

NITRATE AND PHOSPHATE REMOVAL THROUGH
AN OPTIMIZED BIORTENTION SYSTEM

By

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NITRATE AND PHOSPHATE REMOVAL THROUGH
AN OPTIMIZED BIORTENTION SYSTEM:

EARLY RESULTS

Abstract

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Bioretention is an evolving type of Green Stormwater Infrastructure (GSI) now being utilized as a method to clean stormwater runoff and mitigate degradation that has been seen in many aquatic environments. Further regulations enacted by the National Pollution Discharge Elimination System (NPDES) will soon require phase I and phase II communities to reduce stormwater to the maximum extent possible. This imposes an immediate need for further analysis and optimization of bioretention systems to more effectively reduce stormwater pollutants. This thesis examines the capabilities of an optimized bioretention soil mixture to effectively reduce both nutrients and heavy metals from stormwater runoff. Emerging bioretention design features in the forms of saturation, vegetation, and aluminum based water treatment residuals were utilized to further examine their role to reduce two of the most significant nutrient species in nitrate and ortho-phosphate. Experiments were conducted using 12 large mesocosms constructed following standard bioretention design in Western Washington. Results show that utilization of a saturation zone and aluminum based water treatment residuals can significantly reduce nitrate and ortho-phosphate, even in a newly constructed system. Nitrate removal was shown at levels up to 71 percent for the mesocosms with a saturation zone and ortho-phosphate removal was shown at levels up to 80 percent for the mesocosms without a

saturation zone. Early establishment of plants did not significantly improve removal thus showing the need for aluminum based water treatment residuals and a saturation zone during the initial establishment period. Results also show an export of total phosphorus and total nitrogen from the compost amended bioretention soil mixture utilized. While export appears to decrease with an increase in hydraulic loading, this may pose concerns for bioretention systems which utilize an under-drain. Significant removal was also achieved for both zinc and lead, while an export in copper and aluminum was shown.

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CHAPTER 1

INTRODUCTION

Green Stormwater Infrastructure (GSI), also referred to as Low Impact Development (LID), is a sustainable stormwater management method based on the concept of maintaining the natural hydrologic regime of a developed site by managing stormwater as close to the source possible. Utilization of this strategy has been sought to counter-act the ongoing degradation of many aquatic environment seen by urbanization. This degradation has been so severe that the recently developed National Pollution Discharge Elimination System (NPDES) was established by the United States to better regulate non-point source pollutants such as those seen in stormwater runoff. With the early results of GSI utilization, and the need to reduce stormwater pollutants to the maximum extent possible, the NPDES will soon require GSI use in phase I and phase II communities within the next few years.

Some of the most common types of Green Stormwater Infrastructure include pervious concrete, vegetated roof systems, and bioretention. Bioretention is a type of surface drainage design method characterized by a shallow depression in the earth into which stormwater runoff is directed. This depression is typically filled with an engineered media designed to establish flow control via infiltration and/or remove pollutants via filtration through the media. These two design objectives are often shown to be inter-related. While flow control was the initial design objective of bioretention, implementation of the NPDES has put an increased focus on the pollutant removal capabilities of these systems. Initial information of these capabilities is very scarce in places and as such there is a large need for data to promote proper design of bioretention from region to region.

This thesis examines a significant bioretention pilot research study conducted at the Washington State University Puyallup Research and Extension Center. The project examined the performance of emerging bioretention design features, such as vegetation and saturation, when implemented with an optimized bioretention soil mixture. This mixture of sand, compost, shredded cedar bark, and water treatment residuals (WTRs) was formulated to enhance pollutant removal. The main two stormwater constituents of concern evaluated in this thesis include nutrients and heavy metals.

Experiments were conducted in 12 large mesocosms utilized for the inclusion of vegetation in the system. Mesocosms were placed in a greenhouse for the 4 week duration of this experiment. Street and parking lot stormwater runoff from the Washington State University Puyallup campus was spiked with laboratory-grade chemicals and run through each mesocosm in a simulated 6 month, 24 hour storm for Tacoma, WA. A total of 4 storm events were evaluated in this study. Results are representative of an early establishment period. A planned follow-up study will evaluate performance after significant establishment has been achieved.

