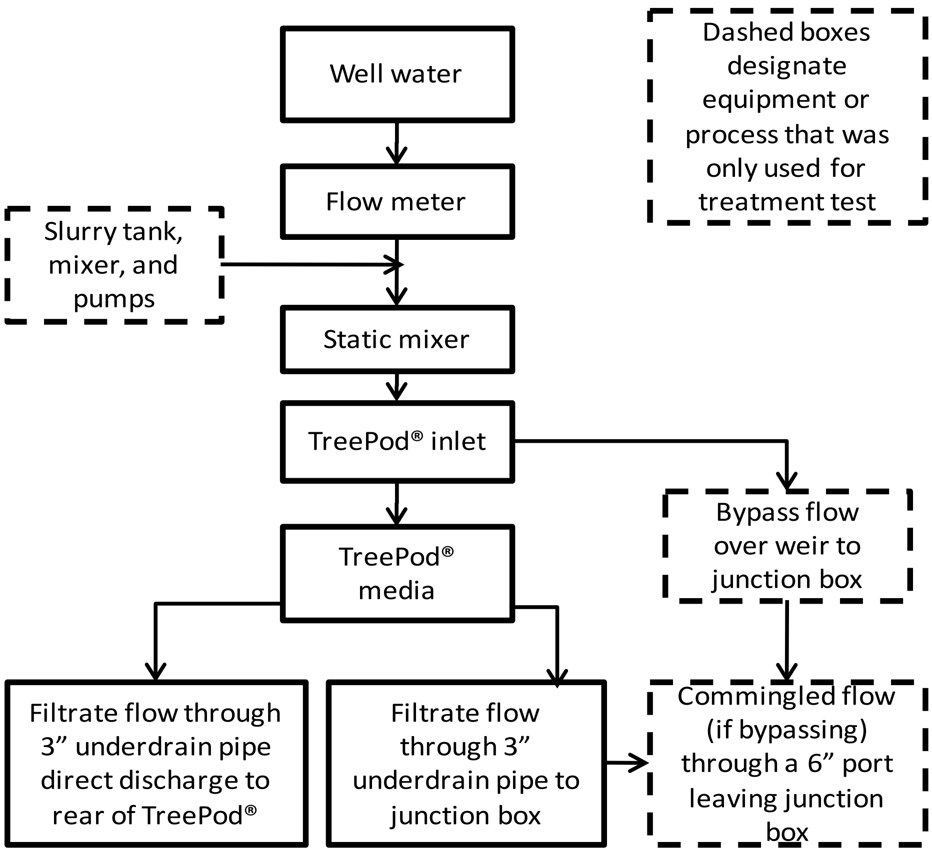


Figure 2 Process Diagram of Water Flow Path

2.1.1 Hydraulic Tests

To perform hydraulic tests, water from the campus irrigation lines was fed through a 1.5-in pipe, which avoided complications due to recirculation of the water after it passed through the filter. The flow was throttled by a gate valve and monitored by a flow meter. The water then flowed out of the pipe and into the TreePod® Filter from the top of the manhole instead of through the curb inlet (Figure 3).

Figure 3 Influent to TreePod® Filter via the Manhole Access

2.1.2 Treatment Tests

To introduce sediment into the influent flow, the setup for treatment tests used a sediment dosing system that consisted of a propeller mixer, slurry tank, recirculation pump, and a peristaltic pump (Figure 4).

The mixer and recirculation pump were needed to keep the extremely high concentrations of sediment suspended within the slurry tank. The peristaltic pump dosed the influent water by taking the slurry from the return line of the recirculation pump.

After injection of slurry, the influent water passed through an inline static mixer that mixed the slurry with the supply water and dampened the pulsation of sediment caused by the peristaltic pump.

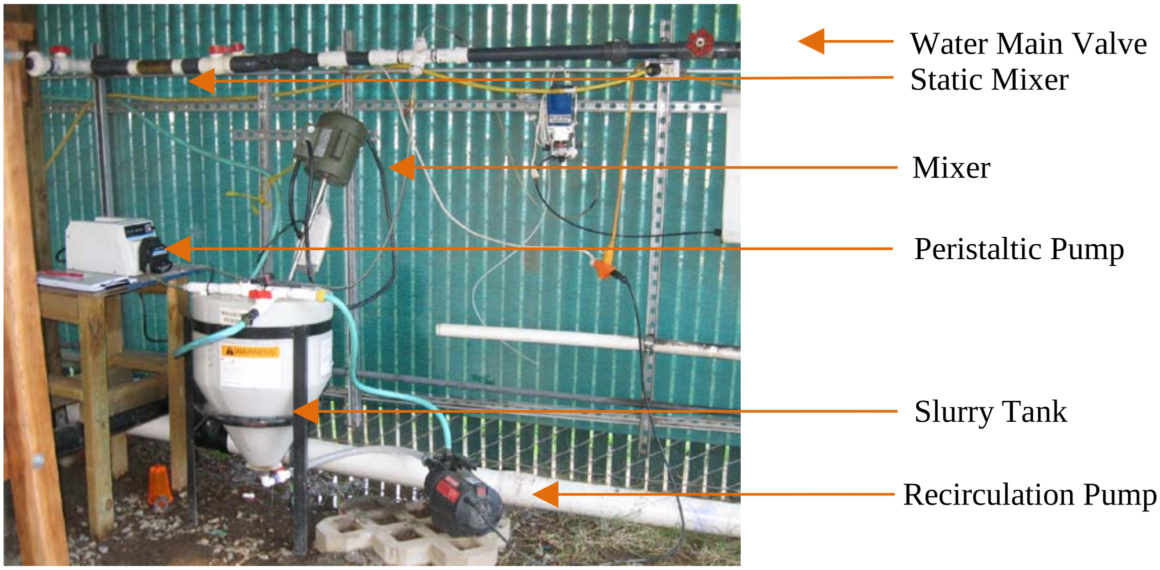


Figure 4 Slurry Injection Setup at the SERF

Sediment Source and Slurry Preparation

Treatment tests were performed with a slurry mix consisting of street dust as the sediment source and irrigation water.

Street Dust

The street dust consisted of particles collected from street sweepings that passed a #200 US sieve (< 0.075 mm). This resulted in sediment that contains the smaller and less-dense particles that are found in stormwater. Street dust already has adequate levels of many other constituents because street dust particles are likely to be the very particles that become entrained in stormwater runoff from paved surfaces.

The target phosphorus content in the street dust was 0.0017 g/g based on monitoring from a watershed in the Pacific Northwest where the TreePod® Filter might be used. This ratio was calculated from runoff concentrations of 0.2 mg/L total phosphorus at 120 mg/L TSS. Street sweepings collected in late June from the City of South Lake Tahoe had phosphorus levels averaging around 0.0007 g/g.

Volatile solids tests were performed to confirm the presence of vegetation-based particles in the street dust. Street dust was 13 percent volatile, which indicates the presence of organic material.

Slurry Preparation

For each test run, the amount of sediment required to produce the specified target influent concentration of 100 mg/L was calculated based on the design flow, the injection flow, and a TSS recovery rate of about 80 percent of the theoretical dose. The sediment was then weighed out and mixed with 13 gallons of water in a 20-gallon cylindrical tank with a conical bottom using a mixer and a circulation pump.

The peristaltic pump was calibrated to 0.067 gpm to inject the correct amount of slurry into the main water supply to achieve the desired influent concentration entering the TreePod® Filter.

2.2 Effluent

Several effluent configurations were employed. Effluent plumbing was changed during both the hydraulic and the treatment tests. Changes were made to observe unimpeded flow, to develop static saturated conditions, and to measure effluent flow rate. Plumbing changes were made to switch between sampling of media effluent that was isolated from bypass water, and to sample water filtrate that was commingled with bypass water. The effluent plumbing configurations are shown below in Figure 5.

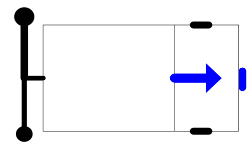
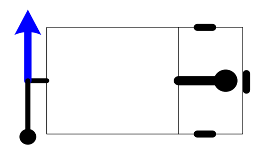
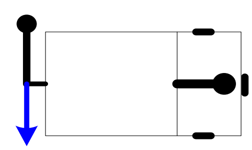
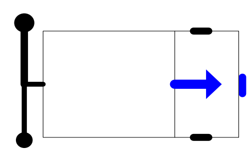
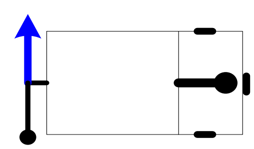
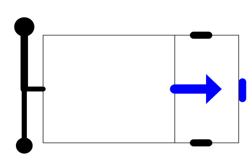
a) 6-inch outlet port from the junction box underneath the inlet

b) 3-inch outlet with 3-inch port ball valve for switching between unrestricted flow in the 3-inch pipe (background) and the 1.5-inch flow meter (foreground)

Figure 5 Variations in Effluent Plumbing from the Junction Box (a) and from the Back of the TreePod® (b).

Initially, to perform a constant-flow hydraulic test, all outlets were capped except for one 6-in outlet port and the 3-in underdrain to the junction box, as seen in Table 1, configuration 1. Then, this 6-inch outlet was capped, the end of the 3-inch drain pipe on the inside of the junction box was plugged, and a 3-inch threaded, external three-way valve was attached on the other end. The three-way valve, or backside tap, allowed the pressure head of the TreePod® to be determined through a ½-inch stand pipe and allowed the TreePod® to be flooded to perform falling head tests. This configuration can be seen in Table 1, configuration 2. After hydraulic testing, the effluent plumbing remained the same to test for constituent removal by the media only. Limited bypass samples were collected separately. Finally, to reduce the cost of separate analyses of filtrate and bypass water, the effluent plumbing was reverted back to the initial setup to test overall treatment as determined by the water quality of commingled filtrate and bypass water (Table 1, configuration 4).

Table 1 Effluent Testing Configurations

Type of Test	Effluent Plumbing Configuration	Pipes from the 3-in drain in the back of the TreePod®		Junction Box Plumbing (inlet side of the TreePod®)		Flow Path Schematic (plan view)
		Pipe A: 3-in open drain	Pipe B: 1.5-in pipe with a paddle-wheel flow meter	Pipe C: 3-in drain into the junction box	6-in junction box outlet ports	
Hydraulics: Constant Head Tests	1. Discharge through orifice in cap on 3-in drain	Closed	Closed	Capped, with restrictor cap	One open, two sealed	
Hydraulics: Saturated Falling Head Tests	2. Discharge through 3-in pipe	Open	Closed	Sealed	All sealed	
Hydraulics: Saturated Falling Head with Flow Meter Test	3. Discharge through 1.5-in pipe	Closed	Open	Sealed	All sealed	
Hydraulics: Infiltrometer Tests	4. Discharge through 3-in drain into the junction box	Closed	Closed	Free-flowing	One open, two sealed	
Treatment: Media Removal Performance Tests (filtrate)	2. Discharge through 3-in pipe	Open	Closed	Sealed	All sealed	
Treatment: Full Device Performance Tests (commingled)	4. Discharge through 3-in drain into the junction box	Closed	Closed	Free-flowing	One open, two sealed	

3 Hydraulics

3.1 Definitions

The following definitions are assumed in this report:

Hydraulic capacity: Infiltration rate at maximum hydraulic gradient for a given conductivity (in/hr)

Hydraulic conductivity: Conductivity resulting from partial saturation (in/hr)

Hydraulic gradient: Height of water above the drain pipe divided by the height of media (unit less)

Infiltration rate: Rate of water flux across the surface of the media (in/hr)

Negative pore pressure: Vacuum pressure

Saturated hydraulic conductivity: Conductivity at the level of saturation achieved after being flooded and static for at least 20 minutes (in/hr)

For one-dimensional Darcy's law $q = KI$ where q is the infiltration rate, K is the conductivity, and I is the hydraulic gradient.

3.2 Hydraulic Test Methods

In general, hydraulic conductivity and capacity is difficult to pinpoint in a system that varies drastically between fairly dry and fairly saturated conditions. As the media saturates, more of the void space is available for flow and hydraulic conductivity increases, but negative pore pressure decreases so infiltration rate across the water-media interface decreases. As flows pass through the media, fines can wash out causing an increase in void space (the area available to flow). However, these fines can redistribute within the media and plug flow channels. Wetting and drying cycles can trap air bubbles inside the media, decreasing the area available for water flow. There may also be an issue of compost swelling due to long-duration wetting.

Figure 6 shows a typical soil conductivity curve for various pore pressures. When the soil is dry conductivity is low, but this is not to say that the infiltration rate is low. When the soil is dry negative pore pressure increases the hydraulic gradient and air voids create space for water storage. As the soil saturates it follows the wetting curve. In an idealized situation the soil fully saturates and the conductivity becomes the saturated conductivity. This really only happens in a lab or highly controlled situation. More typically, trapped air bubbles reduce the final conductivity. (These air bubbles tend to persist in the small flow channels, not the larger flow channels.) In addition, when the soil starts to dry it makes a gradual transition from the wetting curve to the drying curve, so at any time the true observable conductivity can be anywhere between the two curves or have air bubbles that reduce the conductivity. So without controlling the wetting and knowing initial conditions, conductivity covers a large range.

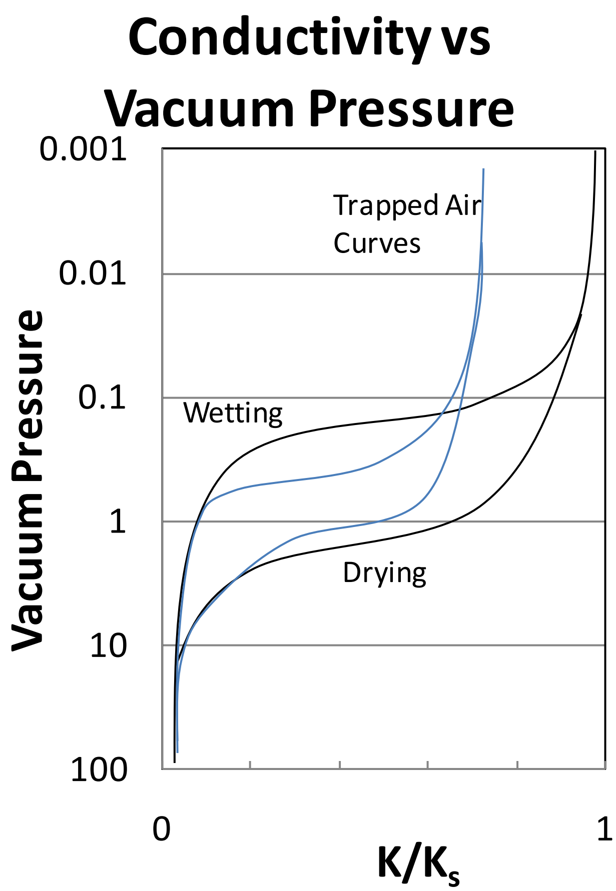


Figure 6 Conductivity During Wetting and Drying Cycles

Due to the many factors that affect hydraulic conductivity, several methods were used to test the media. For the SC blend, constant flow tests, falling head tests, and infiltrometer tests were performed. For the ESC blend, falling head and infiltrometer tests were performed and water level above the media was recorded throughout the treatment tests.

3.2.1 Constant Flow Tests

Short-term constant flow tests were performed to establish a steady hydraulic infiltration rate at different water levels. First, the influent flow rate was set and held constant. The water level and effluent flow rate were observed. If the effluent flow rate and water level were stable for 5 minutes then the infiltration rate was taken as the influent flow rate for that water level. Then influent flow rate was changed to determine steady infiltration at a different water level. Effluent flow rates were measured with a bucket and a stop watch, a practice that could produce large errors at high flow rates.

Longer flow tests were then performed to measure conductivity under more saturated and less variable conditions. The flow rate was changed several times but the water was never turned off over the course of 3 days.

The 3-inch drain pipe was capped inside the junction box. This restricted the flow through a small hole in the cap and perforated pipe slots. The effluent configuration can be seen in Table 1, configuration 1. This cap was removed on June 14 after these tests.

Figure 7 Restrictor Cap and Flow Through Orifice in Restrictor and Exposed Slots in the 3-in Underdrain Pipe

3.2.2 Infiltrometer

Double-ring infiltrometer tests were also conducted using a Turftech® Infiltrometer, which measures the infiltration rate with a hydraulic gradient close to one.

3.2.3 Falling Head Tests

Two types of falling head tests were used. The first is a saturated falling head test where the media was flooded and allowed to sit static and then drain as quickly as possible. Flow was measured by the change in depth of water above the media. A flow meter was also used for one test, but this proved to substantially restrict the flow. The second test is a partially saturated falling head test which consisted of tracking how quickly the TreePod® drains after a test run. All of the partially saturated tests measured flow based on the change in water depth above the media. A summary of the tests that were run on each media are presented in Table 2.

All the flows that were calculated must be adjusted for changes in the area of water above the media. Immediately above the filter media, the effective area was less than 24 square feet, due to the mulch. An estimation of mulch porosity was used to determine the effective area of the water infiltrating into the media. The area also changed above the splash plate, due to inundation of the inlet area. During the tests, the TreePod® was also inspected for leaks that bypass the media. Leak quantities should be subtracted from the flow estimated via the change in water depth.

3.3 Hydraulic Test Performed for Each Media

Table 2 Summary of Hydraulic Tests Performed for Each Media

Test Method	**SC Media**	**ESC Media**	**Effluent Configuration From Table 1**
Constant Flow	3 short-duration tests 1 long-duration test	None	1
Saturated Falling Head	1 test	2 tests with 3-in effluent 1 test with a restriction from the flow meter and back pressure recorded	2 and 3
Turftech Infiltrometer	3 locations on the media surface, multiple tests	1 location on the media surface, multiple tests	2 and 4
Falling Head Following Treatment Testing	None	11 post-run tests	4

3.4 SC Blend Hydraulic Test Results

3.4.1 Constant Flow Tests

The data from the constant flow tests are shown in Figure 8. There are multiple values of hydraulic conductivity, ranging from 17 in/hr to 64 in/hr. These were calculated during intervals of fairly steady flow. During the second constant flow test (Figure 9), the flow was changed and tracked until it stabilized for five minutes. As expected, the water level seems to asymptotically approach a constant water level during the 19.2 gallons per minute flow rate. But when the flow was decreased to 17.7 gallons per minute, the water level suddenly decreased, but then gradually increased and eventually exceeded the water level observed for 19.2 gallons per minute. This indicates a change in the media's conductivity. This could have been caused by swelling of compost, particle migration, or trapped air bubbles. This shows that the conductivity in the TreePod® depends on the wetting conditions.

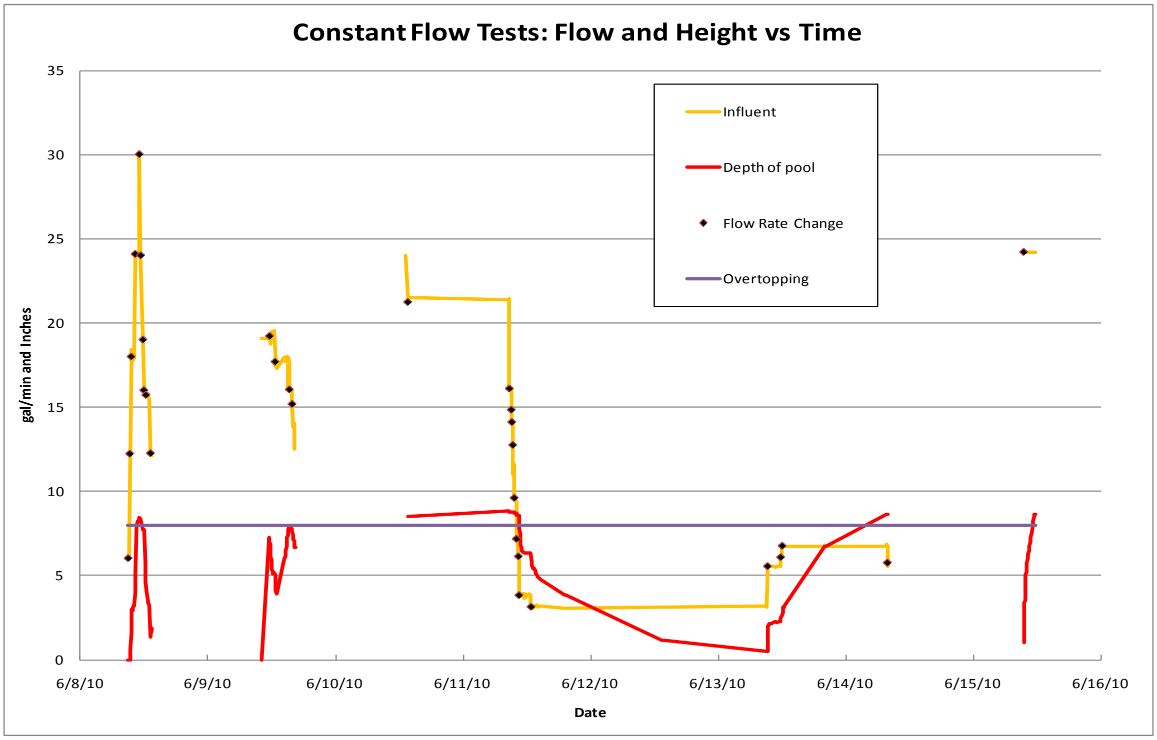


Figure 8 Four Attempts at Constant Flow Rate Tests for SC Blend

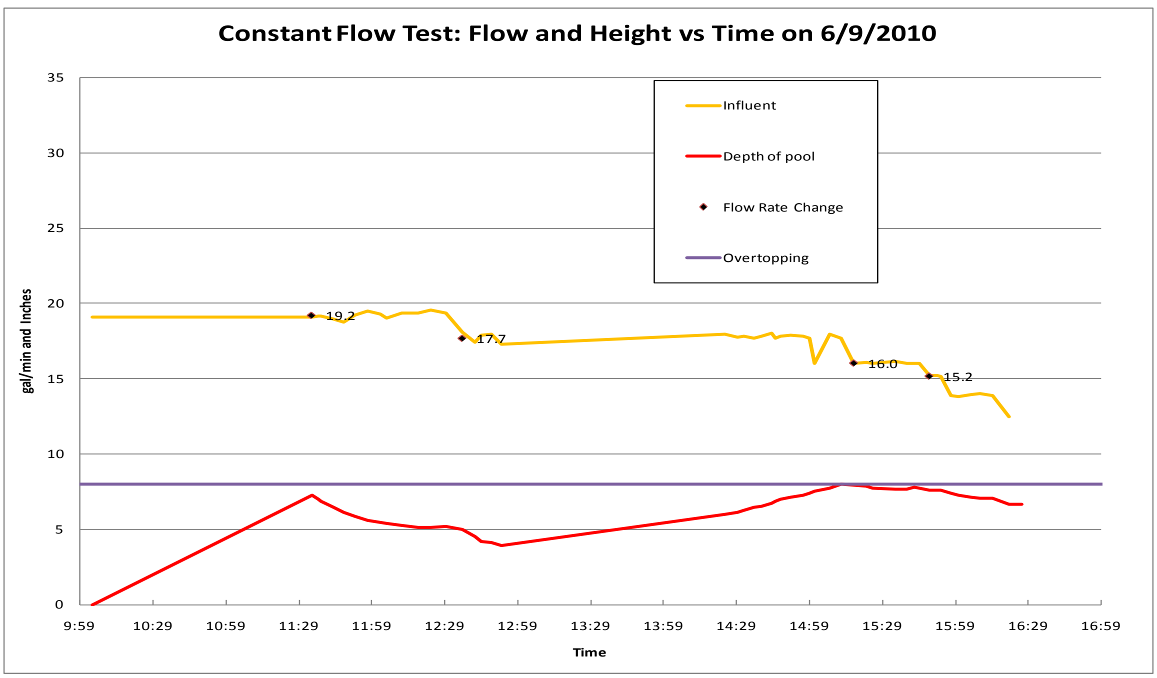


Figure 9 Second Attempt at Constant Flow Test for SC Blend

3.4.2 *Saturated Falling Head Test*

Figure 10 tracks the water surface level during a saturated conductivity test on the SC blend. The saturated conductivity of the media determined by this one falling head test was about 100 in/hr.

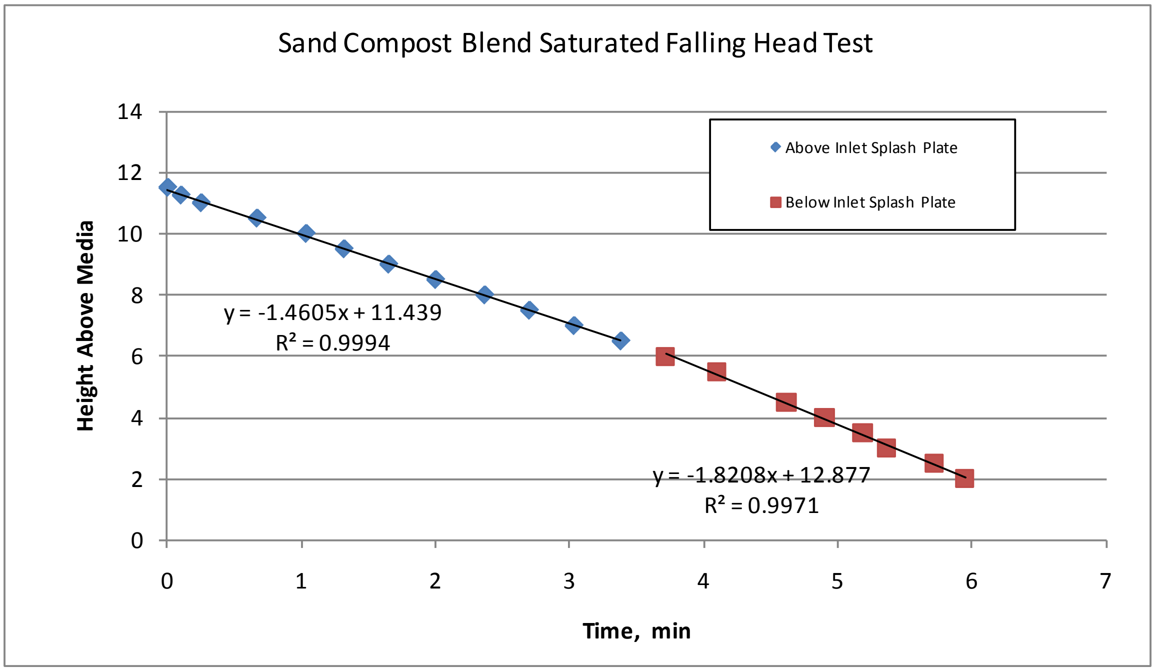


Figure 10 Saturated Falling Head Test of SC Blend

3.4.3 *TurfTech Infiltrometer*

Infiltrometer tests were conducted after the media had been drying for one day. The infiltrometer tests show how quickly the hydraulic capacity of the media can change. For each test the infiltrometer only allows 3-6 inches of water to infiltrate. Performing consecutive tests, up to about 16 inches of infiltrated water, the infiltration rate went from about 250 in/hr to 50 in/hr, as shown in Figure 11. This trend is consistent with what the Green-Ampt infiltration model would predict. When steady infiltration capacity is observed over several consecutive tests, it is reasonable to assume the hydraulic gradient is about 1 so the conductivity of the media is equal to the infiltration rate. For SC this was about 50 in/hr. That is about the same as the average conductivity from the first constant flow test, seen in Figure 8.

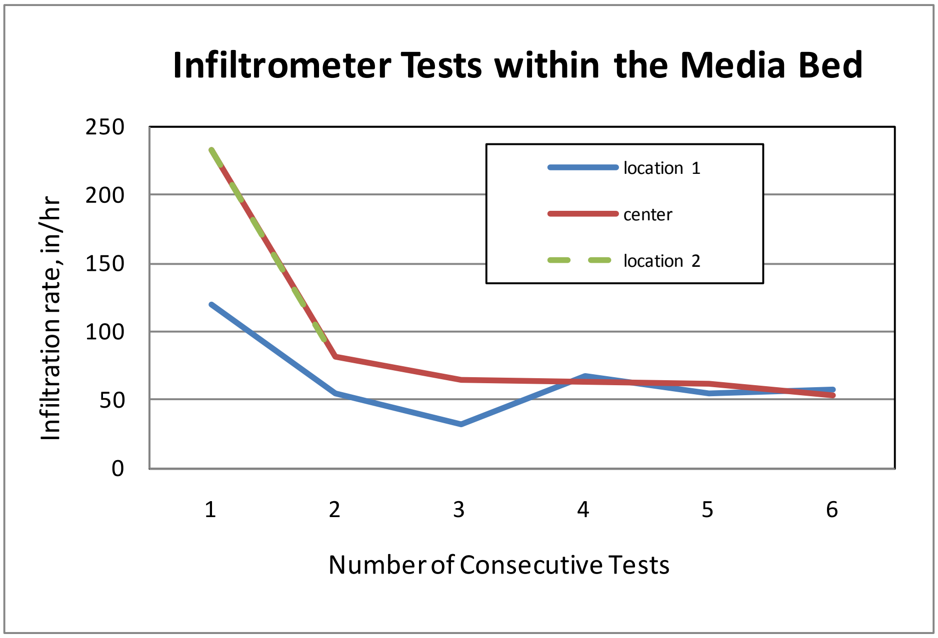


Figure 11 Infiltrometer Test on SC Blend

3.5 ESC Blend Hydraulic Test Results

3.5.1 Saturated Falling Head Tests

Three falling head tests were performed on the ECS blend shortly after installation. The 3-in pipe was plugged inside the junction box and the backside tap was used. Two falling head tests were done with an unobstructed 3-in pipe (Figure 12). The two unrestricted falling head tests yield saturated conductivities of 254 and 256 in/hr. One was run through the flow meter in an attempt to determine hydraulic conductivity (Figure 13). The conductivity was measured at 160 in/hr. This is much lower than the unrestricted tests (without a flow meter) so this was not an accurate measure of saturated conductivity.

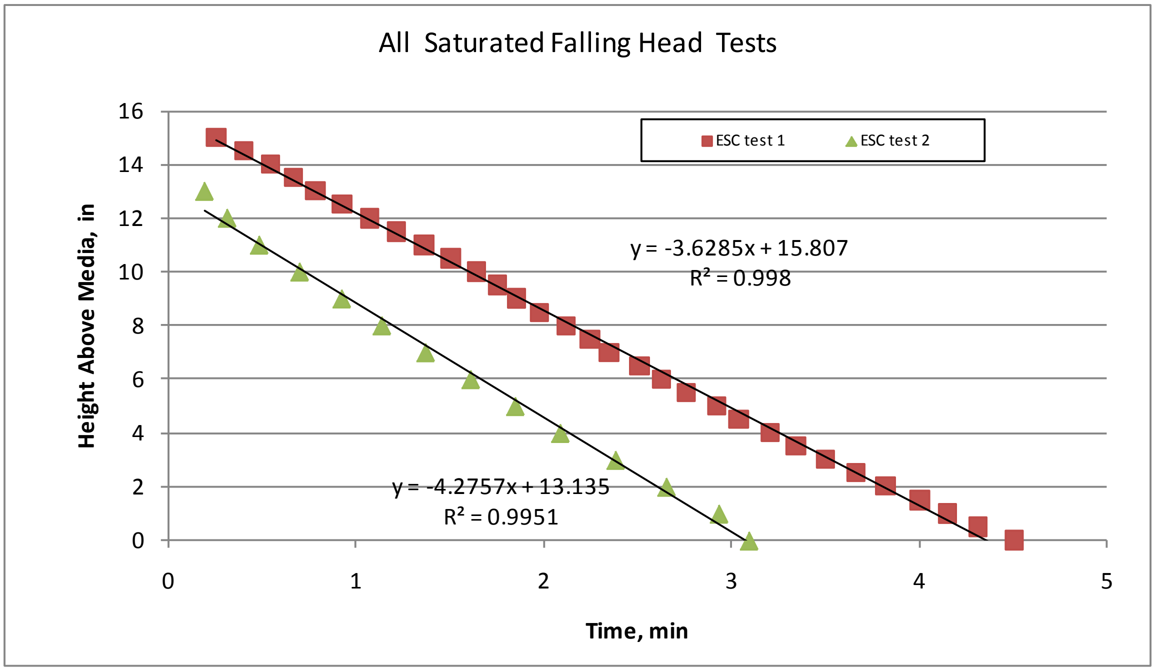


Figure 12 Saturated Falling Head Test on ESC Blend

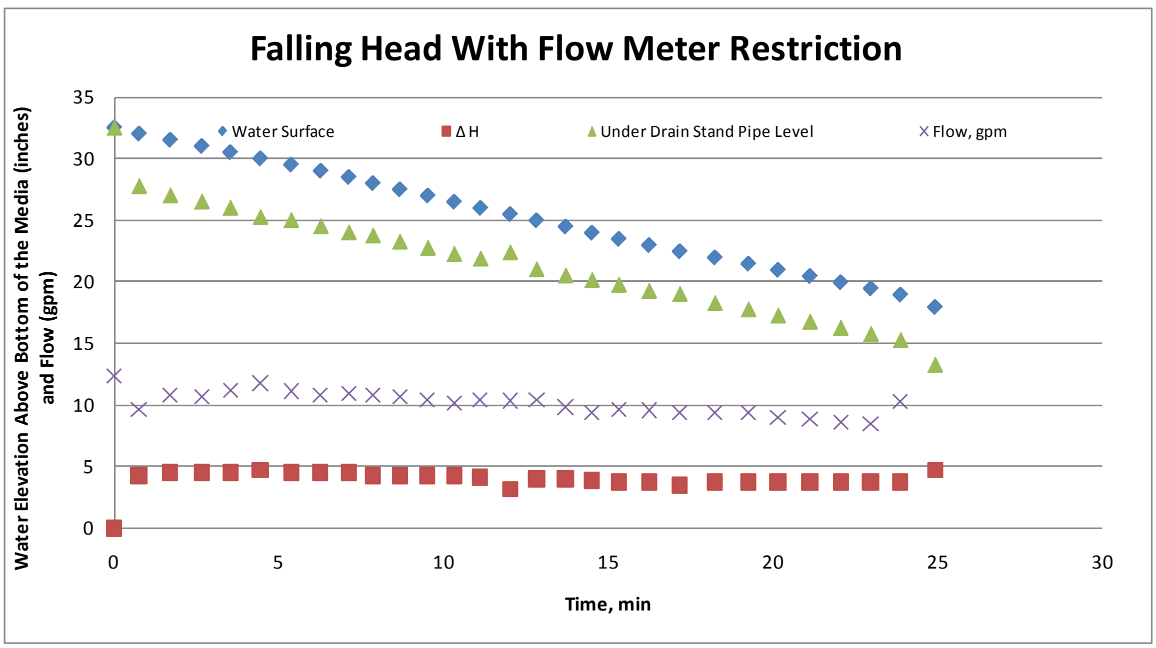


Figure 13 Restricted Falling Head Test with Effluent Flow Meter on ESC Blend

3.5.2 Falling Head Tests Following Individual Treatment Test Runs

Hydraulic characterization of the ESC blend was similar to the SC blend, where conductivity varied depending mainly on wetting and drying. Falling head tests seemed to give the most consistent results. After every treatment test that ponded greater than 4 inches by the end of the test run, a falling head test was conducted. Once the influent water was shut off, water height was recorded versus time. Area changed depending on the depth of ponding. At low depths the mulch decreased the effective area above the media and above the splash plate the ponding extended into the inlet area. The height was adjusted for changes in area so that the height shown in Figure 14 is the height that would have occurred if the area of ponding was held constant at 24 square feet throughout all depths of ponding. The instantaneous flow rate can be calculated along any point of any curve by multiplying the slope of the curve times the normalized water surface area (24 sq ft); however, the measurements of depth were discrete, rather than continuous. Consequently, the resulting flow rates shown in Figure 15 were calculated between the discrete time intervals at which the water depths were recorded.

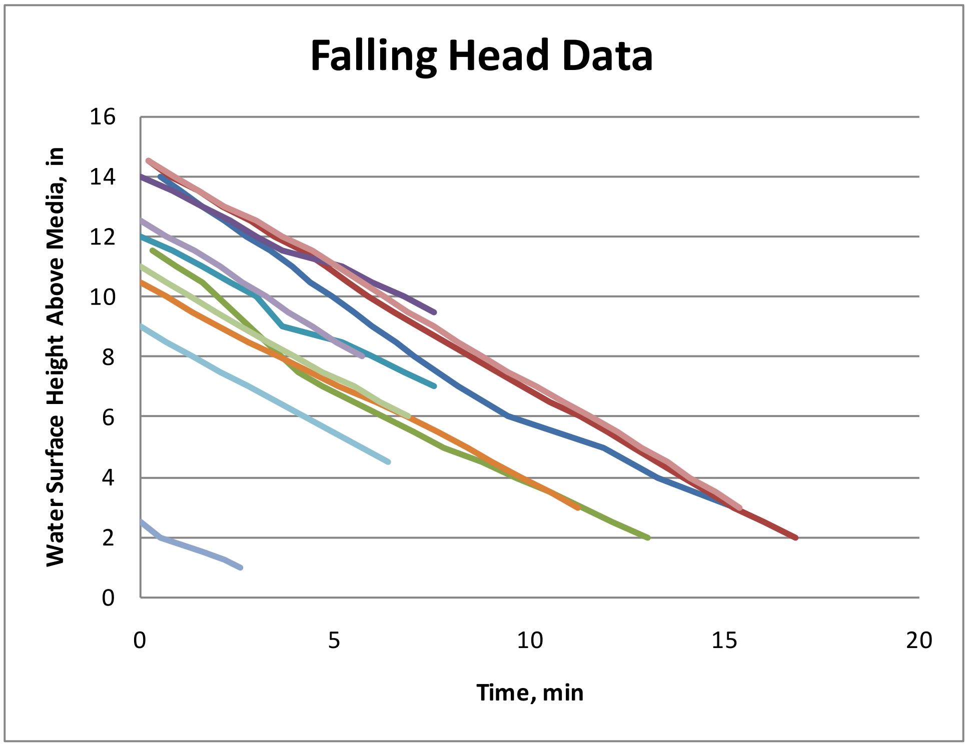
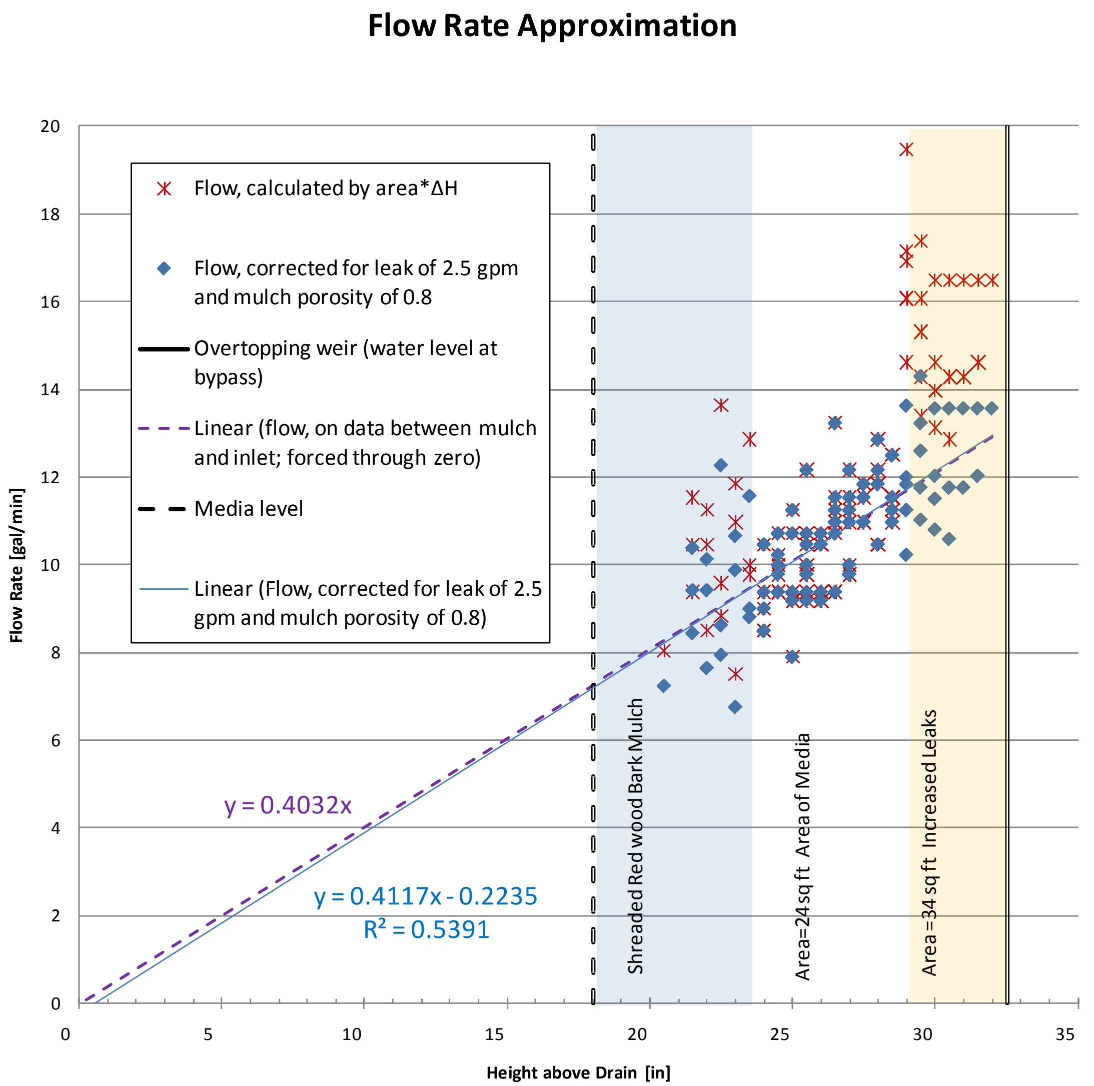


Figure 14 Area-Corrected Falling Head Immediately After Treatment Tests

The falling head data were plotted in Figure 15 as flow rate against height above the bottom of the filter media. Height was measured from bottom of the media to show that flow behaved according to the Darcy relationship between flow and height of water across the media. The fitted line should pass through zero flow at zero height, because height above the drain is the driving head.

An additional adjustment was required because of an increase in leaking when ponding occurs in the inlet box. The leaks occurred around the junction box access panel and in open spaces between the weir and the splash plate. The leaks bypass the media and are caught in the junction box below the inlet. Because of the increase in leaks around the splash plate and because of the uncertainty of the porosity of the mulch, the most reliable data are found in the area from 23 inches to 29 inches above the bottom of the media.

This is shown as the un-shaded area in Figure 15, and the dashed purple line shows the regression line for this data. The regression was forced to intersect the graph at zero flow and zero water height as assumed by Darcy's equation. To assess this assumption, the regression was compared to the regression of all the corrected flow data without forcing an intersect. The two lines are remarkably similar.



The flow rates represented by red stars were first calculated based on the rate that the water level fell times the area of the water surface, using the area of the water surface as 34 square feet above 29 inches, and 24 square feet between 18 and 29 inches, which included the mulch. The jump in flow rate at depths above the height of the inlet splash plate (29 inches above the bottom of the media) was due to an increase in leaks. The increase in leaking was measured between 2 and 4 gallons per minute (gpm). 2.5 gpm was used to estimate leakage by subtracting from the calculated flow due to the fit of the corrected data above 29 inches to the regression line of data between the mulch and the inlet area. The data below 5 inches was also high due to the decrease in effective water surface area. Much of the data found for redwood bark mulch indicate that the ratio of void space to total volume (porosity) should be around 0.75., but the 3-in bed of mulch would float and become loose, occupying 5 inches instead of 3. This increases the void space to about 0.9, which was used in determining the effective water surface area. The corrected flow values are displayed as blue diamonds.

Figure 15 Falling Head Data with Corrections During Sediment Load Testing

3.5.3 Infiltrometer

Infiltrometer tests performed right after a falling head test gave the same infiltration rates as the falling head tests. From the infiltrometer tests, the conductivity can be estimated at about 45-60 in/hr. Infiltration test results can be seen in Figure 16.

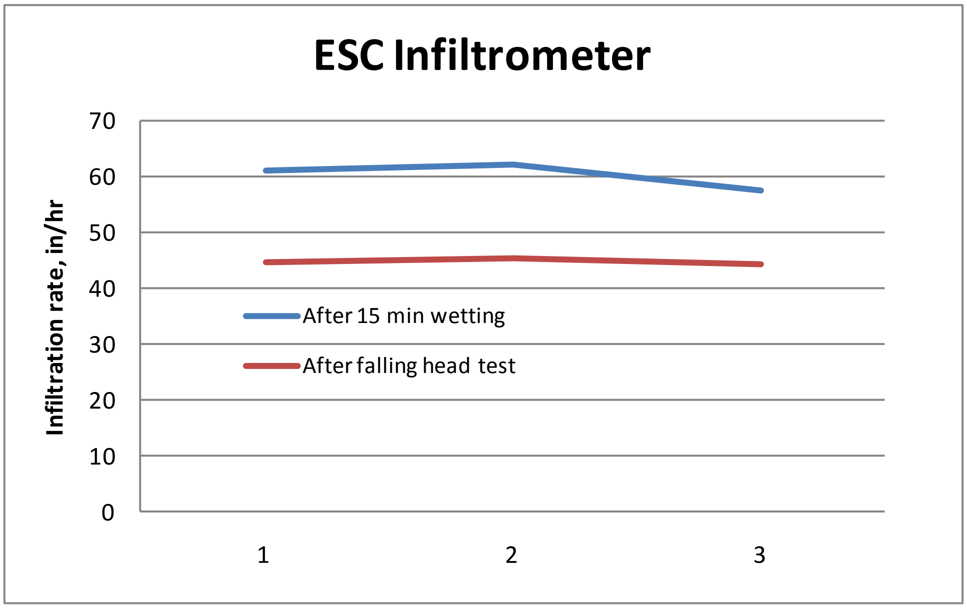


Figure 16 Infiltrometer Tests on ESC Blend

3.6 Media Comparison

The two media are compared using saturated hydraulic conductivities. The two tests from the ESC blend and the one test from the SC blend are shown together in Figure 17. The tests for SC blend occurred after around 24,000 gallons of water had passed through the media, which may have caused compaction and migration of fines, both of which can decrease conductivities. The ESC test 2 shown represents freshly placed ESC blend. The freshly placed ESC blend had about twice the saturated conductivity as the SC blend.