The primary two chapters of this thesis discuss removal of nutrients (Chapter 2) and heavy metals (Chapter 3) from the bioretention systems utilized in this study. While heavy metal removal is included, the major emphasis of this work was directed toward nutrient removal of both nitrate and ortho-phosphate. A detailed introduction and experimental methods section can be found in the nutrient chapter. A majority of the results and discussion section in this chapter is centered on nitrate and ortho-phosphate removal. However, additional topics of interest include suspended sediment, infiltration rates, and competing removal mechanisms. Sections on the implications for early establishment and implications for design are both used to further expand the findings of this research.

Chapter 3 of this thesis discusses removal of heavy metals including zinc, lead, and copper. The introduction and experimental methods sections in this chapter give additional information specific to heavy metals. Similar sections found within the nutrients chapter should be referenced for more detailed information. Although not typical of most stormwater research, aluminum was also analyzed as it is the primary constituent in the water treatment residuals found within the bioretention soil mixture. As with the nutrient chapter, sections on implications for early establishment and implications for design are formulated to further expand the findings of this research as it pertains to heavy metals.

CHAPTER 2

NITRATE AND ORTHO-PHOSPHATE REMOVAL

INTRODUCTION

Stormwater runoff is now considered to be the leading source of degradation in many aquatic environments (US Environmental Protection Agency, 2000). As stormwater runs over developed land it picks up critical pollutants in the form of oils, heavy metals, nutrients and pesticides. These pollutants are then delivered from developed land, through stormwater drainage systems, and into aquatic environments. Pollutant concentrations found within stormwater runoff often exceed levels that are considered both chronic and acutely toxic to aquatic biota.

Excess nutrients, in the form of nitrogen and phosphorus, are a concern in stormwater runoff because of their role in the eutrophication, and ultimate degradation, of both fresh and marine bodies of water. The economic cost of eutrophication on freshwater bodies alone within the United States is estimated to exceed \$2.2 billion dollars a year (Dodds et al., 2009). This assessment is based upon decreased waterfront property values, recreation losses, habitat recovery, and drinking water treatment. Common sources of nutrients found within stormwater runoff include fertilizers, animal waste, and household detergents and soaps.

Green Stormwater Infrastructure (GSI), also referred to as Low Impact Development (LID), is a method recently developed to mitigate the effects of stormwater runoff on aquatic environments. The strategy of implementing this green infrastructure is based on the concept of maintaining the natural hydrologic regime of a developed site by managing stormwater as close to the source possible. Early studies on the utilization of such infrastructure have shown such promising results that the federally mandated National Pollution Discharge Elimination System

(NPDES) has allowed for its use, and is now requiring communities to take steps for preparation of GSI requirements in future permits.

One of the most common types of Green Stormwater Infrastructure is bioretention.

Bioretention is a type of surface drainage design method characterized by a shallow depression in the earth in which stormwater runoff is directed too. Standard design of bioretention includes a mineral aggregate drainage layer on which a bioretention soil mix (BSM) is placed (Hinman, 2005, 2009). Additional components include a thin mulch covering, vegetation, and stormwater ponding zone. The main two design objectives that are looked at when implementing bioretention, similar to most all Green Stormwater Infrastructure, are to establish flow control and/or remove pollutants from stormwater runoff.

Bioretention soil compositions are very inconsistent between jurisdictions. Often, native soils with high permeability such as sandy loam, loamy sand, or loam, are specified. However, depletion of native soil vigor by urbanization has pushed many jurisdictions towards utilization of engineered soil blends (Davis et al., 2009). Typically, mixtures of mineral aggregate sand and organic matter are specified. These are thought to be an acceptable alternative to native soils for their improved soil infiltration/retention and enhanced pollutant removal capabilities (Pitt et al., 1999). Wide ranges of organic matter such as compost, peat moss, and wood mulch have been specified at rates anywhere from 5 to 40 percent by volume (Davis et al., 2009; Hinman, 2009).

Bioretention design specifications are also highly variable between regions.

Environmental and regulatory compliance differences do not make specifications suitable from place to place. Rainfall patterns and climate diversity between regions pose variability in acceptable design storms, sizing requirements, and vegetation that may be utilized. Bioretention soil mixtures are often regulated on material properties such as sand gradation, cation exchange

capacity, percent fines, percent organic matter, and infiltration rate (Hinman, 2009).

Regulations/guidelines are often adopted by jurisdictions without regionally available performance data and appropriate alterations (Davis et al., 2009).

Even with highly variable soil compositions and design specifications, a large sum of research on bioretention has shown good removal of suspended solids, heavy metals, and hydrocarbons (Davis et al., 2001, 2007; Hsieh and Davis, 2005 a, b). Removal mechanisms associated with these pollutants, including sedimentation, filtration, and adsorption, appear to be less susceptible to the variable soil composition and design specifications that are seen in bioretention. On the other hand, removal of nutrients has been highly variable with results ranging from substantial removal, 50 to 99%, (Davis et al., 2006; Henderson et al., 2007; Lucas and Greenway, 2008; Bratieres et al., 2008; Passeport et al., 2009) to limited removal and considerable export, 32 to -240% (Hatt et. al., 2008; Chapman and Horner, 2010; Dietz and Clausen, 2005; Hunt et al., 2006, 2008). The complexity in chemistry associated with the removal mechanisms of nutrients, including sorption, microbial conversation, and vegetation uptake, appear to be highly susceptible to changes in soil composition and design specifications (Davis et al., 2009). For instance, initial plant and bio-available phosphorus found within a bioretention soil mixture's may indicate how effective the system will be for reducing phosphorus in stormwater runoff (Hunt et al., 2006). These results further emphasize the importance of regional bioretention performance analysis.

Two primary nutrient species of concern include both nitrate and ortho-phosphate. These highly mobile forms of nitrogen and phosphorous are readily available for immediate uptake by plants and algae (Cotner and Wetzel, 1992; Lucas and Greenway, 2011b). Studies have shown that nitrate and phosphate removal can be variable or poor unless specific design features, such

as increased depth of bioretention soil mix or an elevated under-drain, are incorporated (Davis et al., 2001, 2006; Hong, 2002; Hunt et al., 2006; Kim et al., 2003; Dietz and Clausen, 2006).

Increased phosphorous and nitrogen removal has been shown when increasing the bioretention soil mixture depth to 24 inches (Davis et al., 2001). This allows for a longer residence time and improved removal. Elevating the under-drain allows for creation of a saturation zone in which anoxic conditions are established. This, along with an acceptable carbon source, has shown substantial removal of nitrate by denitrification in which microbial conversion of nitrate to nitrogen gas occurs (Kim et al., 2003; Zinger et al., 2007). No data is currently available on the performance of a saturation zone when implemented in a system with a compost amended bioretention soil mix.

Plants have also been looked to as a design feature to better manage nitrate and phosphate in bioretention. While vegetation was originally included in bioretention for its aesthetic appeal, many studies have shown that nitrate is often exported from systems that do not incorporate plants (Davis et al., 2006; Henderson et al., 2007; Bratieres et al., 2008; Lucas and Greenway, 2008). The primary factor was lack of uptake by vegetation between storm events. Research also indicates the importance of selecting appropriate plants for nutrient uptake as some species are not shown to be effective (Davis et al., 2006; Bratieres et al., 2008; Read et al., 2008). Additional research is needed on the role of plants that may better manage nitrate and phosphate (Hinman, 2009).

Several different amendments formulated for phosphate sorption and/or precipitation have been tested in applications such as wastewater and wetland treatments. However, very few of these have been evaluated as design features in bioretention. Some amendments that have been looked at for phosphate removal in bioretention include various industrial and municipal

byproducts such as municipal water treatment residuals (WTRs), fly ash, red gypsum, and blast furnace slag (Zhang et al., 2008; Lucus and Greenway, 2011; Ericksen et al., 2007). These soil amendments are thought to be ideal as they are essentially reusable resources often free for the taking. Municipal water treatment residuals are the most widely available amendment out of this group and the only one to be tested in a system including vegetation (Lucus and Greenway, 2011). While results of Lucus and Greenways study showed a 92% removal of phosphate in effluent concentrations, no data is currently available on the performance of WTRs in a bioretention soil containing compost. This clay-like substance is typically calcium (Ca), iron (Fe), or aluminum (Al) based, and removes phosphorous through chemical sorption (Babatunde et al., 2008). Utilization of an aluminum based water treatment residual is thought to be ideal because adsorbed phosphate is less susceptible to desorption during anoxic conditions (Zvomuya et al., 2006; Dietz and Clausen, 2006). This would presumably allow for enhanced removal of both nitrate and phosphate when a saturation zone exists, although no data is currently available of WTRs effectiveness under such conditions.