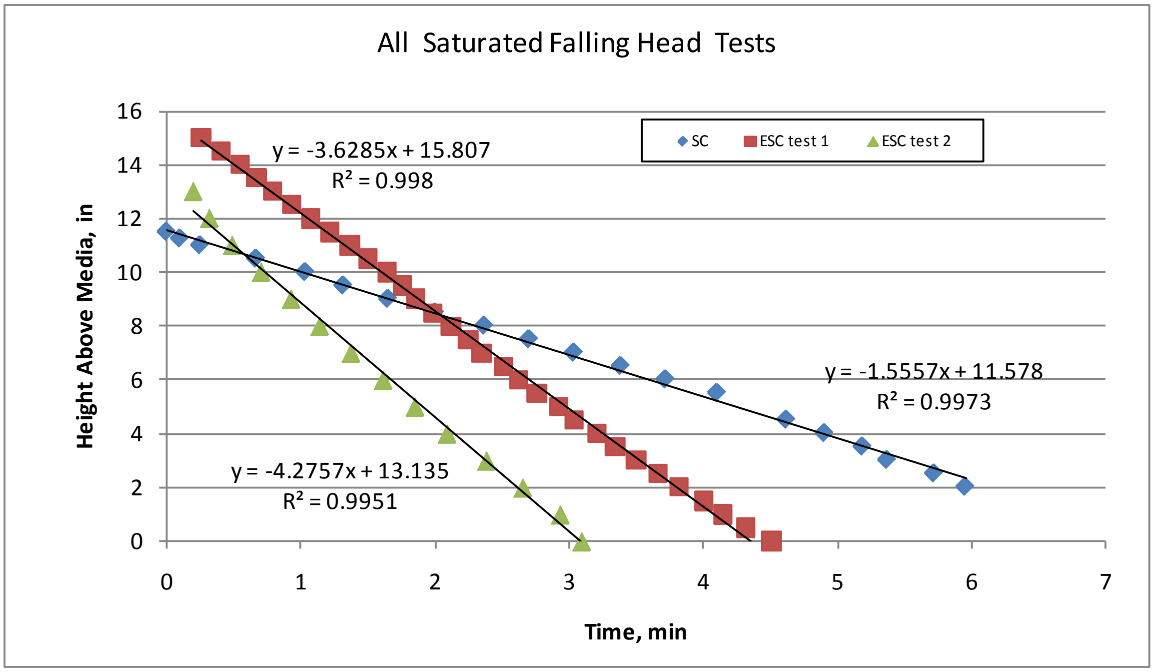


Figure 17 Saturated Falling Head Comparison

During many of the partially saturated tests, the conductivity of the SC blend was around 53 in/hr and after prolonged wetting dropped to about 30 in/hr. When attempting to trap air within the filter, conductivity dropped as low as 17 in/hr. For the ESC blend, conductivity was nearly 60 in/hr during sediment load testing.

Similar infiltration rates were also observed with the infiltrometer tests (Figure 18). The SC tests were run on dry soil until consecutive tests yielded similar results. One set of tests was run on the ESC blend after 15 minutes of wetting and one set was run directly after a falling head test.

So despite the increased saturated conductivity in the ESC blend, the hydraulic capacities are actually very similar and are more dependent on wetting conditions than saturated conductivity. The effect of wetting conditions was also observed in the treatment tests (see Section 4). For example, the first test run of 30 gallons per minute was able to pass the 150-min test with no bypass while subsequent runs of lesser flows bypassed due to the decrease in hydraulic capacity caused by wetting.

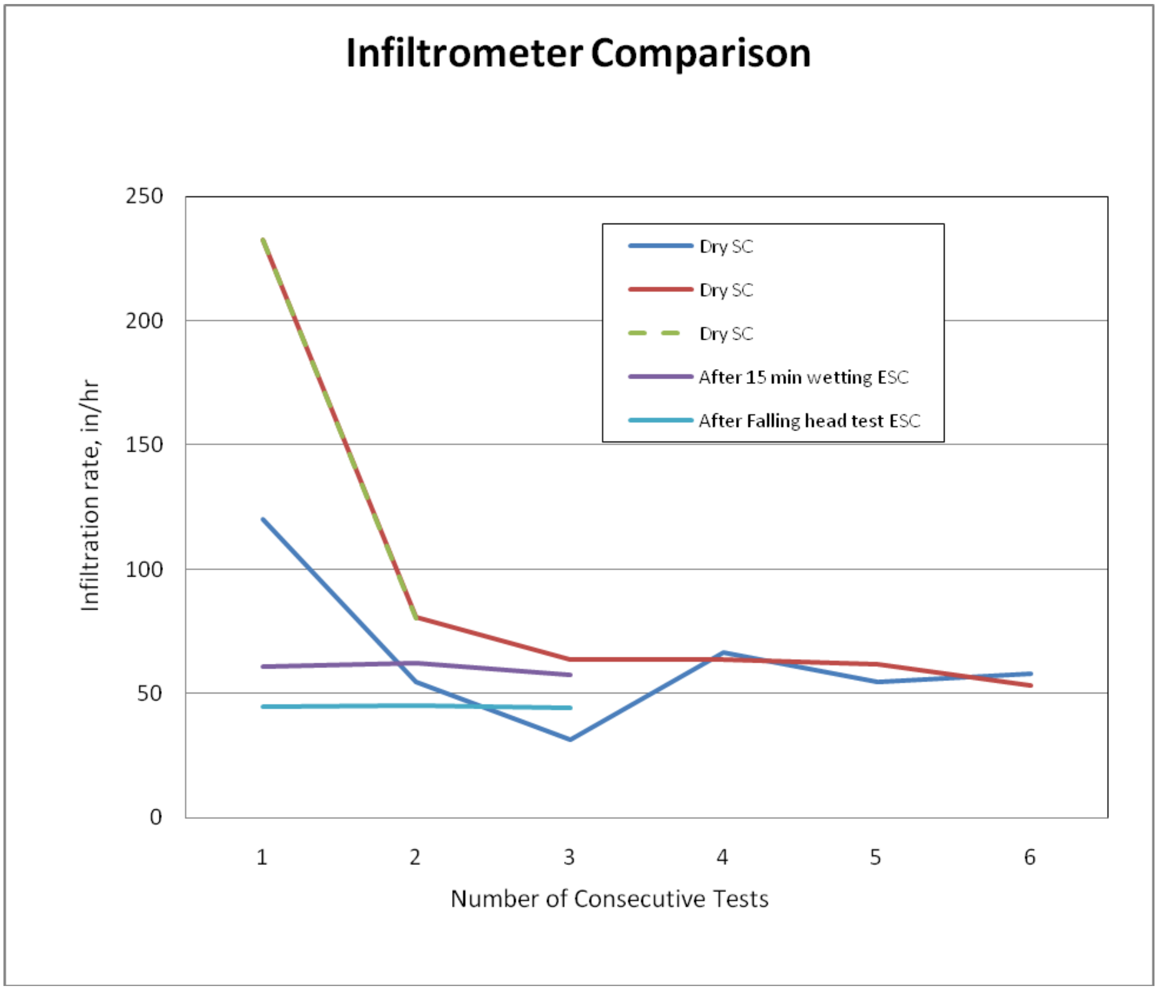


Figure 18 Infiltrometer Comparison of ESC and SC Media

4 Treatment Tests

This section presents methods and results of the water quality treatment tests. The methods used allowed an analysis of the full TreePod® performance, including the effects of bypass (Section 4.2) and the analysis of the isolated media bed performance (Section 4.3).

4.1 Treatment Test Procedures

OWP performed treatment tests based on Washington State's Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE). TAPE's full-scale laboratory test protocol specifies tests be conducted at constant flow rates of 50, 75, 100, and 150 percent of the design flow, with U.S. Silica Sil-Co-Sil 106 as the typical PSD runoff sediment at an influent concentration of 100 mg/L. OWP expanded on the TAPE by adding long-term test runs. OWP also used a finer and less dense sediment source and tested at 25 percent of the design flow. TAPE requires full device treatment testing, which does not isolate any particular components. This was accomplished by mass-balance calculation for six of the runs and by direct measurement for the remaining runs (Section 4.2). However, TAPE does not require a minimum test duration, so the test results that isolate the filtrate through the media will be more comparable to short-duration tests run by other laboratories (Section 4.3).

Treatment tests for the TreePod® Filter were performed using a sediment source that best represents field conditions and treatment performance. Instead of using Sil-Co-Sil 106, which is ground silica particles that are less than approximately 100 microns, OWP used street dust, which is a superior alternative because it is composed of the very particles that are mobilized by storms and entrained into runoff. Street dust is street sweepings that have passed the #200 sieve (75 microns), so removal is not biased by large particles. Street dust particles also represent a more realistic particle composition. The street dust used is about 13 percent volatile, which indicates organic particles, which are much lighter than the silica particles.

OWP also performed long-duration tests, which are not required in most laboratory evaluation procedures throughout the U.S. (Typical tests are much less than an hour in duration.) Each OWP test run for the TreePod® was 150 minutes long and sampling occurred throughout each test run. To compare to the shorter-duration tests performed by others, Section 4.2 presents overall system performance, including the effect of whatever bypass occurred and commingled with the filtrate throughout each 150-minute run. Section 4.3 presents concentration reductions that occur before flow bypass develops.

4.1.1 Monitoring Method

To compare the results of this study to short-term laboratory evaluations of other stormwater treatment products, it is helpful to factor bypass based on hydraulic analysis to estimate the overall performance of the TreePod® system (Section 4.2) and to quantify reduction through media (Section 4.3). To accomplish both objectives, head was monitored during the 150-minute treatment tests, which included monitoring when the flow bypassed, as discussed in Section 4.3.

Some of the test runs only sampled media filtrate. To calculate the overall constituent reduction during the test run, the concentrations in the overtopping bypass and leaking bypass must be estimated (Section 4.2.1). To sample the bypass water a siphon was placed inside the weir to capture the water just before it passed over the weir. Elevation change in the siphon was minimized to maximize efficient transport of sediment through the siphon. Bypass monitoring was performed once for metals and phosphorus and 3 times for solids and turbidity.

4.1.2 Analysis

Various analyses were performed on the influent and effluent of each test. Some analyses were performed by OWP and other analyses were performed by Caltest, an analytical laboratory in Napa, CA. Table 3 is a summary of analyses performed.

Table 3 Summary of Water Quality Analyses Performed

Analysis	Performed By
Total Suspended Solids (TSS)	OWP
Suspended Solids Concentration (SSC)	OWP
Turbidity	OWP
Total Phosphorus	Caltest
Total Copper	Caltest
Total Lead	Caltest
Total Zinc	Caltest

4.1.3 Sampling

Influent and effluent samples were collected from the corresponding outlets in 500-ml plastic bottles. Plastic bottles were marked with 50-ml gradations. Aliquots were taken every 15 minutes for 150 minutes, creating a composite of ten aliquots per sample of both the influent and the effluent. Since flow was consistent (+/- 10 percent of target flow), these time-weighted composites are also flow-weighted composites. Multiple sample bottles were used, depending on the analysis performed. SSC samples were always collected in separate bottles because the analysis procedure requires a filtration of the total volume. Splitting a sample could result in unequal distribution of particles. This is especially true at lower concentrations, where just a few particles contribute substantially to the measurement. TSS and turbidity samples were collected in the same bottle. Total phosphorus was collected in a bottle preserved with sulfuric acid prior to sample collection. Total metals were collected in a bottle preserved with nitric acid. When more than one bottle was needed, the sample collector would cycle through the bottles every 15 minutes. Filling all four bottles with a single aliquot would take about 5 minutes.

4.1.4 Test Schedule, Flows, and Cumulative Filter Loading

Constituent reduction in media filtrate was monitored during the first six tests with the effluent configuration shown in Table 1, configuration 2: two at flow rates of 125 percent of design flow and one test at 100, 75, 50, and 25 percent. These tests were performed within one week, and the time between tests ranged from 24 to 48 hours. For subsequent treatment tests, the effluent configuration shown in Table 1, configuration 4 allowed capture of commingled effluent. A schedule of the tests performed is shown in Table 4, which shows percent of design flow and the corresponding flow value that was used for the test run for that particular day.

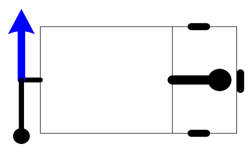
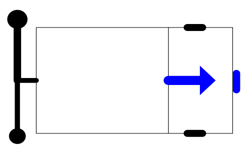
Table 4 Testing Schedule and Effluent Configuration for Sampling

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
No Testing				7/15 125% 30 gpm	7/16 100% 24 gpm	7/17 No Testing
7/18 75% 18 gpm	7/19 50% 12 gpm	7/20 25% 6 gpm	7/21 125% 30 gpm	7/22 75% 18 gpm	7/23 100% 24 gpm	7/24 No Testing
7/25 50% 12 gpm	7/26 25% 6 gpm	7/27 125% 30 gpm	7/28 100% 24 gpm	7/29 75% 18 gpm	7/30 50% 12 gpm	7/31 No Testing
8/1 25% 6 gpm	Testing Complete					

As shown in Table 5, effluent filtrate flow was isolated from bypass flows for the first 6 runs. Samples were taken from the back side of the TreePod® through an extension of the 3-inch underdrain pipe, as seen in Table 1, configuration 2 and Figure 5b. For the remainder of the runs, samples were then taken from the 6-inch pipe as seen in Table 1, configuration 4 and Figure 5a.

The treatment tests used a total of 40,500 gallons of synthetic stormwater. If a storm intensity of 0.16 in/hr is assumed, the catchment size is 0.331 acres for a TreePod® rated at 24 gpm. Using an average rainfall of 18 in/year for the Sacramento region and a runoff coefficient of one, the volume of runoff generated is 161,555 gallons per year. So the device received about 25 percent of annual runoff. Due to bypass of roughly 20 percent of the influent load, the filter media was loaded with about 20 percent of the annual runoff. Since the loading represents less than a full year of operation, the results presented in this report may not represent long-term treatment.

Table 5 Treatment Test Run Summary of Sampling Locations, Occurrence of Bypass, and Sampling of Isolated Filtrate

Date	Effluent Configuration	Flow Rate, gallons per minute	Time to Bypass, minutes	Isolated Filtrate Data?
7/15		30	No Bypass	Yes
7/16		24	75	Yes
7/18		18	120	Yes
7/19		12	No Bypass	Yes
7/20		6	No Bypass	Yes
7/21		30	10	Yes
7/22		18	75	No
7/23		24	30	No
7/25		12	No Bypass	Yes
7/26		6	No Bypass	Yes
7/27		30	16	No
7/28		24	30	No
7/29		18	120	No
7/30		12	No Bypass	Yes
8/1		6	No Bypass	Yes

4.1.5 Background Concentration

Concentrations in the filtrate were measured during the initial hydraulic tests, which ran clean water through the media bed. Prior to performing treatment tests, samples were analyzed for the following constituents: TSS, SSC, turbidity, phosphorus, copper, lead, and zinc. Table 6 shows values of the background concentrations. Analysis showed that these constituents leached out of the filter at fairly low levels, with the exception of total phosphorus. Total phosphorus was not drastically high, but may be at a level that could cause concern for some phosphorus-sensitive watersheds.

Table 6 Average Background Concentration of Grab Samples Prior to Treatment Tests and After about 2,000 Gallons of Flushing Resulting from Hydraulic Tests

Constituent	Units	Average Background Concentration
TSS	mg/L	0.67*
SSC	mg/L	0.53*
Turbidity	NTU	3.55*
Copper	ug/L	4.30**
Lead	ug/L	0.13**
Zinc	ug/L	3.60**
Phosphorus	mg/L	0.94**
* Value from single grab sample		
** Average from 3 grab samples		

4.2 Treatment Performance throughout the 150-Minute Test Runs (including bypass)

This section presents the sample methods, calculation methods, and results of the full-device performance throughout each 150-minute test run. For some runs, the filtrate was sampled instead of the commingled filtrate and bypass flow. For these runs, the isolated media bed effluent data required a mass balance calculation to add in the effects of bypass and express the results as full-device treatment. The calculation method is presented in the following section. The full-device treatment results from both calculated effluent load and direct analysis performance results of commingled effluent samples are presented in Section 4.2.2. Since percent reduction is greatly influenced by influent concentrations, Table 7 shows the average influent concentrations for all 15 runs. There was no relationship between influent concentration and flow, so the influent concentrations were fairly consistent among the test runs.

Table 7 Influent Concentration Summary Statistics

Constituent	Units	Samples*	Average Concentration	Standard Deviation
TSS	mg/L	15	105	3.4
SSC	mg/L	15	104	1.8
Turbidity	NTU	15	28	1
Copper	ug/L	15	9.4	.32
Lead	ug/L	15	2.5	0.08
Zinc	ug/L	15	16.9	0.47
Phosphorus	mg/L	14**	0.08	0.004

*Runs with duplicate samples are only counted once. The average of the duplicate values are used.
** Influent phosphorus was not analyzed for run 14 due to violation of the maximum hold time.

4.2.1 Calculation Method

The performance throughout each 150-minute test run was calculated by dividing the mass of constituents retained in the TreePod® by the mass of constituents in the influent. The mass of constituents retained was determined by subtracting the mass of constituents leaving the unit by the mass that was introduced in the influent. In some cases bypass of the media had occurred. When the commingled water was sampled, the measured concentration could be used directly in the mass balance calculation. In the cases where filtrate was sampled, the measured value was combined with an estimation of the mass in the bypass water to represent the net mass leaving the TreePod®. Nephelometric Turbidity Units (NTU), though a measure of light scatter, were treated in the same way as the other constituents that are expressed as mass. This assumes that NTUs are conservative and respond linearly to dilution.

The effluent mass was calculated for various time periods according to Equation 1. For periods without bypass, the cumulative volume before bypass was multiplied times the filtrate concentration, resulting in the effluent mass before bypass. After bypass it was assumed that 14 gallons per minute would pass through the filter (based on post-run, falling head tests as presented in Section 3.5.2), so 14 gallons per minute was multiplied by the duration of bypass and the filtrate concentration, resulting in the mass leaving the filter bed during the period that bypass occurred. The remaining flow (total flow minus 14 gpm) was multiplied by the duration of bypass, the influent concentration, and the overtopping coefficient. The overtopping coefficient is one minus the loss coefficient for the inlet, since some settling occurred before water bypassed over the weir. This gave the mass bypassing the filter. The sum of these three masses is the total effluent mass leaving the TreePod® device. The total effluent mass divided by the volume of water used during the test gives the calculated effluent concentration. The calculation tables for each constituent are presented in Appendix B.

$$C_e = overall\ effuent\ concentration, including\ bypass = \frac{M_1 + M_2 + M_3}{150 \cdot Q}$$ **Equation 1**

Where:

$$M_1 = effluent\ mass\ before\ bypass = C_f \cdot Q \cdot t$$

$$M_2 = filtrate\ mass\ after\ bypass = C_f \cdot 14 \cdot (150 - t)$$

$$M_3 = bypass\ mass = C_i \cdot \beta \cdot (Q - 14) \cdot (150 - t)$$

$$C_f = filtrate\ concentration$$

$$C_i = influent\ concentration$$

$$t = time\ to\ bypass,\ min$$

$$\beta = overtopping\ coefficient\ = \frac{bypass\ concentration}{influent\ concentration}$$

$$Q = influent\ flowrate$$

4.2.2 Results for Performance Throughout 150-Minute Test Runs

The TreePod® unit tested achieved a high level of treatment for all runs up to the design flow of 24 gpm. Average solids removal exceeded 80 percent and average copper, zinc, and lead removals were all above 50 percent.

For all constituents except total phosphorus, there appears to be a decrease in constituent reduction with flow rate, but this is not due to a decrease in the effectiveness of the filter as flow through the filter increases. Rather, this is due to the bypass of influent water that has undergone very little treatment while in the inlet portion of the TreePod®. This is demonstrated by one test run at 30 gpm that did not bypass: reduction for this run was similar to non-bypass runs at lower flows, as seen in Figures 19 through 24.

There are noticeable differences in load reduction among the three metals. This is expected due to the difference between the background concentration of the media effluent and the influent concentration. Lead was dosed approximately 20 times higher than the background concentration; zinc was about 3 times higher, and copper was only about double. Since the effluent concentrations were similar to the background levels and removal is a function of the influent concentration, higher load reduction is expected for lead, followed by zinc and then copper. This is shown in Figure 22 through Figure 24.

For similar reasons, phosphorus reductions are negative. The influent concentrations were several times lower than the background concentrations. This is further discussed under the "Phosphorus" subheading.

The calculation tables are in Appendix B.

Solids

Solids reduction was above 80 percent for all flows at the design flow rate of 24 gpm and below. There was no evidence of scour or sediment loss at higher flows. The decrease in reduction was due to water that bypassed the media. The result at 98 percent reduction and 30 gpm occurred because of a lack of bypass. Of the other two results at 30 gpm, one sampled commingled effluent and the other was a calculated value based on filtrate and bypass samples. If bypass was not considered in the latter result, the reduction of concentration is above 95 percent (see Section 4.3). Figure 19 presents SSC data and Figure 20 presents TSS data. SSC and TSS were consistent in this analysis. This may be due to screening of influent particles to eliminate particles greater than 75 microns.