Western Washington's Puget Sound region is home to the largest fjord-like estuary in the continental United States (Puget Sound Partnership, 2010). This estuary is fed by numerous freshwater rivers and streams from the surrounding Olympic and Cascade mountain ranges. The marine climate prevalent in this region produces approximately 150 days of rain a year with a total precipitation average of 70 inches. While this area is predominantly covered by evergreen forest, upwards of 32 percent of these forests were converted to developed land between 1988 and 2004 (Puget Sound Partnership, 2010). The area is one of the fastest growing regions in the United States with increased development proving to be a severe stressor on local aquatic systems (USGS, 2010). A recent study indicated that surface runoff is the highest contributor to

toxic chemicals in the Puget Sound (Crowser et al., 2007). Unfortunately, the Puget Sound region presents many common and difficult conditions for implementing GSI techniques such as native soils with low infiltration rates, higher urban densities, and high ground water tables (Hinman, 2005).

The majority of GSI research conducted in the United States has been performed on the eastern half of the country. While bioretention utilization is starting to increase within Western Washington, there is limited performance monitoring on most of these systems. Monitoring which has been conducted typically emphasizes storm water quantity and flow control, and not water quality (Hinman, 2010; Herrera Environmental Consultants, 2008). Regionally available studies which do include water quality analysis have shown an export of ortho-phosphate from the system and do not provide data on nitrate removal (Chapman and Horner, 2010; Horner and Reiners, 2009). Additionally, many of these bioretention systems were designed for natural infiltration. While flow interception is a critical component of bioretention, and natural infiltration is optimal, results do not indicate how nutrient removal may be altered in many areas of the Puget Sound where utilization of an under-drain may be required. Research has shown potential for substantial export of nutrients in systems if an under-drain were present (Hunt et al., 2006).

In Western Washington, a 2009 ruling by the Pollution Control Hearings Board (PCHB) required the Department of Ecology (DOE) to prepare for GSI implementation in all NPDES Phase I and Phase II communities in the near future (PCHB, 2009). This ruling was based on the necessity to reduce pollutants in state waters to the maximum extent practicable. As there is a limited database of studies performed in this region, these requirements impose an immediate need for analysis and optimization of GSI utilization. Due to the sustainable nature of GSI, and

environmental diversity which exists in climates from region to region, it is important that research emphasize locally available resources and regulations which pertain to Washington State communities.

This study was conducted to further evaluate the effects of various bioretention design features on removal of nitrate and ortho-phosphate from stormwater runoff. Specific objectives include:

1. Optimizing nitrate removal through implementation of a saturation zone.
2. Enhancing ortho-phosphate removal by amending soil with water treatment residuals.
3. Analyzing the role vegetation plays in nitrate and ortho-phosphate removal.
4. Evaluating the suitability of applying these design features together.

Experiments were conducted on bioretention mesocosms constructed using design specifications and locally available resources to Western Washington communities. Tests were conducted after a vegetation and hydraulic establishment equivalent to 7 weeks. By this, removal results provided in this study emphasize performance during the early stages of establishment and are considered conservative estimates. A planned follow-up study will evaluate performance after significant establishment has been achieved. Information provided in this study will directly influence future design regulations required for bioretention utilization in Western Washington communities.

EXPERIMENTAL METHODS

This experiment was carried out by utilization of 12 polyvinyl chloride (PVC) mesocosms (Figure 1). The main structure of the mesocosm consists of 14-3/8 inch diameter PVC storm drain piping which was cut to size and mounted on a 1/2 inch PVC base plate for stability. The interior surface was pneumatically sanded in an effort to increase surface roughness and therefore decrease the potential of preferential flow along the edge. The primary reason for utilizing such large mesocosms was for the inclusion of plants within this study.

A riser pipe was installed to control the level at which the mesocosm was saturated with water. Saturation control valves were spaced at 6 inch increments along this pipe. In mesocosms containing a saturation zone, saturation was established in the drainage layer by closing all sampling ports except for the saturation control valve corresponding to the top of the drainage layer. This system allowed for the drainage layer to stay fully submerged in water during test events.

Perforated 1-1/2 diameter PVC pipes were used as sampling ports. These ports were installed at locations corresponding to the base of both the bioretention soil mix and drainage layer. The sampling port at the base of the bioretention soil mix was not used in this experiment. Perforation was designed to retain the drainage layer while allowing water to freely flow through the slots without clogging.

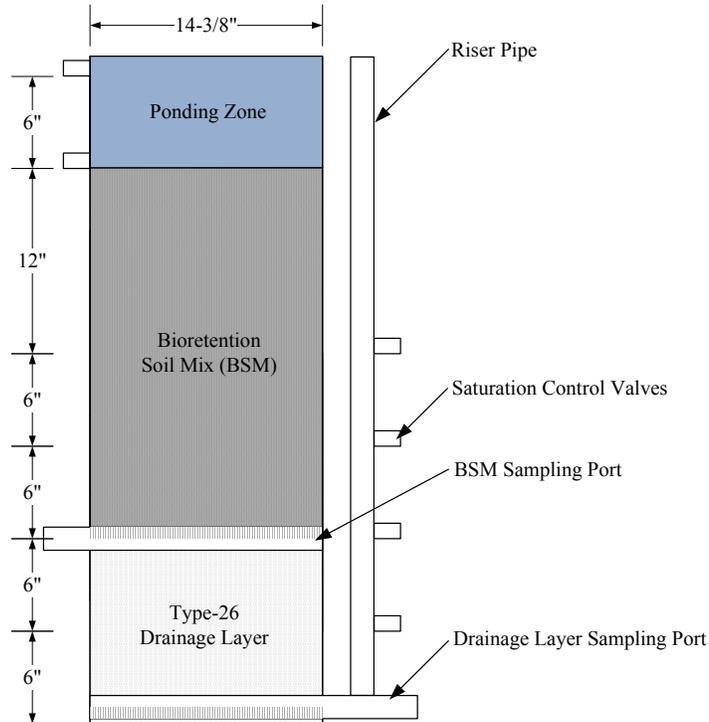


Figure 1. Mesocosm Layout

Mesocosms were constructed to meet Washington State Department of Ecology bioretention design requirements. The bottom layer of the mesocosm consists of a 12 inch drainage layer. This type-26 mineral aggregate mix is designed to retain BSM sediment within the system and provide structural support for bioretention facilities which contain under-drains. The drainage layer was utilized for creation of the saturation zone in respective test conditions. The Type-26 mineral aggregate used here was evaluated for its effectiveness as a suitable substrate for denitrification as recommended in the Puget Sound Low Impact Development Manual (Hinman, 2005).

The Washington State Department of Ecology requires a minimum bioretention soil depth of 18 inches for water quality treatment. To evaluate enhanced nitrate and phosphate removal a 24 inch soil depth was utilized in this study. Designing the mesocosms with a 24 inch

soil depth also provided versatility for a future study in which a two-layered system will be utilized.

The top of the mesocosm consists of a 6 inch ponding zone. Typical ponding design depths range from 2 to 12 inches. Six inches is a common requirement for high density right-of-way applications of bioretention (SPU, 2009).

Bioretention areas are often designed with a 2-3 inch mulch layer on the top of the bioretention soil mix (Hinman, 2005; SPU 2009). This mulch layer can provide many benefits to the system and helps sustain soil moisture content during drought conditions. Research has also shown that attenuation of many stormwater pollutants including heavy metals, oils, and nutrients can be seen with its inclusion (Hinman, 2005). The mulch layer was excluded in this study to allow for better understanding of removal mechanisms associated with each test condition evaluated in this study.