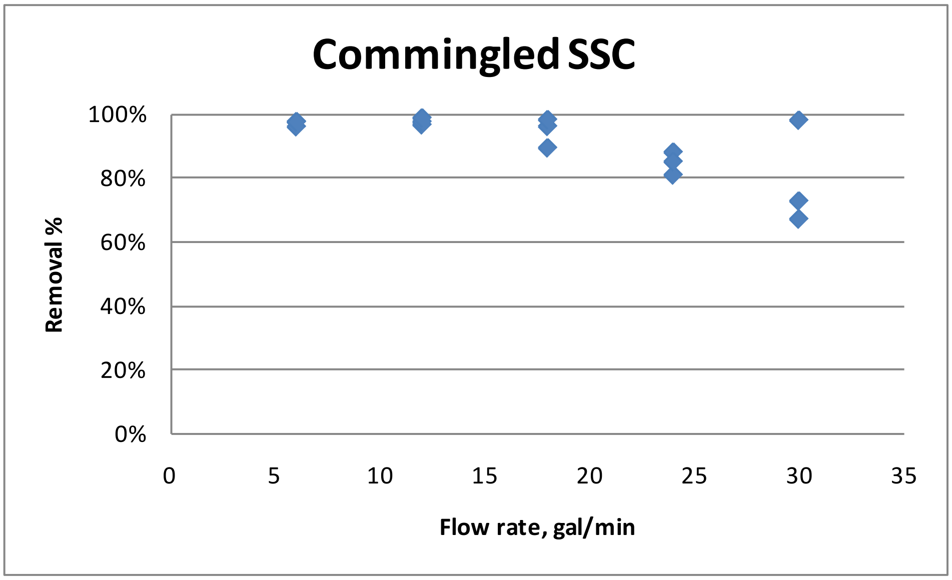


Figure 19 Device Removal of SSC

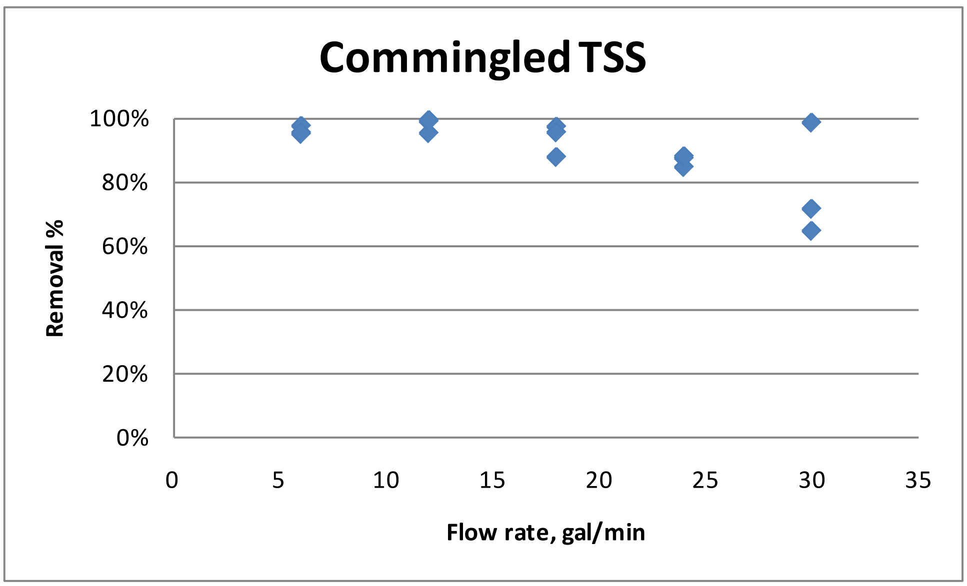


Figure 20 Device Removal of TSS

Turbidity

Turbidity is a measure of light scatter, but the reductions followed the pattern of solids removal. This is expected since particles cause diffraction of light. The agreement between the calculated commingled turbidity and the turbidity that was directly measured for commingled samples also shows that dilution affects turbidity in the same way as it affects mass-based measurements for other constituents.

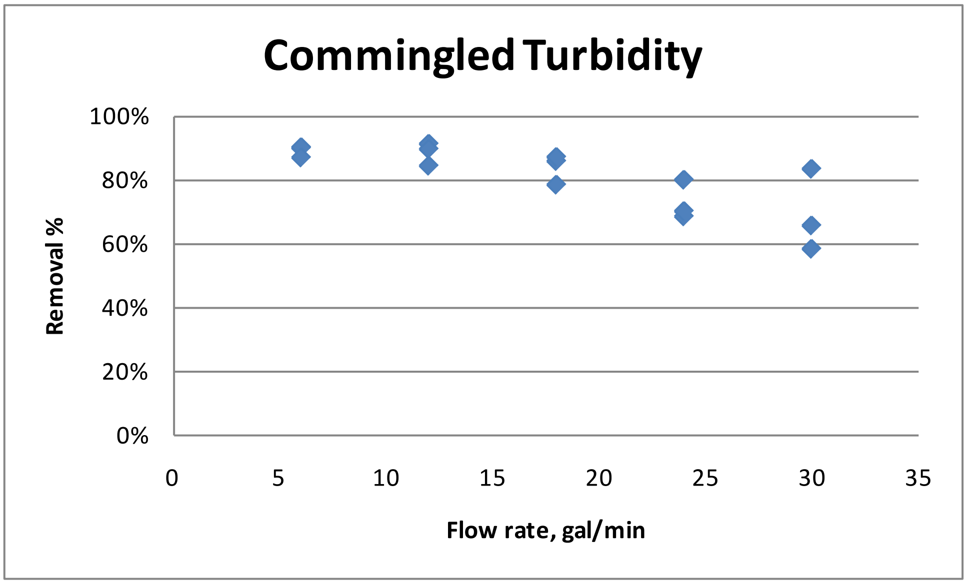


Figure 21 Device Removal of Turbidity

Copper

Reduction of total copper followed the pattern of solids reduction. The magnitude of reduction was less than for both total lead and total zinc. This can be attributed to the difference between influent concentrations and background levels for these three metals.

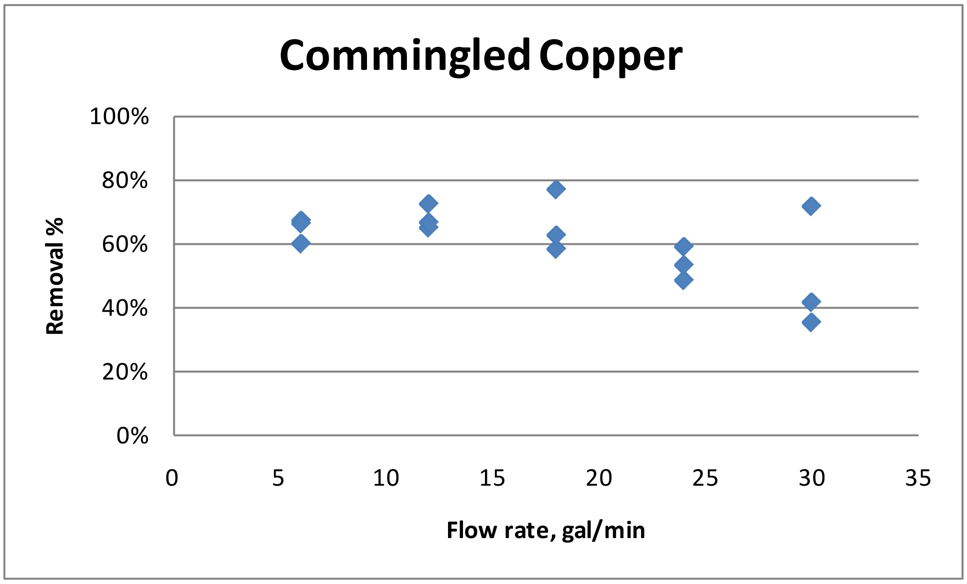


Figure 22 Device Removal of Copper

Lead

Reduction of total lead followed the pattern of solids reduction. The magnitude of reduction was greater than for both total copper and total zinc. This can be attributed to the difference between influent concentrations and background levels for these three metals.

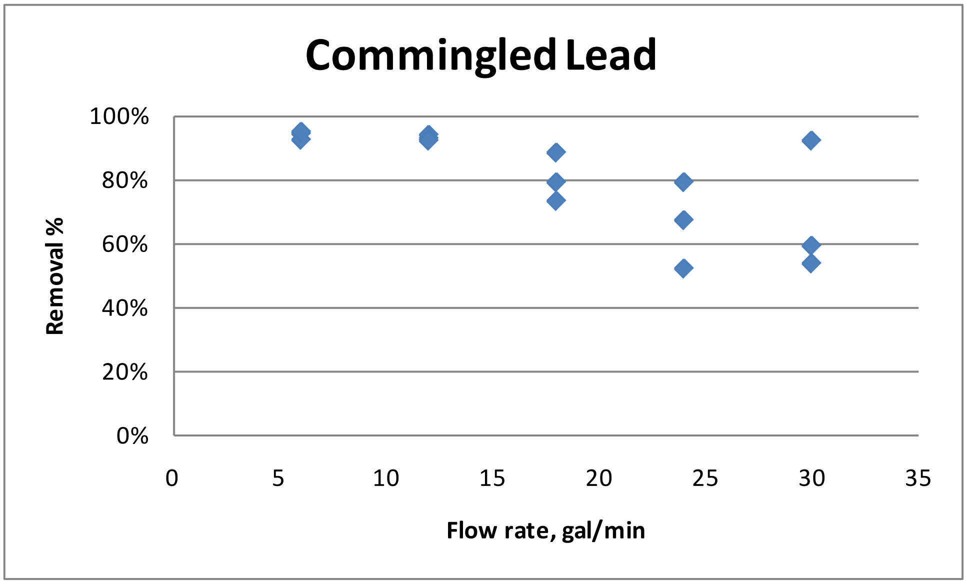


Figure 23 Device Removal of Lead

Zinc

Reduction of total zinc followed the pattern of solids reduction. The magnitude of reduction was less than total lead, but higher than total copper. This can be attributed to the difference between influent concentrations and background levels for these three metals.

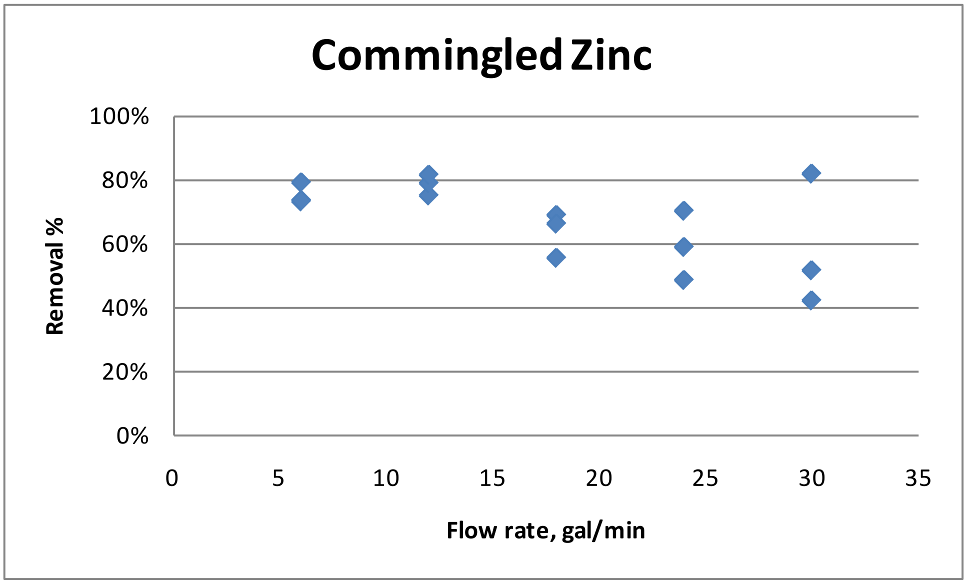


Figure 24 Device Removal of Zinc

Phosphorus

In Figure 25, it appears that phosphorus export may have an inverse relationship to flow rate, but the results are reported as concentration rather than total mass. The concentration increases with lower flows are likely due to the increase in contact time between the water and the compost in the media. The higher contact time and the lower volume of water cause an increase in concentration. When the flow is increased there is actually a higher mass of phosphorus, but over an even larger volume of water. Figure 26 shows how the mass of phosphorus leached is a function of the cumulative volume of water that passed through the filter.

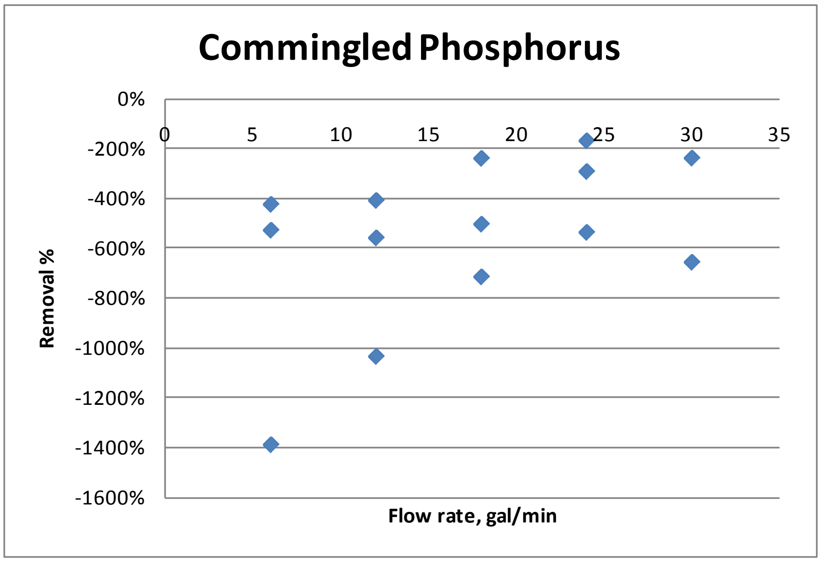


Figure 25 Device Removal of Phosphorus

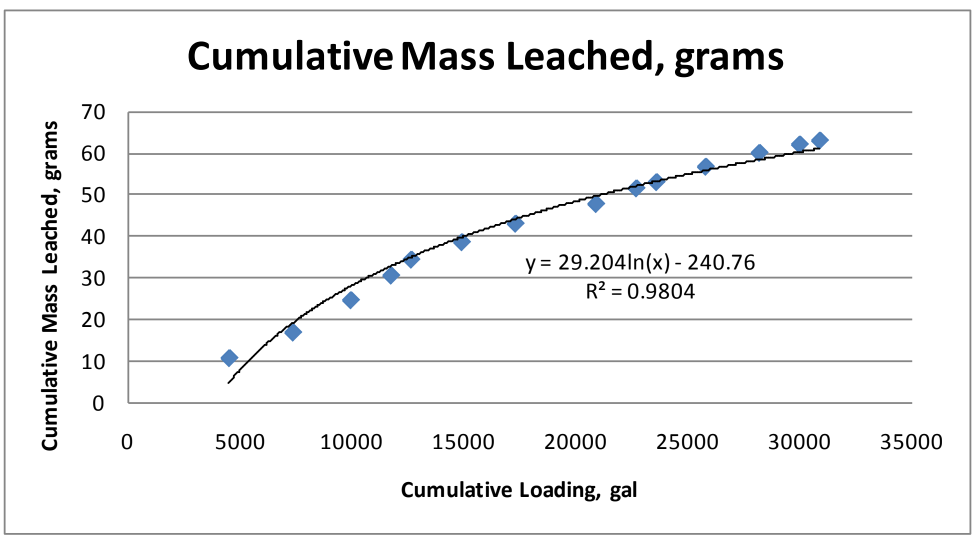


Figure 26 Leached Mass of Phosphorus versus Cumulative Loading

4.3 Treatment Performance of the Isolated Media Bed (filtrate-only)

The media filtrate, water that passed through the filter, is the highest level of treatment that can be achieved because it reflects performance with no bypass. Table 7 shows the test runs from which data were used to isolate the performance of the media bed. The foam plug for the 3-inch pipe, used during hydraulic testing, was left in place for the first 6 runs to test for constituent removal by the media only. When the plug was removed after run 6, test runs that did not bypass (runs 9, 10, 15, and 16) also contributed to the dataset for filtrate.

4.3.1 Results for Treatment Performance of the Isolated Media Bed

The comparison of filtrate and influent are shown in Figure 27, Figure 29, Figure 31, Figure 33, Figure 35, and Figure 37. Effluent concentrations are close to the background levels, which indicate that removal is a function of the influent concentration. Overall, there is little evidence of changes in effluent concentrations for metals and solids with increasing flow rates, as indicated by the consistent effluent concentrations across the tested flow rates. This suggests that physical filtration is the dominant removal mechanism for these constituents.

Removal efficiencies are shown in Figures 28, 30, 32, 34, 36, and 39. As discussed in Section 4.2, the percent reduction in concentrations through a filter are strongly dependent on influent concentrations for many constituents. Constituents with the highest reduction percentages had the greatest difference between influent concentration and background concentration from leaching of the media.

Solids

Solids removal was consistent between TSS and SSC tests. Average reduction of TSS and SSC was 97 percent with an average influent concentration of 107 mg/L TSS and 103 mg/L SSC. However turbidity did show some dependence on flow rate with about a 10 percent reduction in removal between 6 gpm and 30 gpm. Both TSS and SSC show compliance with the “Basic Treatment” requirements of the State of Washington (ECY 2002/2008).

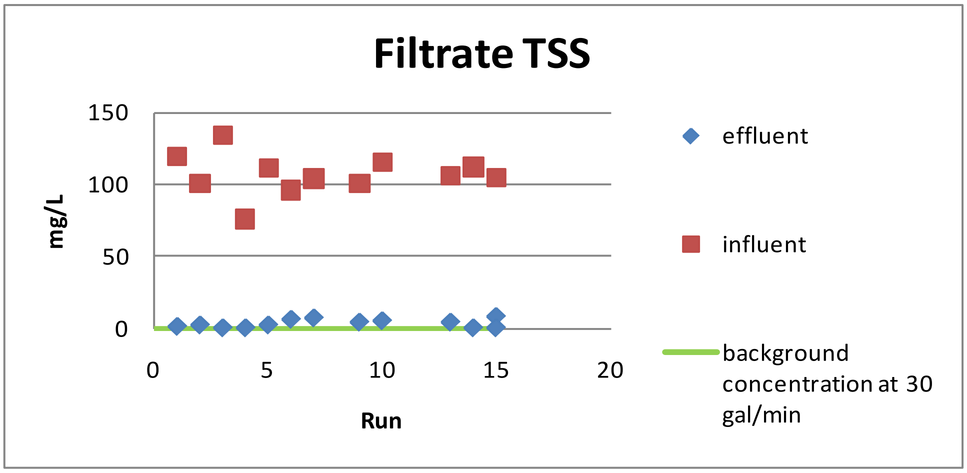


Figure 27 Filtrate Data for TSS Concentrations

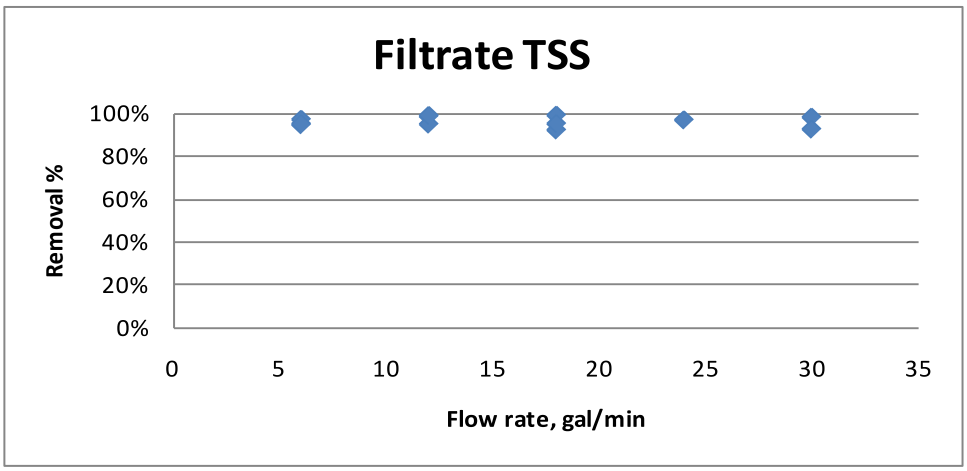


Figure 28 Filtrate Data TSS Removal

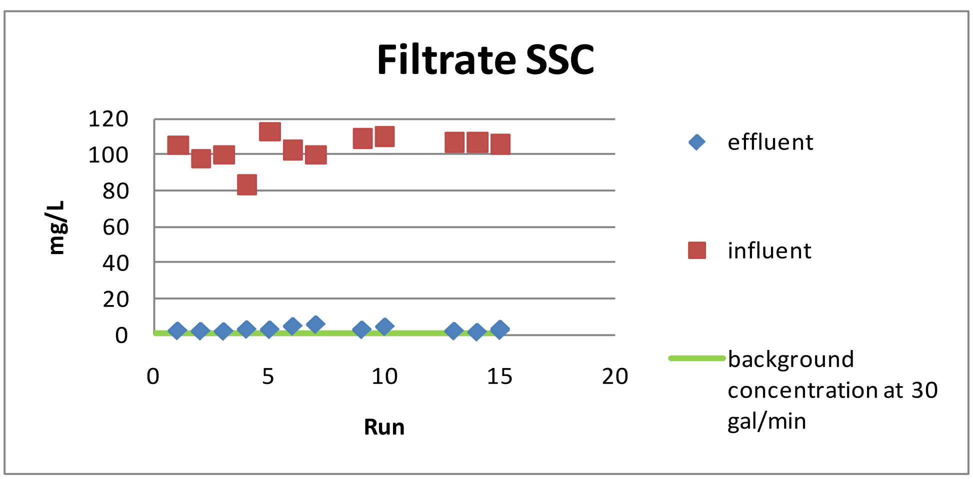


Figure 29 Filtrate Data for SSC Concentrations

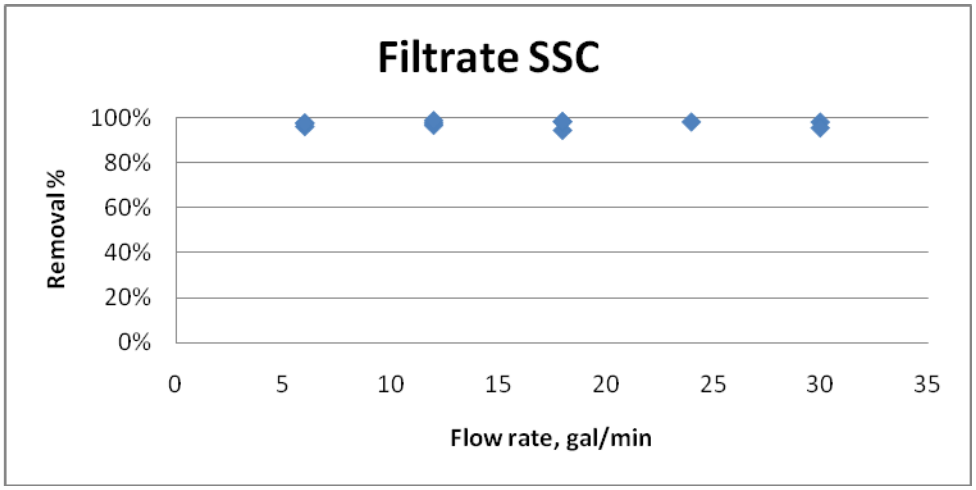


Figure 30 Filtrate Data for SSC Removal

Turbidity

Turbidity was reduced from an average concentration of 28 NTU in the influent to 6 NTU in the effluent. The effluent values were very similar to the initial background concentration.

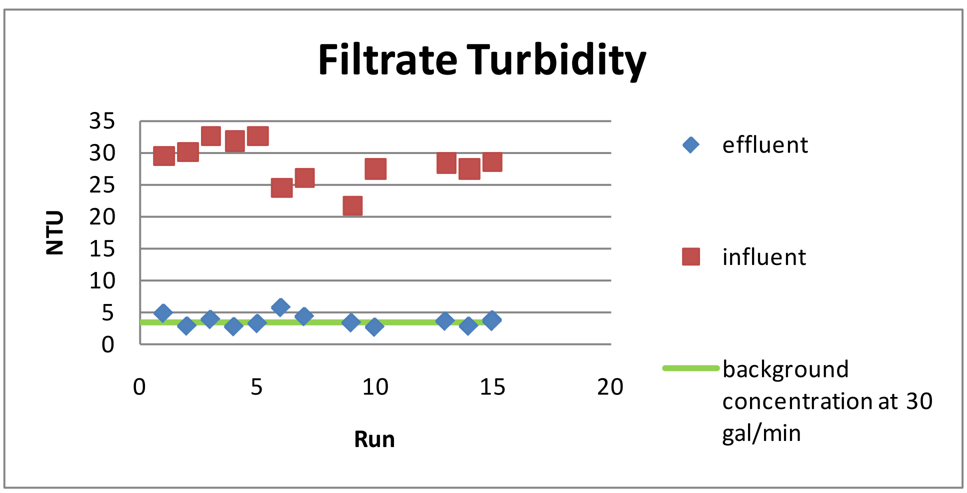


Figure 31 Filtrate Data for Turbidity

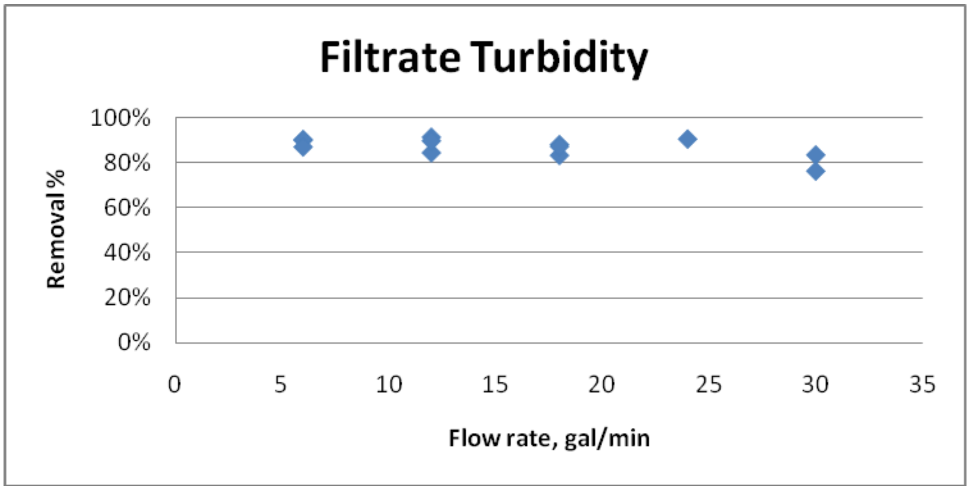


Figure 32 Filtrate Data for Turbidity Removal

Copper

Total copper experienced 69 percent average removal with an average influent concentration of 10 µg/L. The effluent values were similar to the initial background concentration, but may be trending a little lower. Theories for this behavior are premature since the background concentration was established with very few samples.

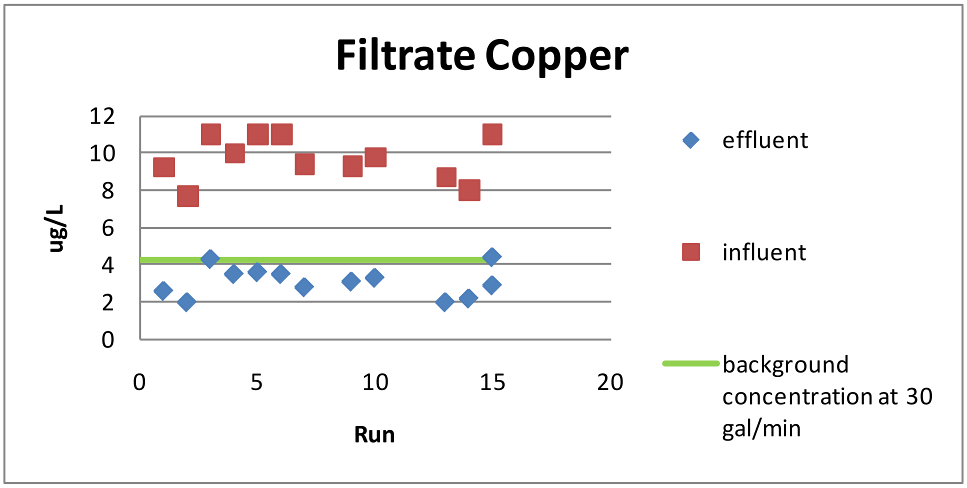


Figure 33 Filtrate Data for Copper Concentrations

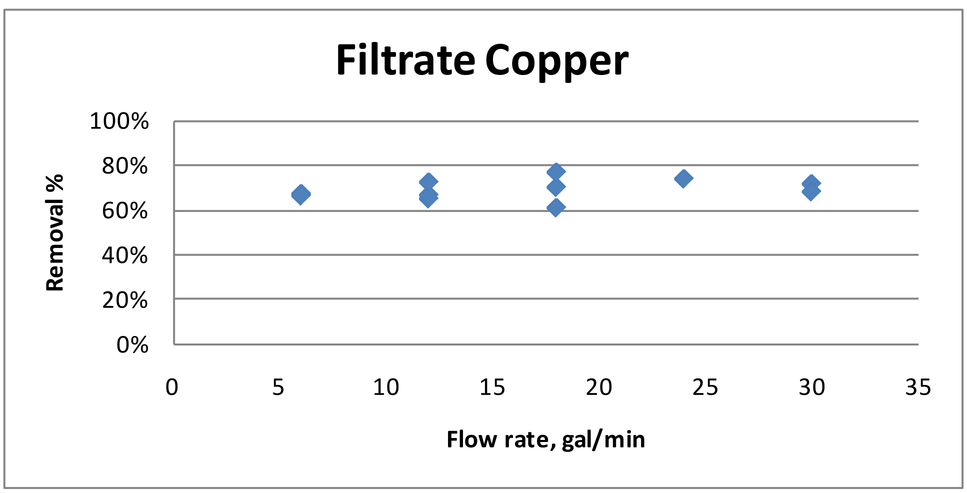


Figure 34 Filtrate Data for Copper Removal

Lead

Total lead experienced 92 percent average removal with an average influent concentration of 2 µg/L. The effluent values were very similar to the initial background concentration.

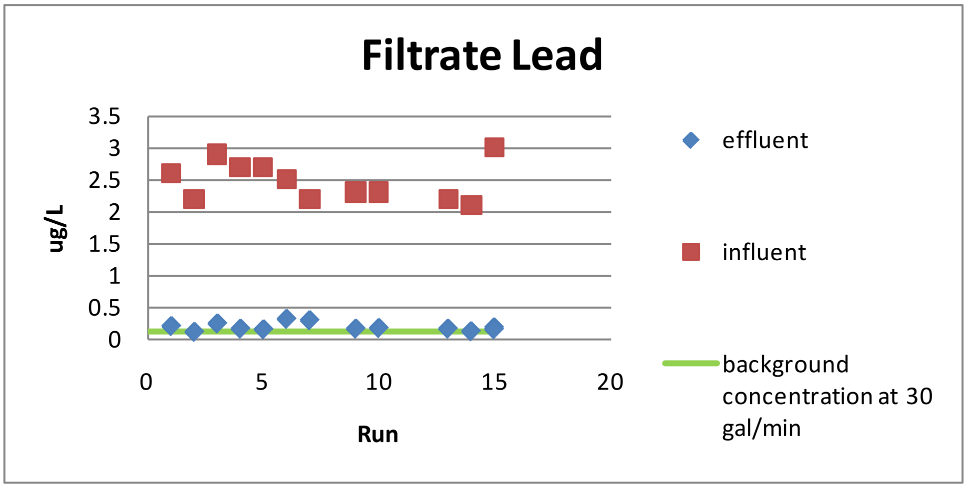


Figure 35 Filtrate Data for Lead Concentrations

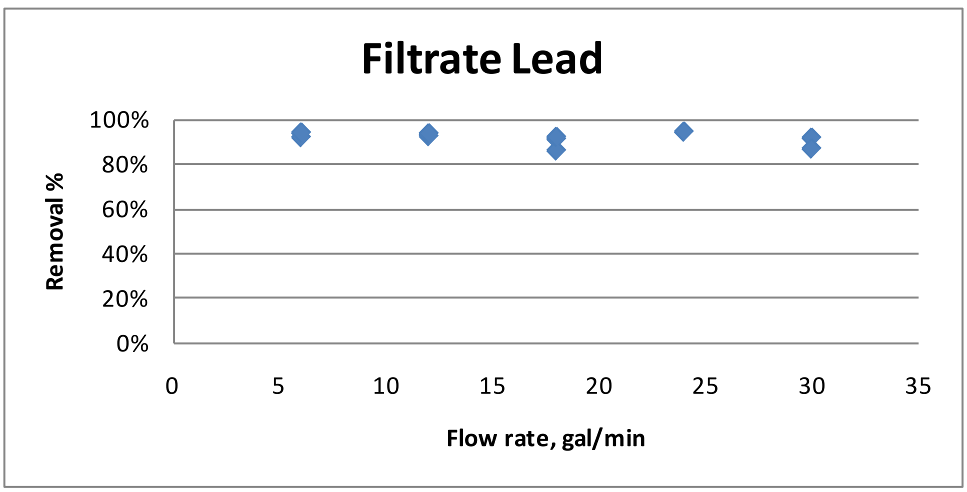


Figure 36 Filtrate Data for Lead Removal

Zinc

Total zinc experienced 77 percent average percent removal with an average influent concentration of 17 ug/L. The effluent values were very similar to the initial background concentration.

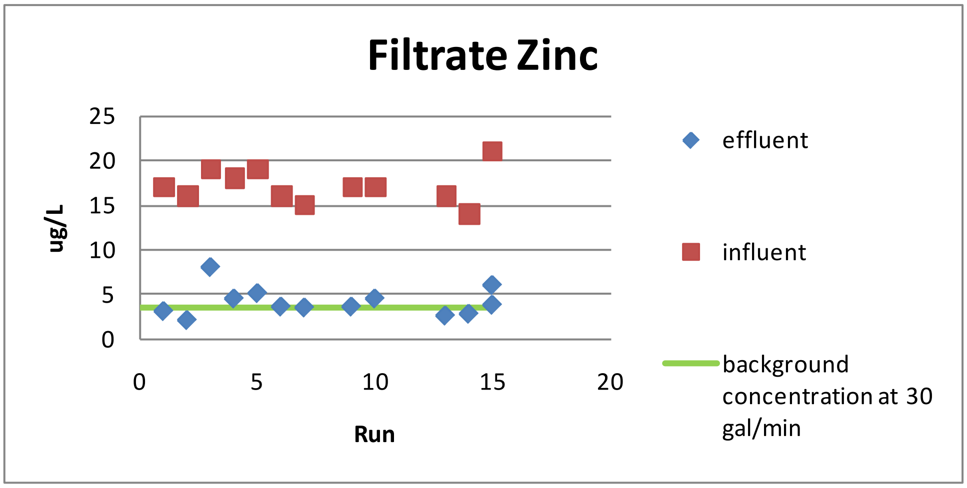


Figure 37 Filtrate Data for Zinc Concentrations

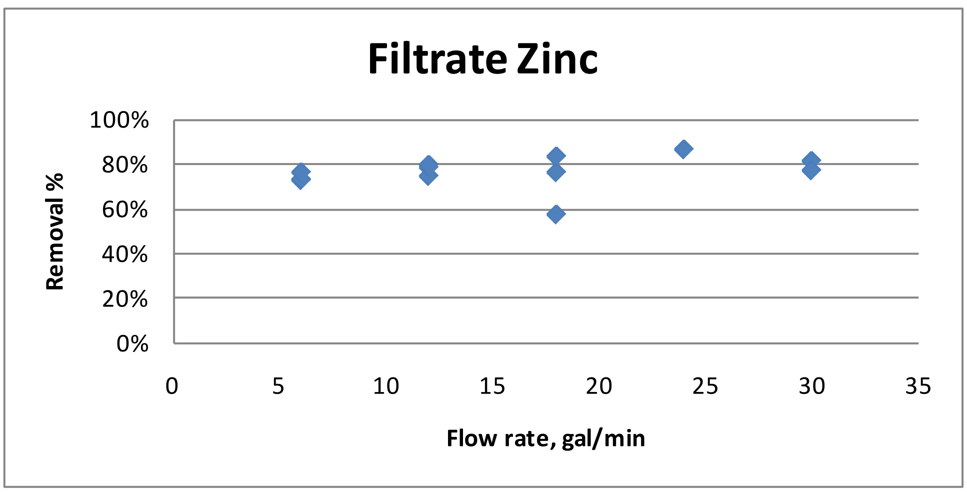


Figure 38 Filtrate Data for Zinc Removal

Phosphorus

For total phosphorus, it appears that phosphorus leaches from the bioretention media, but at concentrations less than 1 mg/L. Still, this may be of concern for applications in watersheds that are impaired due to phosphorus loads. In such scenarios, the open-bottom TreePod® should be analyzed for reduced phosphorus loading due to infiltration losses.

The average removal of phosphate was -642 percent with an average influent concentration of 0.076 mg/L. The average removal is negative because phosphate was leaching from the compost. This is a result of the filter media having a background concentration of 0.94 mg/L. With the influent concentration lower than the background concentration the filter always added phosphorus to the water.

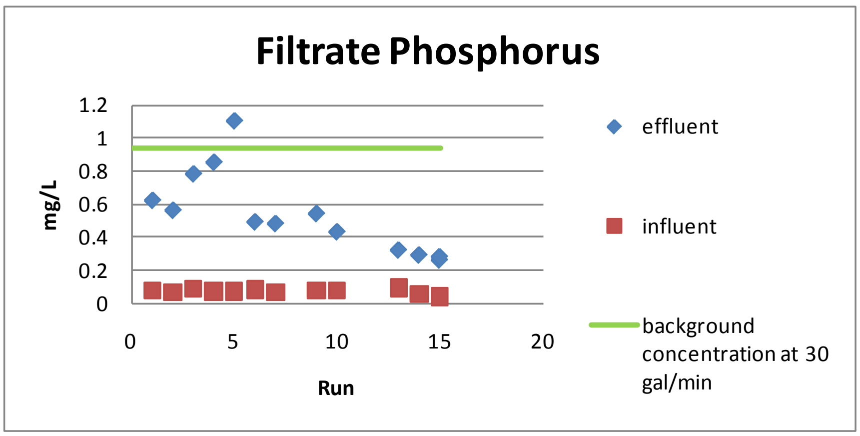


Figure 39 Filtrate Data for Phosphorus Concentrations

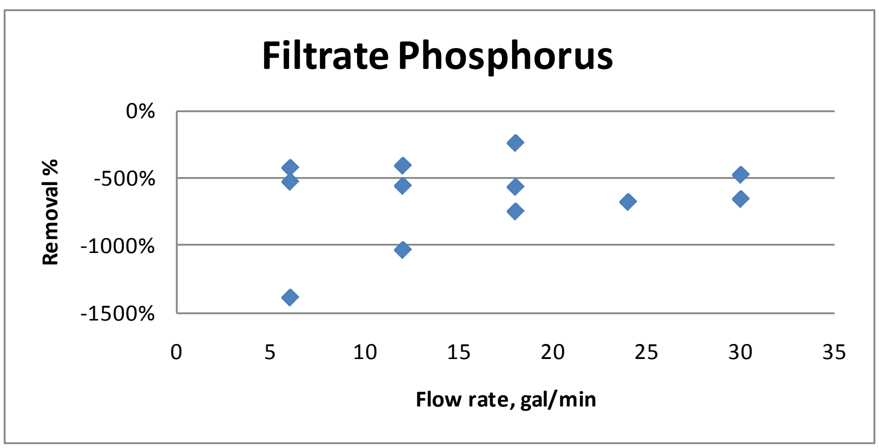


Figure 40 Filtrate Data for Phosphorus Removal

5 Guidelines for Estimating Site-Specific Device Performance

The treatment performance of the TreePod® is dependent on local hydrology, drainage area, influent concentration, and TreePod® size. Hydrology is a critical component because of the effect that bypass has on treatment performance. A site with higher peak rainfall intensities will cause more water to bypass the TreePod® than a site with milder rainfall intensities, even when the two areas have the same annual rainfall.

There are two components to estimating media hydraulic capacity and bypass. The first is the initial wetting of the filter. Theoretical conductivity of the media is low because of air in the pore spaces, but negative pore pressure can compensate and draw water into the media very quickly. Once the filter is thoroughly wet, the hydraulic capacity of the filter is fairly constant. Bypass occurs when the runoff exceeds the hydraulic capacity of the filter. A conservative estimate would assume no treatment of bypassed water or measured bypass concentrations can be used. Runoff can be estimated from rain gauge data using a standard approach such as the rational method or the SCS method. The instantaneous infiltration rate can be empirically estimated by considering data of time-to-bypass, drying periods, and wetted hydraulic capacity. A mass balance is then used to calculate pollutant reduction.

6 References

OWP (Office of Water Programs). 2007. *Perk Filter™ Final Report*. Office of Water Programs, California State University, Sacramento.

ECY (Washington State Department of Ecology). 2002/2008. *Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE).* Publ. # 02-10-037. http://www.ecy.wa.gov/biblio/0210037.html (accessed October 2, 2009).

UNH (University of New Hampshire). 2007. *University of New Hampshire Stormwater Center 2007 Annual Report*. University of New Hampshire Stormwater Center, UNH/NOAA Cooperative Institute for Coastal Estuarine Environmental Technology.

U.S. Silica Company (USSC). 1997. Sil-Co-Sil 106. Product Data. http://www.u-s-silica.com/msds/SILICA-MSDS-0210.pdf (accessed September 30, 2009).

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APPENDIX A: Media Characteristics Provided by Kristar

Disclaimer: Kristar reports that the Green Roof media shown in this appendix has a grain size distribution (GSD) similar to the SC and ESC blends, but the GSD of the compost used in the tests was not verified by OWP.

The media specifications provided by Kristar are reproduced on pages A-2 and A-3. The SC media analysis is on pages A-4 and A-5. The ESC media analysis is on pages A-6 and A-7. Page A-8 contains the grain size distribution for expanded slate. Pages A-9 through A-11 contain analysis of compost.

TreePod® Media Specificaions

TreePod™ Media Specifications

1. General

Selection of material used as filter media must consider the local requirements at the site under consideration. However, typical material specifications intended to provide the required system performance are provided herein.

2. Sand/Aggregate Component

Sand or aggregate shall conform to ASTM C33 with the following particle size distribution:

Sieve (Specification E 11)	Percent Passing
9.5-mm (3⁄8-in.)	100
4.75-mm (No. 4)	95 to 100
2.36-mm (No. 8)	80 to 100
1.18-mm (No. 16)	50 to 85
600-µm (No. 30)	25 to 60
300-µm (No. 50)	5 to 30
150-µm (No. 100)	0 to 10

Material shall be sieved to remove all material passing a No. 200 sieve. Sand shall be clean and not contain calcium carbonated or dolomitic sand, or "rock dust."

3. Compost Component

3.1 Compost producers shall comply with the following:

a. Be fully permitted to produce compost as specified under Local Enforcement Agencies and any other State and Local Agencies that regulate Solid Waste Facilities.
b. Be a participant in United States Composting Council's Seal of Testing Assurance program.

3.2 Compost shall be composted and may be derived from any single, or mixture of any of the following feedstock materials:

a. Green material consisting of chipped, shredded, or ground vegetation; or clean processed recycled wood products
b. Biosolids
c. Mixed food waste

3.3 Compost feedstock materials shall be composted to reduce weed seeds, pathogens and deleterious materials.

3.4 Compost shall not be derived from mixed municipal solid waste or animal manure and must be reasonably free of visible contaminates. Compost must not contain paint, petroleum products, pesticides or any other chemical residues harmful to animal life or plant growth. Compost must not possess objectionable odors.

3.5 Metal concentrations in compost must not exceed the maximum metal concentrations listed by Local Enforcement Agencies and any other State and Local Agencies.

3.6 Compost must comply with the following:

TreePod® Media Specificaions

Compost Physical/Chemical Requirements

Property	Test Method	Requirement
pH	*TMECC 04.11-A, Elastometric pH 1:5 Slurry Method, pH Units	6.0–8.0
Soluble Salts	TMECC 04.10-A, Electrical Conductivity 1:5 Slurry Method dS/m (mmhos/cm)	0-10.0
Moisture Content	TMECC 03.09-A, Total Solids & Moisture at 70+/- 5 deg C, % Wet Weight Basis	30–60
Organic Matter Content	TMECC 05.07-A, Loss-On-Ignition Organic Matter Method (LOI), % Dry Weight Basis	30–65
Maturity	TMECC 05.05-A, Germination and Vigor Seed Emergence Seedling Vigor % Relative to Positive Control	 80 or Above 80 or Above
Stability	TMECC 05.08-B, Carbon Dioxide Evolution Rate mg CO_2-C/g OM per day	8 or below
Particle Size	TMECC 02.02-B Sample Sieving for Aggregate Size Classification % Dry Weight Basis	95% Passing 5/8 inch 70% Passing 3/8 inch
Pathogen	TMECC 07.01-B, Fecal Coliform Bacteria < 1000 MPN/gram dry wt.	Pass
Pathogen	TMECC 07.01-B, Salmonella < 3 MPN/4 grams dry wt.	Pass
Physical Contaminants	TMECC 02.02-C, Man Made Inert Removal and Classification: Plastic, Glass and Metal, % > 4mm fraction	Combined Total: < 1.0
Physical Contaminants	TMECC 02.02-C, Man Made Inert Removal and Classification: Sharps (Sewing needles, straight pins and hypodermic needles), % > 4mm fraction	None Detected

*TMECC refers to "Test Methods for the Examination of Composting and Compost," published by the United States Department of Agriculture and the United States Compost Council (USCC).

4. Mixing

Components shall be blended thoroughly. Recommended ratio is 75-80% sand/20-25% compost, though local requirements or specific project needs may dictate necessary variation.

5. Testing and Certification

5.1 Producer shall provide copies of the Sand Technical Data Sheet, Compost Technical Data Sheet and STA certification. The Compost Technical Data Sheet shall include laboratory analytical test results, directions for product use, and a list of product ingredients.

5.2 A sample of the final mix shall be tested by a certified laboratory and meet the following specifications:

Final Mix Physical/Chemical Requirements

Property	Test Method	Requirement
Average Permeability (k)	ASTM D2434	>80 in/hr
Cation Exchange Capacity (CEC)	EPA 9080	>50 meq/100 g
Available Phosphorus	Bray 1	<300 mg/kg

10/2009

SC Media Blend Analysis (KE 15b)

E T S

975 Transport Way, Suite 2
Petaluma, CA 94954
(707) 778-9605 / FAX 778-9612

Environmental Technical Services

-Soil, Water & Air Testing & Monitoring
-Analytical Labs
-Technical Support

Serving people and the environment so that both benefit.