Four test conditions were evaluated in this experiment. Each condition was replicated in three different mesocosms for statistical analysis. Test conditions were designed to evaluate nutrient removal capabilities of vegetation (*Carex Flacca*) and saturation with respect to the optimized soil mixture utilized in this study. A summary of test conditions evaluated in this study are as follows:

- Condition 1: Bioretention Soil Mix with Saturated Zone
- Condition 2: Bioretention Soil Mix Only
- Condition 3: Bioretention Soil Mix with Vegetation
- Condition 4: Bioretention Soil Mix with Saturated Zone and Vegetation

The same bioretention soil mix was utilized in every mesocosm and consisted of a 60% sand / 15% compost / 15% shredded cedar bark / 10% WTR mixture. Supplier information and

material specification of these components are provided in Table 1. All bioretention components evaluated in this study are from local resources of the Pacific Northwest.

Table 1. Supplier and material specification of components used in experiment.

Component	Supplier	Specification
Compost	Cedar Grove Composting Maple Valley, WA	Type 1 Feedstock WAC 173-350-220
Sand	Walrath Trucking, Inc. Tacoma, WA	BSM Gradation 5% fines
WTR	Anachortes Water Treatment Plant Anachortes, WA	Aluminum Based
Cedar Bark	Swansons Bark and Wood Products Longview, WA	Shredded
Drainage Layer	Walrath Trucking, Inc. Tacoma, WA	Type-26
Vegetation	Blooming Nursery, Inc. Cornelius, OR	Carex Flacca Grassy Foliage

Cedar Grove Compost was added to the bioretention sand to help sustain vegetation and microbial populations, both seen as significant factors for nutrient removal (Hunt et al., 2006; Lucas and Greenway, 2008; Hinman, 2005, 2009). Addition of compost (organic matter) has also been shown to increase water holding capacities and improve drought tolerance within bioretention systems; a 2.5% increase of organic matter within a sandy soil has been shown to increase water holding capacity by 20% (Saxton and Rawls, 2005). This should effectively enhance nitrogen and phosphorus removal from stormwater because increased retention time is seen with high holding capacities.

Aluminum based water treatment residuals from the Anachortes Water Treatment Plant were utilized in the bioretention soil mix at a 10% ratio. This is thought to be a sufficient ratio

for proper stormwater treatment of phosphate (O’Niell, 2011). To remove clogging potential that can be seen by utilization of this fine material, shredded cedar bark was included in the mix at a rate of 15%. Shredded cedar bark is thought to be an acceptable alternative to both triple shredded hardwood and coir peat, which have been used to open infiltration flow paths in WTR enriched soils (O’Niell, 2011; Lucas and Greenway, 2011). It holds similar material characteristics to both triple shredded hardwood and coir peat, and is native to the region. Shredded cedar bark, along with the compost, should also provide a carbon source required for denitrification in the saturation zone.

Carex Flacca (Blue Zinger) was the vegetation selected for use in this study. It is an evergreen ground cover with tufted bluish-gray, grassy foliage. The Carex species has been shown to have effective root systems for nutrient removal (Bratieres et al., 2008). Their dense root system and fine root structure provide increased surface area for plant uptake. The Carex species is also tolerable to both saturated and drought conditions and requires limited maintenance, all factors making it an acceptable option for utilization in bioretention. When fully established, Carex Flacca sedges are 10-18 inches tall and 12-16 inches wide.

The mesocosms were placed in a greenhouse located in Puyallup, WA for the duration of the experiment. Utilization of the greenhouse allowed for control of experimental rainfall dosing. The greenhouse also provided an adequate environment for vegetation growth. The daily temperature range within the greenhouse was set between 60 and 70 °F. Vegetation lighting was on for 14 hours a day to ensure proper light within the greenhouse as required for plant growth during the winter months.

Soil media for each mesocosm was identically mixed in a 55 gallon HDPE barrel drum mixer. Components added into the mix were measured by volume and verified by weight to

ensure a consistent blend in every mesocosm. As little or no artificial compaction is seen in field construction of bioretention, a natural settlement technique was also utilized in the mesocosms. Following the installation of the Type-26 drainage layer, the bioretention soil mix was lightly tamped in the mesocosms in eight layers. The same tamping technique, replicated in all mesocosms, was formulated to remove possible inconsistencies or voids created within the bioretention soil during loading. To allow for further settling, DI water was uniformly run over every mesocosm. Bioretention soil was then added to achieve a total depth of 24 inches.