CLIENT: Kristar Enterprises, Inc, 360 Sutton Place, Santa Rosa, CA 95407
ATTN: Jonathan McDonald
PROJECT ID: contrived filter media of crushed expanded slate

ANALYST(S)	DATE COLLECTED	DATE RECEIVED	DATE of REPORT
D. Jacobson	5/14/10	5/14/10	5/19/10

PERMEABILITY AND HYDRAULIC CONDUCTIVITY TEST RESULTS (ASTM D2434)

SAMPLE ID	SAMPLE SOURCE	SAMPLE MASS gm	PERCENT MOISTURE DRY/WET	DRY DENSITY lbs/cuft (Start)	DRY DENSITY lbs/cuft (End)	SPECIFIC GRAVITY gm/cc	SATURATION PERCENT (Start)	SATURATION PERCENT (End)	VOID RATIO (Start)	VOID RATIO (End)	PERMEABILITY (average K) cm/sec
KE15B/SR [03990-2B]	Filter Sand, Cmpst & Mirifi	780.0	16.01 13.80	62.3	86.2	2.65	28.41	75.04	1.288	0.654	0.0985

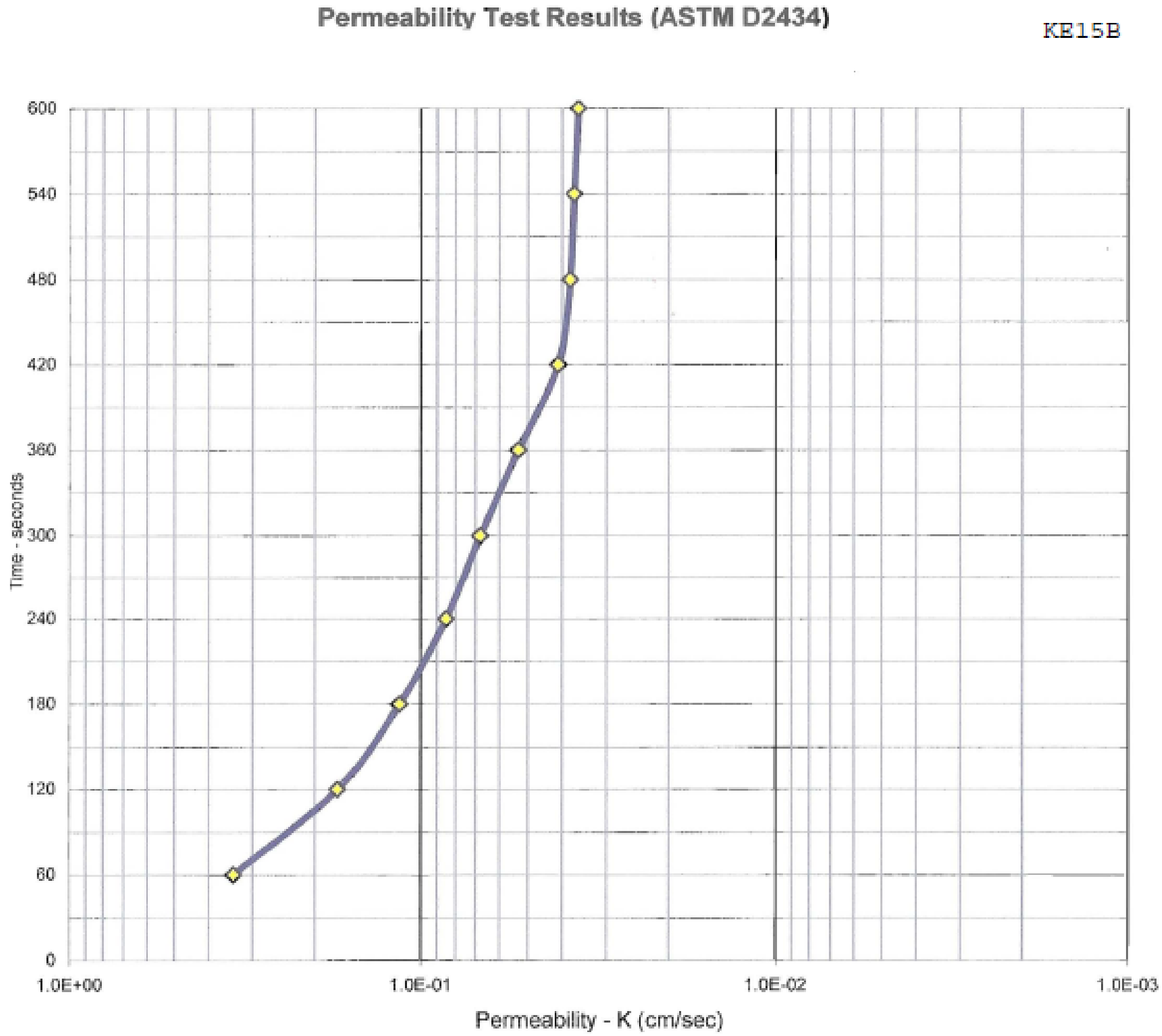
PERMEAMETER, SAMPLE TEST SPECIFICATIONS, SAMPLE DESCRIPTION

Specs/Smpl ID	KE15B/SR
Volume (Q) [cm3]:	673.38
Diameter (d) [cm]:	9.50
Length (L) [cm]:	9.50
Area (A) [cm2]:	70.88
Time (t) [sec]:	300
Head (h) [cm]:	30.48
Sample Description	Dk Grn-Gray Sand w/ Silt
Permeameter	fixed wall, constant head

COMMENTS/NOTES:

\\\\\ NOTES: Testing follows methodology as per the Association of Testing Materials (ASTM) protocols as follows: ASTM D-2434 Test Method for Permeability of Granular Soils (Constant Head). ASTM D-2937 Test Method for Density of Soil in Place by Drive-Cylinder - dry bulk or native densities; and ASTM D-854 Test Method for Specific Gravity of Soils, or ASTM C97 Standard Test Method for Absorption and Bulk Specific Gravity of Dimension Stone, or other appropriate methods. Permeameter base is screened, not fritted.

SC Media Blend Analysis (KE 15b)



TEST DATA		SAMPLE INFORMATION	
Specimen Height (cm):	9.50	Sample No.:	03990-2B
Specimen Diameter (cm):	9.50	Sample ID:	KE15B/SR
Area (sq cm)	70.88	Sample Condition:	Remold
Sample Mass (gm):	780.0	Maximum Dry Density (pcf):	
Sample Volume (cc):	574.1	Optimum Moisture (%):	
Void Ratio	1.288	Percent Compaction:	
Moisture (%):	13.80	Assumed Specific Gravity (gm/cc):	2.65
Saturation %:	28.41	Permeameter Type/Method:	
Dry Density (lbs/cuft)	62.34	Gross Soil/SedimentText.:	Dark Greenish Gray Sand w/ Silt (w/ compost)
Matrix Porosity (%)	0.6230		

PERMEABILITY (cm/sec): 9.85×10^{-2} @ 20° C

Environmental Technical Services	PERMEABILITY REPORT	Plate:
	CLIENT: KriStar Enterprises, Inc 360 Sutton Place, Santa Rosa, CA ATTENTION: Jonathan MacDonald DATE: 5/19/10 PROJECT ID: Filter Crushed Expanded Slate Medium	1

ESC Media Blend Analysis (KE 13b)

KE13B

E T S

975 Transport Way, Suite 2
Petaluma, CA 94954
(707) 778-9605 / FAX 778-9612

Environmental Technical Services

-Soil, Water & Air Testing & Monitoring
-Analytical Labs
-Technical Support

Serving people and the environment so that both benefit.

CLIENT: Kristar Enterprises, Inc, 360 Sutton Place, Santa Rosa, CA 95407
ATTN: Jonathan McDonald
PROJECT ID: contrived filter media of fine and coarse river sands w/ & w/o compost & geotextile

ANALYST(S)	DATE COLLECTED	DATE RECEIVED	DATE of REPORT
D. Jacobson	5/13/10	5/13/10	5/24/10

PERMEABILITY AND HYDRAULIC CONDUCTIVITY TEST RESULTS (ASTM D2434)

SAMPLE ID	SAMPLE SOURCE	SAMPLE MASS gm	PERCENT MOISTURE DRY/WET	DRY DENSITY lbs/cuft (Start)	DRY DENSITY lbs/cuft (End)	SPECIFIC GRAVITY gm/cc	SATURATION PERCENT (Start)	SATURATION PERCENT (End)	VOID RATIO (Start)	VOID RATIO (End)	PERMEABILITY (average K) cm/sec
KE13B/SR [03987-4B]	Filter Sand w/ Cmpst & Pd	660.3	13.67 12.03	55.0	56.9	2.65	19.37	51.24	1.646	1.032	0.052

PERMEAMETER, SAMPLE TEST SPECIFICATIONS, SAMPLE DESCRIPTION

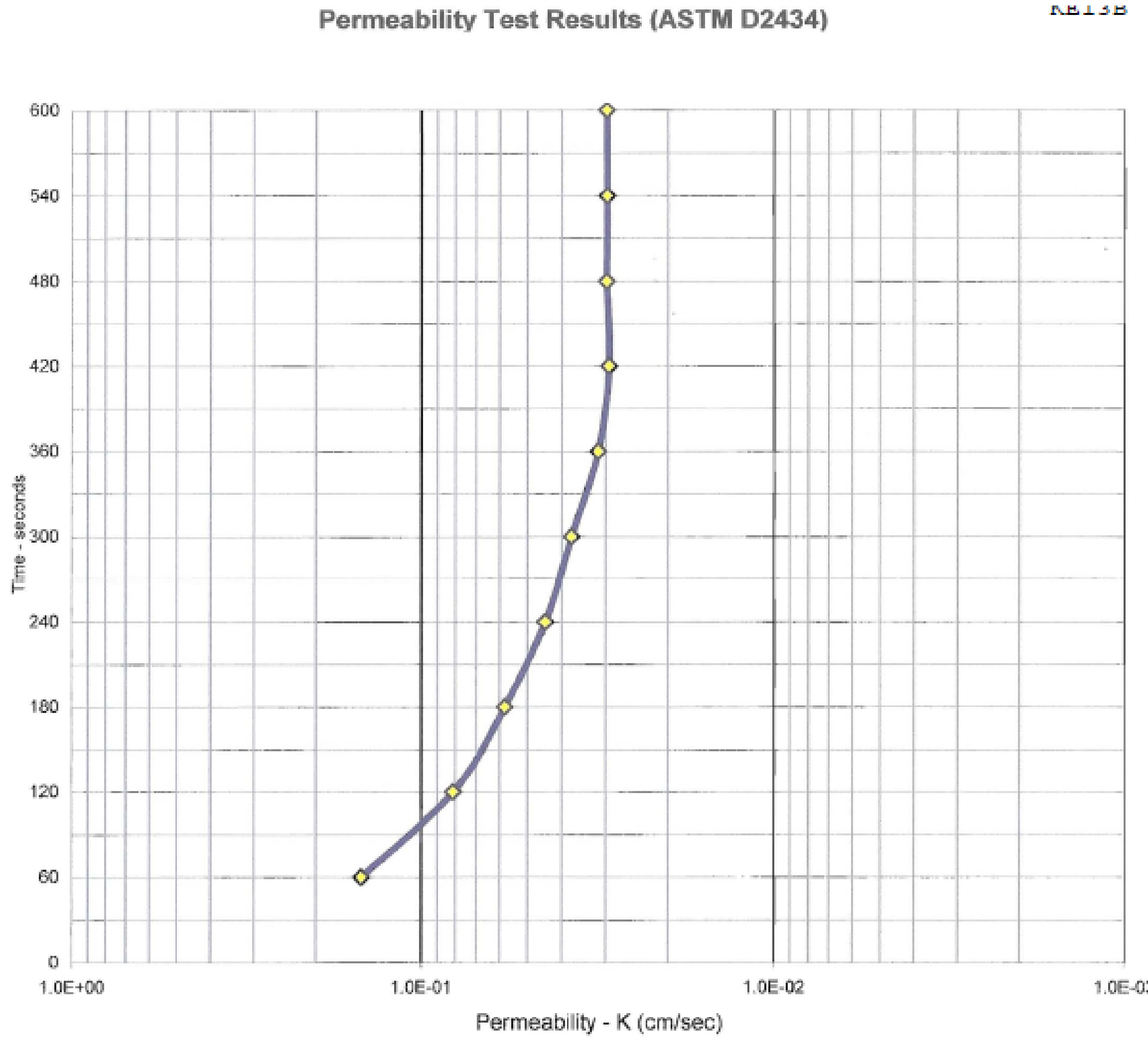
Specs/Smpl ID	KE13B/SR
Volume (Q) [cm3]:	659.21
Diameter (d) [cm]:	9.50
Length (L) [cm]:	9.30
Area (A) [cm2]:	70.88
Time (t) [sec]:	720
Head (h) [cm]:	30.48
Sample Description	Bluish Gry Brn Snd w/ Slt&Grvl
Permeameter	fixed wall, constant head

SAMPLE ID	RATE in/hr	MATRIX POROSITIES start	MATRIX POROSITIES end
KE13B/SR	73.6	62.20	60.94

COMMENTS/NOTES:

\\\\ NOTES: Testing follows methodology as per the Association of Testing Materials (ASTM) protocols as follows: ASTM D-2434 Test Method for Permeability of Granular Soils (Constant Head). ASTM D-2937 Test Method for Density of Soil in Place by Drive-Cylinder - dry bulk or native densities; and ASTM D-854 Test Method for Specific Gravity of Soils, or ASTM C97 Standard Test Method for Absorption and Bulk Specific Gravity of Dimension Stone, or other appropriate methods. Permeameter base is screened, not fritted.

ESC Media Blend Analysis (KE 13b)



TEST DATA		SAMPLE INFORMATION	
Specimen Height (cm):	9.30	Sample No.:	03987-4B
Specimen Diameter (cm):	9.60	Sample ID:	KE13B/SR
Area (sq cm)	70.88	Sample Condition:	Remold
Sample Mass (gm):	660.3	Maximum Dry Density (pcf):	
Sample Volume (cc):	659.2	Optimum Moisture (%):	
Void Ratio	1.646	Percent Compaction:	
Moisture (%):	13.67	Assumed Specific Gravity (gm/cc):	2.65
Saturation %:	19.37	Permeameter Type/Method:	
Dry Density (lbs/cuft)	55.0	Gross Soil/SedimentText.:	Bluish Gray Brown Sand
Calculated Porosity (%)	0.6673		w/ Silt & Gravel (& compost [pad])

PERMEABILITY (cm/sec): 5.19 x 10^{-2} @ 20º C

Environmental Technical Services	PERMEABILITY REPORT	Plate:
	CLIENT: KriStar Enterprises, Inc 360 Sutton Place, Santa Rosa, CA ATTENTION: Jonathan MacDonald DATE: 5/24/10 PROJECT ID: Coarse Sand Filter Medium w/ Compost (& pad)	1

Expanded Slate Grain Size Distribution

STALITE: Masonry Aggregate Gradations

Tank A

Sieve Size		% Retained
# 4	(4.75mm)	12-16
# 8	(2.36mm)	34-50
# 16	(1.18mm)	55-67
# 30	(600µm)	70-80
# 50	(300µm)	76-84
# 100	(150µm)	84-89
F.M.		3.31-3.86

Tank B

Sieve Size		% Retained
# 4	(4.75mm)	12-16
# 8	(2.36mm)	34-50
# 16	(1.18mm)	58-70
# 30	(600µm)	71-81
# 50	(300µm)	79-87
# 100	(150µm)	86-91
F.M.		3.40-3.95

Tank C

Sieve Size		% Retained
# 4	(4.75mm)	6-10
# 8	(2.36mm)	32-46
# 16	(1.18mm)	53-65
# 30	(600µm)	67-79
# 50	(300µm)	78-86
# 100	(150µm)	85-90
F.M.		3.21-3.76

Tank D

Sieve Size		% Retained
# 4	(4.75mm)	4-8
# 8	(2.36mm)	28-38
# 16	(1.18mm)	46-58
# 30	(600µm)	63-75
# 50	(300µm)	74-84
# 100	(150µm)	82-90
F.M.		2.97-3.53

Tank E

Sieve Size		% Retained
# 4	(4.75mm)	5-9
# 8	(2.36mm)	28-38
# 16	(1.18mm)	43-55
# 30	(600µm)	60-70
# 50	(300µm)	71-79
# 100	(150µm)	80-85
F.M.		2.87-3.36

Tank F

Sieve Size		% Retained
# 4	(4.75mm)	25-35
# 8	(2.36mm)	70-85
# 16	(1.18mm)	80-87
# 30	(600µm)	85-91
# 50	(300µm)	89-94
# 100	(150µm)	93-97
F.M.		4.42-4.89

Tank G

Sieve Size		% Retained
# 4	(4.75mm)	20-27
# 8	(2.36mm)	47-63
# 16	(1.18mm)	64-78
# 30	(600µm)	75-85
# 50	(300µm)	82-90
# 100	(150µm)	87-95
F.M.		3.75-4.38

Tank H

Sieve Size		% Retained
# 4	(4.75mm)	70-85
# 8	(2.36mm)	80-90
# 16	(1.18mm)	-
# 30	(600µm)	-
# 50	(300µm)	90-98
# 100	(150µm)	92-100

FINES

Sieve Size		% Retained
# 4	(4.75mm)	0-3
# 8	(2.36mm)	15-30
# 16	(1.18mm)	45-60
# 30	(600µm)	60-70
# 50	(300µm)	75-83
# 100	(150µm)	83-86
F.M.		2.78-3.32

Compost Analysis

US COMPOSTING COUNCIL

Seal of Testing Assurance

Date Sampled/Received: 11 May. 09 / 12 May. 09

Novozymes NA, Inc.
Novozymes North America, Inc.
P.O. Box 576
Franklinton
NC 27525-0576 (919) 494-3489

Product Identification Compost
Compost Sample

COMPOST TECHNICAL DATA SHEET

LABORATORY: Soil Control Lab; 42 Hangar Way; Watsonville, CA 95076 *tel:* 831.724.5422 *fax:* 831.724.3188

Compost Parameters	***Reported as*** *(units of measure)*	***Test Results***	***Test Results***
Plant Nutrients:	%, weight basis	Not reported	Not reported
Moisture Content	%, wet weight basis	55.7	
Organic Matter Content	%, dry weight basis	65.3	
pH	units	6.75	
Soluble Salts *(electrical conductivity EC 5)*	dS/m (mmhos/cm)	4.3	
Particle Size or Sieve Size	maxium aggregate size, inches	0.38	
Stability Indicator *(respirometry)*			*Stability Rating:*
CO_2 Evolution	mg CO_2-C/g OM/day mg CO_2-C/g TS/day	0.7 0.42	Very Stable
Maturity Indicator (bioassay)			
Percent Emergence	average % of control	100.0	
Relative Seedling Vigor	average % of control	100.0	
Select Pathogens	PASS/FAIL: per US EPA Class A standard, 40 CFR § 503.32(a)	Pass	*Fecal coliform*
		Pass	*Salmonella*
Trace Metals	PASS/FAIL: per US EPA Class A standard, 40 CFR § 503.13, Tables 1 and 3.	Pass	*As,Cd,Cr,Cu,Pb,Hg* Mo,Ni,Se,Zn

Participants in the US Composting Council's Seal of Testing Assurance Program have shown the commitment to test their compost products on a prescribed basis and provide this data, along with compost end use instructions, as a means to better serve the needs of their compost customers.

Laboratory Group: May.09 C Laboratory Number: 9050297-1/1

Analyst: Assaf Sadeh www.compostlab.com

Compost Analysis

PENNSTATE

(814) 863-0841 Fax (814) 863-4540
Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

ANALYSIS FOR:	ADDITIONAL COPY TO:
Chuck Friedrich Carolina Stalite Co. PO Box 1037 Salisbury NC 28145	

LAB ID	SAMPLE ID	SAMPLE TYPE	DATE SAMPLED	DATE RECEIVED	DATE COMPLETED
SM02407	EXT1	Multi-layer extensive	4/5/2007	4/12/2007	4/23/2007

Green Roof Media Analysis

Results on dry weight basis unless specified otherwise

Analysis	Units	Result	FLL Guidelines for Multi Course Extensive Sites[1]
Particle Size Distribution (See accompanying report)			
$\leq$ 0.05 mm *(Fll reference value based on < 0.06 mm)*	mass %	5.8	$\leq$ 15
Density Measurements			
Bulk Density (dry weight basis)	g/cm^3	1.00	—
Bulk Density (dry weight basis)	lb/ft^3	62.40	—
Bulk Density (at max. water-holding capacity)	g/cm^3	1.41	—
Bulk Density (at max. water-holding capacity)	lb/ft^3	87.93	—
Water/Air Measurements			
Moisture *(as received basis)*	mass %	14.2	—
Total Pore Volume[2]	Vol. %	52.1	—
Maximum water-holding Capacity	Vol. %	40.9	$\geq$ 35
Air-Filled Porosity (at max water-holding capacity)	Vol. %	11.2	$\geq$ 10
Water permeability (saturated hydraulic conductivity)	cm/s	0.023	$\geq$ 0.001
Water permeability (saturated hydraulic conductivity)	in/min	0.545	$\geq$ 0.0236
pH and Salt Content			
pH ($CaCl_2$)		8.0	6.5 - 8.0
Soluble salts (water, 1:10, m:v)	mmhos/cm	0.18	—
Soluble salts (water, 1:10, m:v)	g (KCl)/L	1.12	$\leq$ 3.5
Organic Measurements			
Organic matter content	mass %	4.1	$\leq$ 6.0
Nutrients			
Phosphorus, P_2O_5 (CAL)	mg/L	105.7	$\leq$ 200
Potassium, K_2O (CAL)	mg/L	381.1	$\leq$ 700
Magnesium, Mg ($CaCl_2$)	mg/L	108.6	$\leq$ 160
Nitrate + Ammonium ($CaCl_2$)	mg/L	10.3	$\leq$ 80

GR01: Multi Course Extensive

[1]*Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). 2002. Guidelines for the Planning Execution and Upkeep of Green-Roof Sites*
[2]*Total pore volume determined using measured particle density instead of assumed particle density as specified in FLL*

page 1

Compost Analysis

PENNSTATE

1855

(814) 863-0841 Fax (814) 863-4540

Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

ANALYSIS FOR:	ADDITIONAL COPY TO:
ChuckFriedrich Carolina Stalite Co. PO Box 1037 Salisbury NC 28145	

LAB ID	SAMPLE ID	SAMPLE TYPE	DATE SAMPLED	DATE RECEIVED	DATE COMPLETED
SM02407	EXT1	Multi-layer extensive	4/5/2007	4/12/2007	4/23/2007

Green Roof Media
Particle Size Distribution

Particle Size Analysis		Sum of particles less than size specified				
Diameter -mm-	%		Diameter -mm-	Diameter -in-	Sieve size	% sum of particles
< 0.002	1.8	<	0.002	---	---	1.8
0.002-0.05	4.0	<	0.05	---	---	5.8
0.05-0.25	6.2	<	0.25	0.0098	60 mesh	11.9
0.25-1.0	11.9	<	1.0	0.0394	18 mesh	23.8
1.0-2.0	12.9	<	2.0	0.0787	10 mesh	36.7
2.0-3.2	16.7	<	3.2	0.125	1/8 inch	53.4
3.2-6.3	36.1	<	6.3	0.250	1/4 inch	89.5
6.3-9.5	10.5	<	9.5	0.375	3/8 inch	100.0
9.5-12.5	0.0	<	12.5	0.500	1/2 inch	100.0
> 12.5	0.0					

Compost Analysis

PENNSTATE

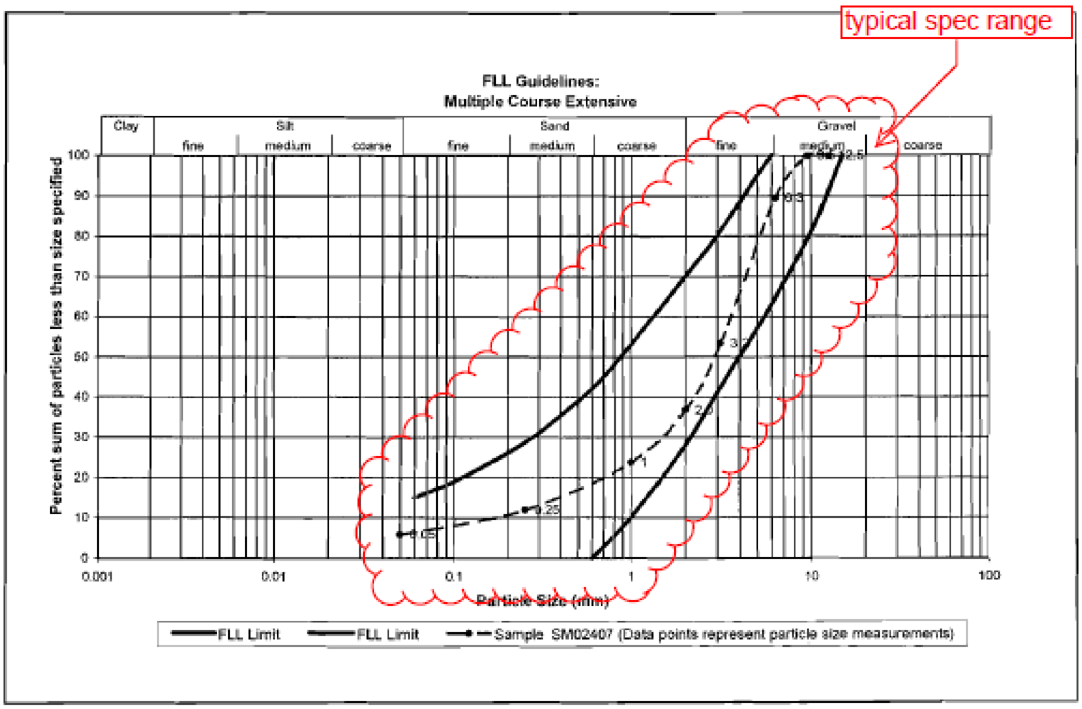
1855

(814) 863-0841 Fax (814) 863-4540
Agricultural Analytical Services Laboratory
The Pennsylvania State University
University Park PA 16802

ANALYSIS FOR:	ADDITIONAL COPY TO:
Chuck Friedrich Carolina Stalite Co. PO Box 1037 Salisbury NC 28145	

LAB ID	SAMPLE ID	SAMPLE TYPE	DATE SAMPLED	DATE RECEIVED	DATE COMPLETED
SM02407	EXT1	Multi-layer extensive	4/5/2007	4/12/2007	4/23/2007

Green Roof Media
FLL[1] Particle Size Distribution Graph
for Multiple Course Extensive Systems



[1]*Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). 2002. Guidelines for the Planning Execution and Upkeep of Green-Roof Sites*

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APPENDIX B: Raw Water Quality Data, Treatment Calculations, and Quality Assurance/Quality Control Analysis

The raw water quality data are displayed on pages B-2 through B-7. The treatment calculations are displayed on pages B-8 through B-11. The QA/QC analysis is on pages B-12 and B-14.

Raw Water Quality Data

(see following pages)

Raw Water Quality Data

Run	ANALYTE	RESULT	UNITS	SAMPLE DESCRIPTION	REPORTING LIMIT	Sample Location	Flow rate	DATE SAMPLED
0	Copper	4.3	ug/L	2-TCUPBZN-CT-OUTSIDE OFFICE-0	0.5	effluent	30	7/15/2010
1	Copper	2.6	ug/L	2-TCUPBZN-CT-071510-i-I	0.5	effluent	30	7/15/2010
1	Copper	9.2	ug/L	2-TCUPBZN-CT-071510-e-I	0.5	influent	30	7/15/2010
2	Copper	2	ug/L	2-TCUPBZN-CT-071610-e-2	0.5	effluent	24	7/16/2010
2	Copper	7.7	ug/L	2-TCUPBZN-CT-071610-i-2	0.5	influent	24	7/16/2010
3	Copper	4.3	ug/L	2-TCUPBZN-071810-e-3	0.5	effluent	18	7/18/2010
3	Copper	11	ug/L	2-TCUPBZN-071810-i-3	0.5	influent	18	7/18/2010
4	Copper	3.5	ug/L	2-TCUPBZN-071910-e-4	0.5	effluent	12	7/19/2010
4	Copper	10	ug/L	2-TCUPBZN-071910-i-4	0.5	influent	12	7/19/2010
5	Copper	3.6	ug/L	2-TCUPBZN-072010-e-5	0.5	effluent	6	7/20/2010
5	Copper	11	ug/L	2-TCUPBZN-072010-i-5	0.5	influent	6	7/20/2010
6	Copper	11	ug/L	2-TPCUPBZN-072110-eb-6	0.5	bypass effluent with leaking filtrate	30	7/21/2010
6	Copper	3.5	ug/L	2-TPCUPBZN-072110-e-6	0.5	effluent	30	7/21/2010
6	Copper	11	ug/L	2-TPCUPBZN-072110-i-6	0.5	influent	30	7/21/2010
7	Copper	9.2	ug/L	2-TPCUPBZN-CT-072210-ib-7	0.5	bypass influent	18	7/22/2010
7	Copper	2.8	ug/L	2-TPCUPBZN-CT-072210-e-7	0.5	effluent	18	7/22/2010
7	Copper	9.4	ug/L	2-TPCUPBZN-CT-072210-i-7	0.5	influent	18	7/22/2010
8	Copper	3.9	ug/L	2-TCUPBZN-CT-072310-E-8-2	0.5	effluent	24	7/23/2010
8	Copper	4.5	ug/L	2-TCUPBZN-CT-072310-E-8	0.5	effluent	24	7/23/2010
8	Copper	8.2	ug/L	2-TCUPBZN-CT-072310-I-8-2	0.5	influent	24	7/23/2010
8	Copper	8.1	ug/L	2-TCUPBZN-CT-072310-I-8	0.5	influent	24	7/23/2010
9	Copper	3.1	ug/L	2-TCUPBZN-CT-072510-E-9	0.5	effluent	12	7/25/2010
9	Copper	9.3	ug/L	2-TCUPBZN-CT-072510-I-9	0.5	influent	12	7/25/2010
10	Copper	3.3	ug/L	2-TCUPBZN-CT-072610-E-10	0.5	effluent	6	7/26/2010
10	Copper	9.8	ug/L	2-TCUPBZN-CT-072610-I-10	0.5	influent	6	7/26/2010
11	Copper	5.2	ug/L	2-TCUPBZN-CT-082710-e-11	0.5	effluent	30	7/27/2010
11	Copper	8.7	ug/L	2-TCUPBZN-CT-072710-i-11-2	0.5	influent	30	7/27/2010
11	Copper	9.1	ug/L	2-TCUPBZN-CT-072710-i-11	0.5	influent	30	7/27/2010
12	Copper	3.6	ug/L	2-TCUPBZN-CT-072810-E-12	0.5	effluent	24	7/28/2010
12	Copper	7.7	ug/L	2-TCUPBZN-CT-072810-I-12	0.5	influent	24	7/28/2010
13	Copper	2	ug/L	2-TCUPBZN-CT-072910-E-13	0.5	effluent	18	7/29/2010
13	Copper	8.7	ug/L	2-TCUPBZN-CT-072910-I-13	0.5	influent	18	7/29/2010
14	Copper	2.2	ug/L	2-TCuPbZn-CT-073010-e-14	0.5	effluent	12	7/30/2010
14	Copper	8	ug/L	2-TCuPbZn-CT-073010-i-14	0.5	influent	12	7/30/2010
15	Copper	4.4	ug/L	2-TCuPBZn-CT-0801108-e-15-2	0.5	effluent	6	8/1/2010
15	Copper	2.9	ug/L	2-TCuPBZn-CT-0801108-e-15	0.5	effluent	6	8/1/2010
15	Copper	11	ug/L	2-TCuPBZn-CT-0801108-i-15	0.5	influent	6	8/1/2010
0	Lead	0.13	ug/L	2-TCUPBZN-CT-OUTSIDE OFFICE-0	0.25	effluent	30	7/15/2010
1	Lead	0.21	ug/L	2-TCUPBZN-CT-071510-i-I	0.25	effluent	30	7/15/2010
1	Lead	2.6	ug/L	2-TCUPBZN-CT-071510-e-I	0.25	influent	30	7/15/2010
2	Lead	0.12	ug/L	2-TCUPBZN-CT-071610-e-2	0.25	effluent	24	7/16/2010

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2	Lead	2.2	ug/L	2-TCUPBZN-CT-071610-i-2	0.25	influent	24	7/16/2010
3	Lead	0.25	ug/L	2-TCUPBZN-071810-e-3	0.25	effluent	18	7/18/2010
3	Lead	2.9	ug/L	2-TCUPBZN-071810-i-3	0.25	influent	18	7/18/2010
4	Lead	0.17	ug/L	2-TCUPBZN-071910-e-4	0.25	effluent	12	7/19/2010
4	Lead	2.7	ug/L	2-TCUPBZN-071910-i-4	0.25	influent	12	7/19/2010
5	Lead	0.16	ug/L	2-TCUPBZN-072010-e-5	0.25	effluent	6	7/20/2010
5	Lead	2.7	ug/L	2-TCUPBZN-072010-i-5	0.25	influent	6	7/20/2010
6	Lead	1.9	ug/L	2-TPCUPBZN-072110-eb-6	0.25	bypass effluent with leaking filtrate	30	7/21/2010
6	Lead	0.32	ug/L	2-TPCUPBZN-072110-e-6	0.25	effluent	30	7/21/2010
6	Lead	2.5	ug/L	2-TPCUPBZN-072110-i-6	0.25	influent	30	7/21/2010
7	Lead	1.9	ug/L	2-TPCUPBZN-CT-072210-ib-7	0.25	bypass influent	18	7/22/2010
7	Lead	0.3	ug/L	2-TPCUPBZN-CT-072210-e-7	0.25	effluent	18	7/22/2010
7	Lead	2.2	ug/L	2-TPCUPBZN-CT-072210-i-7	0.25	influent	18	7/22/2010
8	Lead	0.7	ug/L	2-TCUPBZN-CT-072310-E-8	0.25	effluent	24	7/23/2010
8	Lead	0.71	ug/L	2-TCUPBZN-CT-072310-E-8-2	0.25	effluent	24	7/23/2010
8	Lead	2.1	ug/L	2-TCUPBZN-CT-072310-I-8	0.25	influent	24	7/23/2010
8	Lead	2.2	ug/L	2-TCUPBZN-CT-072310-I-8-2	0.25	influent	24	7/23/2010
9	Lead	0.17	ug/L	2-TCUPBZN-CT-072510-E-9	0.25	effluent	12	7/25/2010
9	Lead	2.3	ug/L	2-TCUPBZN-CT-072510-I-9	0.25	influent	12	7/25/2010
10	Lead	0.18	ug/L	2-TCUPBZN-CT-072610-E-10	0.25	effluent	6	7/26/2010
10	Lead	2.3	ug/L	2-TCUPBZN-CT-072610-I-10	0.25	influent	6	7/26/2010
11	Lead	1.1	ug/L	2-TCUPBZN-CT-082710-e-11	0.25	effluent	30	7/27/2010
11	Lead	2.8	ug/L	2-TCUPBZN-CT-072710-i-11-2	0.25	influent	30	7/27/2010
11	Lead	2.6	ug/L	2-TCUPBZN-CT-072710-i-11	0.25	influent	30	7/27/2010
12	Lead	0.59	ug/L	2-TCUPBZN-CT-072810-E-12	0.25	effluent	24	7/28/2010
12	Lead	2.3	ug/L	2-TCUPBZN-CT-072810-I-12	0.25	influent	24	7/28/2010
13	Lead	0.17	ug/L	2-TCUPBZN-CT-072910-E-13	0.25	effluent	18	7/29/2010
13	Lead	2.2	ug/L	2-TCUPBZN-CT-072910-I-13	0.25	influent	18	7/29/2010
14	Lead	0.13	ug/L	2-TCuPbZn-CT-073010-e-14	0.25	effluent	12	7/30/2010
14	Lead	2.1	ug/L	2-TCuPbZn-CT-073010-i-14	0.25	influent	12	7/30/2010
15	Lead	0.19	ug/L	2-TCuPBZn-CT-0801108-e-15-2	0.25	effluent	6	8/1/2010
15	Lead	0.16	ug/L	2-TCuPBZn-CT-0801108-e-15	0.25	effluent	6	8/1/2010
15	Lead	3	ug/L	2-TCuPBZn-CT-0801108-i-15	0.25	influent	6	8/1/2010
0	Phosphorus	0.94	mg/L	2-TP-CT-0	0.1	effluent	30	7/15/2010
0	Phosphorus	0.28	mg/L	2-TP-CT-072610-INLETDUST	0.1	Inlet	30	7/26/2010
1	Phosphorus	0.62	mg/L	2-TP-CT-071510-i-I	0.1	effluent	30	7/15/2010
1	Phosphorus	0.082	mg/L	2-TP-CT-071510-e-I	0.1	influent	30	7/15/2010
2	Phosphorus	0.56	mg/L	2-TP-CT-071610-e-2	0.1	effluent	24	7/16/2010
2	Phosphorus	0.072	mg/L	2-TP-CT-071610-i-2	0.1	influent	24	7/16/2010
3	Phosphorus	0.78	mg/L	2-TP-071810-e-3	0.1	effluent	18	7/18/2010
3	Phosphorus	0.092	mg/L	2-TP-071810-i-3	0.1	influent	18	7/18/2010
4	Phosphorus	0.85	mg/L	2-TP-071910-e-4	0.1	effluent	12	7/19/2010
4	Phosphorus	0.075	mg/L	2-TP-071910-i-4	0.1	influent	12	7/19/2010

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5	Phosphorus	1.1	mg/L	2-TP-CT-072010-e-5	0.1	effluent	6	7/20/2010
5	Phosphorus	0.074	mg/L	2-TP-CT-072010-i-5	0.1	influent	6	7/20/2010
6	Phosphorus	0.053	mg/L	2-TP-CT-072110-eb-6	0.1	bypass effluent with leaking filtrate	30	7/21/2010
6	Phosphorus	0.49	mg/L	2-TP-CT-072110-e-6	0.1	effluent	30	7/21/2010
6	Phosphorus	0.085	mg/L	2-TP-CT-072110-i-6	0.1	influent	30	7/21/2010
7	Phosphorus	0.079	mg/L	2-TP-CT-072210-ib-7	0.1	bypass influent	18	7/22/2010
7	Phosphorus	0.48	mg/L	2-TP-CT-072210-e-7	0.1	effluent	18	7/22/2010
7	Phosphorus	0.072	mg/L	2-TP-CT-072210-i-7	0.1	influent	18	7/22/2010
8	Phosphorus	0.34	mg/L	2-TP-CT-072310-E-8-2	0.1	effluent	24	7/23/2010
8	Phosphorus	0.34	mg/L	2-TP-CT-072310-E-8	0.1	effluent	24	7/23/2010
8	Phosphorus	0.082	mg/L	2-TP-CT-072310-I-8-2	0.1	influent	24	7/23/2010
8	Phosphorus	0.091	mg/L	2-TP-CT-072310-I-8	0.1	influent	24	7/23/2010
9	Phosphorus	0.54	mg/L	2-TP-CT-072510-E-9	0.1	effluent	12	7/25/2010
9	Phosphorus	0.082	mg/L	2-TP-CT-072510-I-9	0.1	influent	12	7/25/2010
10	Phosphorus	0.43	mg/L	2-TP-CT-072610-E-10	0.1	effluent	6	7/26/2010
10	Phosphorus	0.082	mg/L	2-TP-CT-072610-I-10	0.1	influent	6	7/26/2010
12	Phosphorus	0.27	mg/L	2-TP-CT-072810-E-12	0.1	effluent	24	7/28/2010
12	Phosphorus	0.1	mg/L	2-TP-CT-072810-I-12	0.1	influent	24	7/28/2010
13	Phosphorus	0.32	mg/L	2-TP-CT-072910-E-13	0.1	effluent	18	7/29/2010
13	Phosphorus	0.094	mg/L	2-TP-CT-072910-I-13	0.1	influent	18	7/29/2010
14	Phosphorus	0.29	mg/L	2-TP-CT-073010-e-14	0.1	effluent	12	7/30/2010
14	Phosphorus	0.057	mg/L	2-TP-CT-073010-i-14	0.1	influent	12	7/30/2010
15	Phosphorus	0.26	mg/L	2-TP-CT-080110-e-15-2	0.1	effluent	30	8/1/2010
15	Phosphorus	0.28	mg/L	2-TP-CT-080110-e-15	0.1	effluent	6	8/1/2010
15	Phosphorus	0.043	mg/L	2-TP-CT-080110-i-15	0.1	influent	6	8/1/2010
0	SSC	0	mg/L	2-SSC-OWP-071510-e-0a		effluent	30	7/15/2010
0	SSC	0	mg/L	2-SSC-OWP-071510-e-0b		effluent	30	7/15/2010
0	SSC	2	mg/L	2-SSC-OWP-071510-e-0c		effluent	30	7/15/2010
1	SSC	2	mg/L	2-SSC-OWP-071510-i-1		effluent	30	7/15/2010
1	SSC	105	mg/L	2-SSC-OWP-071510-e-1		influent	30	7/15/2010
2	SSC	2	mg/L	2-SSC-OWP-071610-e-2		effluent	24	7/16/2010
2	SSC	98	mg/L	2-SSC-OWP-071610-i-2		influent	24	7/16/2010
3	SSC	2	mg/L	2-SSC-OWP-071810-e-3		effluent	18	7/18/2010
3	SSC	100	mg/L	2-SSC-OWP-071810-i-3		influent	18	7/18/2010
4	SSC	3	mg/L	2-SSC-OWP-071910-e-4		effluent	12	7/19/2010
4	SSC	83	mg/L	2-SSC-OWP-071910-i-4		influent	12	7/19/2010
5	SSC	3	mg/L	2-SSC-OWP-072010-e-5		effluent	6	7/20/2010
5	SSC	113	mg/L	2-SSC-OWP-072010-i-5		influent	6	7/20/2010
6	SSC	5	mg/L	2-SSC-OWP-072110-e-6		effluent	30	7/21/2010
6	SSC	102	mg/L	2-SSC-OWP-072110-i-6		influent	30	7/21/2010
7	SSC	6	mg/L	2-SSC-OWP-072210-e-7		effluent	18	7/22/2010
7	SSC	100	mg/L	2-SSC-OWP-072210-i-7		influent	18	7/22/2010
8	SSC	24	mg/L	2-SSC-OWP-072310-e-8		effluent	24	7/23/2010

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8	SSC	17	mg/L	2-SSC-OWP-072310-e-8-2	effluent	24	7/23/2010
8	SSC	108	mg/L	2-SSC-OWP-072310-i-8	influent	24	7/23/2010
8	SSC	106	mg/L	2-SSC-OWP-072310-i-8-2	influent	24	7/23/2010
9	SSC	3	mg/L	2-SSC-OWP-072510-e-9	effluent	12	7/25/2010
9	SSC	109	mg/L	2-SSC-OWP-072510-i-9	influent	12	7/25/2010
10	SSC	4	mg/L	2-SSC-OWP-072610-e-10	effluent	6	7/26/2010
10	SSC	110	mg/L	2-SSC-OWP-072610-i-10	influent	6	7/26/2010
11	SSC	34	mg/L	2-SSC-OWP-072710-e-11	effluent	30	7/27/2010
11	SSC	106	mg/L	2-SSC-OWP-072710-i-11	influent	30	7/27/2010
11	SSC	101	mg/L	2-SSC-OWP-072710-i-11-2	influent	30	7/27/2010
12	SSC	16	mg/L	2-SSC-OWP-072810-e-12	effluent	24	7/28/2010
12	SSC	108	mg/L	2-SSC-OWP-072810-i-12	influent	24	7/28/2010
13	SSC	2	mg/L	2-SSC-OWP-072910-e-13	effluent	18	7/29/2010
13	SSC	107	mg/L	2-SSC-OWP-072910-i-13	influent	18	7/29/2010
14	SSC	1	mg/L	2-SSC-OWP-073010-e-14	effluent	12	7/30/2010
14	SSC	107	mg/L	2-SSC-OWP-073010-i-14	influent	12	7/30/2010
15	SSC	2	mg/L	2-SSC-OWP-080110-e-15	effluent	6	8/1/2010
15	SSC	3	mg/L	2-SSC-OWP-080110-e-15-2	effluent	6	8/1/2010
15	SSC	106	mg/L	2-SSC-OWP-080110-i-15	influent	6	8/1/2010
0	TSS	0.00	mg/L	2-TSS-OWP-071510-e-0b	effluent	30	7/15/2010
0	TSS	-1.00	mg/L	2-TSS-OWP-071510-e-0c	effluent	30	7/15/2010
1	TSS	2	mg/L	2-TSS-OWP-071510-i-1	effluent	30	7/15/2010
1	TSS	119	mg/L	2-TSS-OWP-071510-e-1	influent	30	7/15/2010
2	TSS	3	mg/L	2-TSS-OWP-071610-e-2	effluent	24	7/16/2010
2	TSS	101	mg/L	2-TSS-OWP-071610-i-2	influent	24	7/16/2010
3	TSS	-1	mg/L	2-TSS-OWP-071810-e-3	effluent	18	7/18/2010
3	TSS	134	mg/L	2-TSS-OWP-071810-i-3	influent	18	7/18/2010
4	TSS	-6	mg/L	2-TSS-OWP-071910-e-4	effluent	12	7/19/2010
4	TSS	76	mg/L	2-TSS-OWP-071910-i-4	influent	12	7/19/2010
5	TSS	3	mg/L	2-TSS-OWP-072010-e-5	effluent	6	7/20/2010
5	TSS	111	mg/L	2-TSS-OWP-072010-i-5	influent	6	7/20/2010
6	TSS	7		2-TSS-OWP-072110-e-6	effluent	30	7/21/2010
6	TSS	96		2-TSS-OWP-072110-i-6	influent	30	7/21/2010
7	TSS	8		2-TSS-OWP-072210-e-7	effluent	18	7/22/2010
7	TSS	104		2-TSS-OWP-072210-i-7	influent	18	7/22/2010
8	TSS	17		2-TSS-OWP-072310-e-8	effluent	24	7/23/2010
8	TSS	15		2-TSS-OWP-072310-e-8-2	effluent	24	7/23/2010
8	TSS	105		2-TSS-OWP-072310-i-8	influent	24	7/23/2010
8	TSS	101		2-TSS-OWP-072310-i-8-2	influent	24	7/23/2010
9	TSS	5		2-TSS-OWP-072510-e-9	effluent	12	7/25/2010
9	TSS	101		2-TSS-OWP-072510-i-9	influent	12	7/25/2010
10	TSS	6		2-TSS-OWP-072610-e-10	effluent	6	7/26/2010
10	TSS	115		2-TSS-OWP-072610-i-10	influent	6	7/26/2010

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11	TSS	31		2-TSS-OWP-072710-e-11	effluent	30	7/27/2010
11	TSS	88		2-TSS-OWP-072710-i-11	influent	30	7/27/2010
11	TSS	87		2-TSS-OWP-072710-i-11-2	influent	30	7/27/2010
12	TSS	13		2-TSS-OWP-072810-e-12	effluent	24	7/28/2010
12	TSS	107		2-TSS-OWP-072810-i-12	influent	24	7/28/2010
13	TSS	5		2-TSS-OWP-072910-e-13	effluent	18	7/29/2010
13	TSS	106		2-TSS-OWP-072910-i-13	influent	18	7/29/2010
14	TSS	1		2-TSS-OWP-073010-e-14	effluent	12	7/30/2010
14	TSS	112		2-TSS-OWP-072710-i-14	influent	12	7/30/2010
15	TSS	9		2-TSS-OWP-080110-e-15	effluent	6	8/1/2010
15	TSS	1		2-TSS-OWP-080110-e-15-2	effluent	6	8/1/2010
15	TSS	105		2-TSS-OWP-080110-i-15	influent	6	8/1/2010
0	Turbidity	6.38	NTU	2-TSS-OWP-071510-i-0a	effluent	30	7/15/2010
0	Turbidity	2.36	NTU	2-TSS-OWP-071510-e-0b	effluent	30	7/15/2010
0	Turbidity	1.9	NTU	2-TSS-OWP-071510-e-0c	effluent	30	7/15/2010
1	Turbidity	4.89	NTU	2-TSS-OWP-071510-i-1	effluent	30	
1	Turbidity	29.5	NTU	2-TSS-OWP-071510-e-1	influent	30	
2	Turbidity	2.85	NTU	2-TSS-OWP-071610-e-2	effluent	24	
2	Turbidity	30	NTU	2-TSS-OWP-071610-i-2	influent	24	
3	Turbidity	3.9	NTU	2-TSS-OWP-071810-e-3	effluent	18	
3	Turbidity	32.5	NTU	2-TSS-OWP-071810-i-3	influent	18	
4	Turbidity	2.75	NTU	2-TSS-OWP-071910-e-4	effluent	12	
4	Turbidity	31.71	NTU	2-TSS-OWP-071910-i-4	influent	12	
5	Turbidity	3.25	NTU	2-TSS-OWP-072010-e-5	effluent	6	
5	Turbidity	32.5	NTU	2-TSS-OWP-072010-i-5	influent	6	
6	Turbidity	5.8	NTU	2-TSS-OWP-072110-e-6	effluent	30	
6	Turbidity	24.4	NTU	2-TSS-OWP-072110-i-6	influent	30	
7	Turbidity	4.36	NTU	2-TSS-OWP-072210-e-7	effluent	18	
7	Turbidity	26	NTU	2-TSS-OWP-072210-i-7	influent	18	
8	Turbidity	7.8	NTU	2-TSS-OWP-072310-e-8	effluent	24	
8	Turbidity	24.7	NTU	2-TSS-OWP-072310-i-8	influent	24	
9	Turbidity	3.37	NTU	2-TSS-OWP-072510-e-9	effluent	12	
9	Turbidity	21.6	NTU	2-TSS-OWP-072510-i-9	influent	12	
10	Turbidity	2.67	NTU	2-TSS-OWP-072610-e-10	effluent	6	
10	Turbidity	27.4	NTU	2-TSS-OWP-072610-i-10	influent	6	
11	Turbidity	11.4	NTU	2-TSS-OWP-072710-e-11	effluent	30	
11	Turbidity	33	NTU	2-TSS-OWP-072710-i-11	influent	30	
11	Turbidity	33.2	NTU	2-TSS-OWP-072710-i-11-2	influent	30	
12	Turbidity	8.22	NTU	2-TSS-OWP-072810-e-12	effluent	24	
12	Turbidity	27.5	NTU	2-TSS-OWP-072810-i-12	influent	24	
13	Turbidity	3.63	NTU	2-TSS-OWP-072910-e-13	effluent	18	
13	Turbidity	28.3	NTU	2-TSS-OWP-072910-i-13	influent	18	
14	Turbidity	2.83	NTU	2-TSS-OWP-073010-e-14	effluent	12	

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14	Turbidity	27.4	NTU	2-TSS-OWP-073010-i-14		influent	12	
15	Turbidity	3.83	NTU	2-TSS-OWP-080110-e-15		effluent	6	
15	Turbidity	3.58	NTU	2-TSS-OWP-080110-e-15-2		effluent	6	
15	Turbidity	28.5	NTU	2-TSS-OWP-080110-e-15		influent	6	
0	Zinc	3.6	ug/L	2-TCUPBZN-CT-OUTSIDE OFFICE-0	10	effluent	30	7/15/2010
1	Zinc	3.1	ug/L	2-TCUPBZN-CT-071510-i-I	10	effluent	30	7/15/2010
1	Zinc	17	ug/L	2-TCUPBZN-CT-071510-e-I	10	influent	30	7/15/2010
2	Zinc	2.1	ug/L	2-TCUPBZN-CT-071610-e-2	10	effluent	24	7/16/2010
2	Zinc	16	ug/L	2-TCUPBZN-CT-071610-i-2	10	influent	24	7/16/2010
3	Zinc	8	ug/L	2-TCUPBZN-071810-e-3	10	effluent	18	7/18/2010
3	Zinc	19	ug/L	2-TCUPBZN-071810-i-3	10	influent	18	7/18/2010
4	Zinc	4.5	ug/L	2-TCUPBZN-071910-e-4	10	effluent	12	7/19/2010
4	Zinc	18	ug/L	2-TCUPBZN-071910-i-4	10	influent	12	7/19/2010
5	Zinc	5.1	ug/L	2-TCUPBZN-072010-e-5	10	effluent	6	7/20/2010
5	Zinc	19	ug/L	2-TCUPBZN-072010-i-5	10	influent	6	7/20/2010
6	Zinc	14	ug/L	2-TPCUPBZN-072110-eb-6	10	bypass effluent with leaking filtrate	30	7/21/2010
6	Zinc	3.6	ug/L	2-TPCUPBZN-072110-e-6	10	effluent	30	7/21/2010
6	Zinc	16	ug/L	2-TPCUPBZN-072110-i-6	10	influent	30	7/21/2010
7	Zinc	14	ug/L	2-TPCUPBZN-CT-072210-ib-7	10	bypass influent	18	7/22/2010
7	Zinc	3.5	ug/L	2-TPCUPBZN-CT-072210-e-7	10	effluent	18	7/22/2010
7	Zinc	15	ug/L	2-TPCUPBZN-CT-072210-i-7	10	influent	18	7/22/2010
8	Zinc	5.8	ug/L	2-TCUPBZN-CT-072310-E-8-2	10	effluent	24	7/23/2010
8	Zinc	6.5	ug/L	2-TCUPBZN-CT-072310-E-8	10	effluent	24	7/23/2010
8	Zinc	15	ug/L	2-TCUPBZN-CT-072310-I-8-2	10	influent	24	7/23/2010
8	Zinc	15	ug/L	2-TCUPBZN-CT-072310-I-8	10	influent	24	7/23/2010
9	Zinc	3.6	ug/L	2-TCUPBZN-CT-072510-E-9	10	effluent	12	7/25/2010
9	Zinc	17	ug/L	2-TCUPBZN-CT-072510-I-9	10	influent	12	7/25/2010
10	Zinc	4.5	ug/L	2-TCUPBZN-CT-072610-E-10	10	effluent	6	7/26/2010
10	Zinc	17	ug/L	2-TCUPBZN-CT-072610-I-10	10	influent	6	7/26/2010
11	Zinc	8.2	ug/L	2-TCUPBZN-CT-082710-e-11	10	effluent	30	7/27/2010
11	Zinc	17	ug/L	2-TCUPBZN-CT-072710-i-11-2	10	influent	30	7/27/2010
11	Zinc	17	ug/L	2-TCUPBZN-CT-072710-i-11	10	influent	30	7/27/2010
12	Zinc	5.4	ug/L	2-TCUPBZN-CT-072810-E-12	10	effluent	24	7/28/2010
12	Zinc	16	ug/L	2-TCUPBZN-CT-072810-I-12	10	influent	24	7/28/2010
13	Zinc	2.6	ug/L	2-TCUPBZN-CT-072910-E-13	10	effluent	18	7/29/2010
13	Zinc	16	ug/L	2-TCUPBZN-CT-072910-I-13	10	influent	18	7/29/2010
14	Zinc	2.8	ug/L	2-TCuPbZn-CT-073010-e-14	10	effluent	12	7/30/2010
14	Zinc	14	ug/L	2-TCuPbZn-CT-073010-i-14	10	influent	12	7/30/2010
15	Zinc	6	ug/L	2-TCuPBZn-CT-0801108-e-15-2	10	effluent	6	8/1/2010
15	Zinc	3.8	ug/L	2-TCuPBZn-CT-0801108-e-15	10	effluent	6	8/1/2010
15	Zinc	21	ug/L	2-TCuPBZn-CT-0801108-i-15	10	influent	6	8/1/2010

Treatment Calculations

Treatment Calculations

For the following treatment calculations, the effluent values for runs 8, 11, 12, and 13 were from samples of commingled filtrate and bypass. Consequently, the values in the "Device Effluent Concentration" column are equal to those effluent measurements. For other runs where bypass occurred, the values were calculated according to the Equation 1 in Section 4.2.

Overtopping Coefficient (bypass concentration/influent concentration)						
0.5						
Run	Influent	Effluent	Flow Rate gpm	Time to Bypass	Device Effluent Concentration	Percent Reduction
1	105.00	2.00	30	No Bypass	2	98%
2	97.80	1.80	24	75	11.6125	88%
3	100.00	1.67	18	120	3.821478	96%
4	83.19	2.78	12	No Bypass	2.777778	97%
5	112.92	2.64	6	No Bypass	2.642405	98%
6	102.40	4.60	30	10	27.79644	73%
7	99.80	5.60	18	75	10.52222	89%
8	107.11	20.37	24	30	20.36582	81%
9	109.03	2.60	12	No Bypass	2.597403	98%
10	110.00	4.33	6	No Bypass	4.329004	96%
11	103.39	33.90	30	10	33.90192	67%
12	107.91	16.03	24	30	16.02597	85%
13	106.82	1.84	18	15	1.84196	98%
14	106.88	1.27	12	No Bypass	1.268767	99%
15	105.58	2.58	6	No Bypass	2.576591	98%

SSC

Treatment Calculations

Overtopping Coefficient (bypass concentration/influent concentration)						
0.5						
Run	Influent	Effluent	Flow Rate gpm	Time to Bypass	Device Effluent Concentration	Percent Reduction
1	119	2	30	No Bypass	2	98%
2	101	3	24	75	12.89583	87%
3	134	1	18	120	3.933333	97%
4	76	1	12	No Bypass	1	99%
5	111	3	6	No Bypass	3	97%
6	96	7	30	10	27.40889	71%
7	104	8	18	75	12.88889	88%
8	103	16	24	30	16	84%
9	101	5	12	No Bypass	5	95%
10	115	6	6	No Bypass	6	95%
11	87.5	31	30	10	31	65%
12	107	13	24	30	13	88%
13	106	5	18	15	5	95%
14	112	1	12	No Bypass	1	99%
15	105	5	6	No Bypass	5	95%

TSS

Overtopping Coefficient (bypass concentration/influent concentration)						
0.6						
Run	Influent	Effluent	Flow Rate gpm	Time to Bypass	Device Effluent Concentration	Percent Reduction
1	29.5	4.89	30	No Bypass	4.89	83%
2	30	2.85	24	75	6.00625	80%
3	32.5	3.9	18	120	4.593333333	86%
4	31.71	2.75	12	No Bypass	2.75	91%
5	32.5	3.25	6	No Bypass	3.25	90%
6	24.4	5.8	30	10	10.20035556	58%
7	26	4.36	18	75	5.608888889	78%
8	24.7	7.8	24	30	7.8	68%
9	21.6	3.37	12	No Bypass	3.37	84%
10	27.4	2.67	6	No Bypass	2.67	90%
11	33.1	11.4	30	10	11.4	66%
12	27.5	8.22	24	30	8.22	70%
13	28.3	3.63	18	15	3.63	87%
14	27.4	2.83	12	No Bypass	2.83	90%
15	28.5	3.705	6	No Bypass	3.705	87%

Turbidity

Treatment Calculations

Overtopping Coefficient (bypass concentration/influent concentration)						
0.98						
Run	Influent	Effluent	Flow Rate gpm	Time to Bypass	Device Effluent Concentration	Percent Reduction
1	9.2	2.6	30	No Bypass	2.6	72%
2	7.7	2	24	75	3.2	59%
3	11	4.3	18	120	4.6	58%
4	10	3.5	12	No Bypass	3.5	65%
5	11	3.6	6	No Bypass	3.6	67%
6	11	3.5	30	10	7.1	35%
7	9.4	2.8	18	75	3.5	63%
8	8.15	4.2	24	30	4.2	48%
9	9.3	3.1	12	No Bypass	3.1	67%
10	9.8	3.3	6	No Bypass	3.3	66%
11	8.9	5.2	30	10	5.2	42%
12	7.7	3.6	24	30	3.6	53%
13	8.7	2	18	15	2	77%
14	8	2.2	12	No Bypass	2.2	73%
15	11	4.4	6	No Bypass	4.4	60%

Copper

Overtopping Coefficient (bypass concentration/influent concentration)						
0.8						
Run	Influent	Effluent	Flow Rate gpm	Time to Bypass	Device Effluent Concentration	Percent Reduction
1	2.6	0.21	30	No Bypass	0.21	92%
2	2.2	0.12	24	75	0.461666667	79%
3	2.9	0.25	18	120	0.342	88%
4	2.7	0.17	12	No Bypass	0.17	94%
5	2.7	0.16	6	No Bypass	0.16	94%
6	2.5	0.32	30	10	1.156266667	54%
7	2.2	0.3	18	75	0.462222222	79%
8	2.15	0.705	24	30	0.705	67%
9	2.3	0.17	12	No Bypass	0.17	93%
10	2.3	0.18	6	No Bypass	0.18	92%
11	2.7	1.1	30	10	1.1	59%
12	2.3	1.1	24	30	1.1	52%
13	2.2	0.59	18	15	0.59	73%
14	2.1	0.17	12	No Bypass	0.17	92%
15	3	0.16	6	No Bypass	0.16	95%

Lead

Treatment Calculations

Overtopping Coefficient (bypass concentration/influent concentration)						
0.93						
Run	Influent	Effluent	Flow Rate gpm	Time to Bypass	Device Effluent Concentration	Percent Reduction
1	17	3.1	30	No Bypass	3.1	82%
2	16	2.1	24	75	4.7625	70%
3	19	8	18	120	8.429777778	56%
4	18	4.5	12	No Bypass	4.5	75%
5	19	5.1	6	No Bypass	5.1	73%
6	16	3.6	30	10	9.214933333	42%
7	15	3.5	18	75	4.661111111	69%
8	15	6.15	24	30	6.15	59%
9	17	3.6	12	No Bypass	3.6	79%
10	17	4.5	6	No Bypass	4.5	74%
11	17	8.2	30	10	8.2	52%
12	16	8.2	24	30	8.2	49%
13	16	5.4	18	15	5.4	66%
14	14	2.6	12	No Bypass	2.6	81%
15	21	4.4	6	No Bypass	4.4	79%

Zinc

Overtopping Coefficient (bypass concentration/influent concentration)						
1.0						
Run	Influent	Effluent	Flow Rate gpm	Time to Bypass	Device Effluent Concentration	Percent Reduction
1	0.082	0.62	30	No Bypass	0.62	-656%
2	0.072	0.56	24	75	0.458333333	-537%
3	0.092	0.78	18	120	0.749422222	-715%
4	0.075	0.85	12	No Bypass	0.85	-1033%
5	0.074	1.1	6	No Bypass	1.1	-1386%
6	0.085	0.49	30	10	0.2884	-239%
7	0.072	0.48	18	75	0.434666667	-504%
8	0.0865	0.34	24	30	0.34	-293%
9	0.082	0.54	12	No Bypass	0.54	-559%
10	0.082	0.43	6	No Bypass	0.43	-424%
11			30	10		
12	0.1	0.27	24	30	0.27	-170%
13	0.094	0.32	18	15	0.32	-240%
14	0.057	0.29	12	No Bypass	0.29	-409%
15	0.043	0.27	6	No Bypass	0.27	-528%

Phosphorus

QA/QC

Quality Assurance/Quality Control Analysis (QA/QC)

Duplicates were taken for runs 8 (24 gpm), 11 (30 gpm), and 15 (6 gpm). Duplicate influent and effluent samples were taken for run 8. Only duplicate influent samples were taken for run 11 and only duplicate effluent samples were taken for run 15. The selection between influent and effluent was random.

The relative percent differences are shown in the Table B-1. The duplicate samples were not split, but rather the collection of two completely independent samples that each comprises a separate set of 10 aliquots. The aliquots of the duplicates were offset from the primary sample by approximately 1 to 2 minutes. This means that greater variability should be expected between primary and duplicate samples. It also means that the average of the duplicate and primary sample represents the concentration of a single 20-aliquot sample.

The traditional standard for relative percent difference (RPD) for split samples is 20 percent. This standard is applied to these non-split, quasi-duplicates. For influent samples all RPD were less than 20 percent. For effluent samples, Cu, TSS, SSC, and Zn were greater than 20 percent. This is explainable due to the collection method of the duplicate as previously discussed. Values closer to the reporting limit are also more likely to violate RPD standards because of the potentially true but small differences between the primary and duplicate samples. Unfortunately, the duplicate collection method obscures error that may have been due to sample transport and analysis. For analysis error for metals and phosphorus, the laboratory QA/QC reports in Appendix C should be consulted.

QA/QC

Table B-1 Relative Percent Difference for Duplicates

Run	Flow Rate, gpm	Sample Description	Constituent	Sample Location	Concentration		Relative % Difference
8	24	2-TCUPBZN-CT-072310-E-8-2	Copper	effluent	3.9	ug/L	14.3%
8	24	2-TCUPBZN-CT-072310-E-8	Copper	effluent	4.5	ug/L	
8	24	2-TCUPBZN-CT-072310-I-8-2	Copper	influent	8.2	ug/L	1.2%
8	24	2-TCUPBZN-CT-072310-I-8	Copper	influent	8.1	ug/L	
11	30	2-TCUPBZN-CT-072710-i-11-2	Copper	influent	8.7	ug/L	4.5%
11	30	2-TCUPBZN-CT-072710-i-11	Copper	influent	9.1	ug/L	
15	6	2-TCuPBZn-CT-0801108-e-15-2	Copper	effluent	4.4	ug/L	41.1%
15	6	2-TCuPBZn-CT-0801108-e-15	Copper	effluent	2.9	ug/L	
8	24	2-TCUPBZN-CT-072310-E-8	Lead	effluent	0.7	ug/L	1.4%
8	24	2-TCUPBZN-CT-072310-E-8-2	Lead	effluent	0.71	ug/L	
8	24	2-TCUPBZN-CT-072310-I-8	Lead	influent	2.1	ug/L	4.7%
8	24	2-TCUPBZN-CT-072310-I-8-2	Lead	influent	2.2	ug/L	
11	30	2-TCUPBZN-CT-072710-i-11-2	Lead	influent	2.8	ug/L	7.4%
11	30	2-TCUPBZN-CT-072710-i-11	Lead	influent	2.6	ug/L	
15	6	2-TCuPBZn-CT-0801108-e-15-2	Lead	effluent	0.19	ug/L	17.1%
15	6	2-TCuPBZn-CT-0801108-e-15	Lead	effluent	0.16	ug/L	
8	24	2-TP-CT-072310-E-8-2	Phosphorus	effluent	0.34	mg/L	0.0%
8	24	2-TP-CT-072310-E-8	Phosphorus	effluent	0.34	mg/L	
8	24	2-TP-CT-072310-I-8-2	Phosphorus	influent	0.082	mg/L	10.4%
8	24	2-TP-CT-072310-I-8	Phosphorus	influent	0.091	mg/L	
15	6	2-TP-CT-080110-e-15-2	Phosphorus	effluent	0.26	mg/L	7.4%
15	6	2-TP-CT-080110-e-15	Phosphorus	effluent	0.28	mg/L	
8	24	2-SSC-OWP-072310-e-8	SSC	effluent	23.68	mg/L	32.5%
8	24	2-SSC-OWP-072310-e-8-2	SSC	effluent	17.06	mg/L	
8	24	2-SSC-OWP-072310-i-8	SSC	influent	108.21	mg/L	2.1%
8	24	2-SSC-OWP-072310-i-8-2	SSC	influent	106.01	mg/L	
11	30	2-SSC-OWP-072710-i-11	SSC	influent	105.71	mg/L	4.5%
11	30	2-SSC-OWP-072710-i-11-2	SSC	influent	101.08	mg/L	
15	6	2-SSC-OWP-080110-e-15	SSC	effluent	2.11	mg/L	36.2%
15	6	2-SSC-OWP-080110-e-15-2	SSC	effluent	3.04	mg/L	
8	24	2-TSS-OWP-072310-e-8	TSS	effluent	17	mg/L	12.5%

QA/QC

8	24	2-TSS-OWP-072310-e-8-2	TSS	effluent	15	mg/L	
8	24	2-TSS-OWP-072310-i-8	TSS	influent	105	mg/L	3.9%
8	24	2-TSS-OWP-072310-i-8-2	TSS	influent	101	mg/L	
11	30	2-TSS-OWP-072710-i-11	TSS	influent	88	mg/L	1.1%
11	30	2-TSS-OWP-072710-i-11-2	TSS	influent	87	mg/L	
15	6	2-TSS-OWP-080110-e-15	TSS	effluent	9	mg/L	160.0%
15	6	2-TSS-OWP-080110-e-15-2	TSS	effluent	1	mg/L	
8	24	2-TSS-OWP-072310-e-8	Turbidity	effluent	7.8	NTU	8.2%
8	24	2-TSS-OWP-072310-e-8-2	Turbidity	effluent	8.47	NTU	
8	24	2-TSS-OWP-072310-i-8	Turbidity	influent	24.7	NTU	10.4%
8	24	2-TSS-OWP-072310-i-8-2	Turbidity	influent	27.4	NTU	
11	30	2-TSS-OWP-072710-i-11	Turbidity	influent	33	NTU	0.6%
11	30	2-TSS-OWP-072710-i-11-2	Turbidity	influent	33.2	NTU	
15	6	2-TSS-OWP-080110-e-15	Turbidity	effluent	3.83	NTU	6.7%
15	6	2-TSS-OWP-080110-e-15-2	Turbidity	effluent	3.58	NTU	
8	24	2-TCUPBZN-CT-072310-E-8-2	Zinc	effluent	5.8	ug/L	11.4%
8	24	2-TCUPBZN-CT-072310-E-8	Zinc	effluent	6.5	ug/L	
8	24	2-TCUPBZN-CT-072310-I-8-2	Zinc	influent	15	ug/L	0.0%
8	24	2-TCUPBZN-CT-072310-I-8	Zinc	influent	15	ug/L	
11	30	2-TCUPBZN-CT-072710-i-11-2	Zinc	influent	17	ug/L	0.0%
11	30	2-TCUPBZN-CT-072710-i-11	Zinc	influent	17	ug/L	
15	6	2-TCuPBZn-CT-0801108-e-15-2	Zinc	effluent	6	ug/L	44.9%
15	6	2-TCuPBZn-CT-0801108-e-15	Zinc	effluent	3.8	ug/L	

APPENDIX C: Laboratory Reports and Excel Spreadsheets (available on CD)