As would be seen in typical field construction, pre-established vegetation was transplanted into respective mesocosms. During the final addition of bioretention soil, empty 4"x4" rectangular planting pots were placed into the top layer of six mesocosms to help facilitate transplanting of vegetation. These pots were then taken out and filled with genetically similar *Carex Flacca* sedges. Vegetation was established in the mesocosms for 7 weeks prior to starting the experiment. During this time, approximately 16 liters of stormwater runoff was utilized to water vegetation. The same watering routine was replicated on all 12 mesocosms.

Initial infiltration rates were determined in all mesocosms by use of the falling head saturated hydraulic conductivity test. This test was run approximately two weeks before initiation of the first storm event and was also used to establish the saturated zone in respective mesocosms. Saturated infiltration rates of all mesocosms were fairly high with an average of 47.9 ± 8.0 in/hr.

The experiment was carried out over a duration of 4 weeks. Each mesocosm was dosed with stormwater once per week and allowed to gravity drain between events. A 6 month return frequency, 24 hour storm for Tacoma, WA was used for this experiment. This is the water quality design storm per Washington State Technology Assessment Protocol – Ecology (TAPE)

guidelines (WSDOE, 2011). Mesocosms were assumed to be 6.5% of the hypothetical impervious catchment area. With a mesocosm surface area of 163 in², and an assumed 90% impervious catchment, the design storm runoff volume for each test event was approximately 45 liters ($[163 \text{ in}^2 / 6.5\%] \times 1.21 \text{ in} \times 0.9 = 12 \text{ gal} = 45 \text{ liters}$). Sizing for this experiment meets typical “peak flow control standards” as seen in the Puget Sound Region.

Before commencement of the initial test event, approximately 42 gallons (159 liters) of both DI water and stormwater was run through each mesocosm in the 7 week establishment period. Water was delivered to the mesocosms for watering vegetation, determining infiltration rates, and conducting practice test runs. Assuming an equal distribution of yearly precipitation totals over every day, the mesocosms were equivalently aged to 12 percent of the first year’s total establishment. For this reason, test results are assumed to give an indication of how each testing condition performs during the early stages of establishment.

Street and parking lot stormwater runoff from the Washington State University Puyallup campus was used for this study. During storm events, campus stormwater runoff gravity drains to large outdoor cisterns. Runoff from these cisterns was pumped to a synthetic stormwater mixing tank located in the greenhouse. Prior to each test event, this stormwater runoff was spiked with laboratory-grade chemicals to achieve nutrient and heavy metal levels resembling first flush concentrations seen in multiple land uses (Maestre et al., 2004). Table 3 gives the average nutrient and heavy metal influent concentration for all test events performed in this study. Spiked influent concentrations for this experiment also met applicable requirements established by the Washington State TAPE (Technology Assessment Protocol – Ecology) Guidelines. Ammonia levels were found to be negligible in all influent concentrations. While suspended solid concentrations in this stormwater runoff were fairly low (4-20 mg/L), no

additional solids were added for fear the stormwater delivery system would become clogged during test events. Variations in spiked influent concentrations are a result of variable concentrations in un-spiked runoff.

Table 2. Average influent concentrations for all test events

Constituent	Influent	
Nitrate+Nitrite (mg/L)	0.56	0.17
Ortho Phosphate (mg/L)	0.37	0.02
Total Nitrogen (mg/L)	1.18	0.18
Total Phosphorus (mg/L)	0.43	0.04
Total Copper (µg/L)	26.3	1.4
Dissolved Copper (µg/L)	15.3	4.4
Total Zinc (µg/L)	207	46
Dissolved Zinc (µg/L)	159	27
Total Lead (µg/L)	15.9	3.2
Dissolved Lead (µg/L)	1.53	0.55

The experimental setup of this study is shown in Figure 2. Semi-synthetic stormwater was continuously mixed in a 300 gallon high density polyethylene (HDPE) tank during the duration of each test event. Mixing was achieved by utilization of a 1-hp stainless steel pump and eductor mixing nozzles within the HDPE tank. While mixing occurred, semi-synthetic stormwater was simultaneously pumped through a PVC manifold (stormwater delivery system) to the top of each mesocosm. This was done to help ensure homogeneity within influent concentrations throughout the experiment. Flow to each mesocosm was regulated by a stainless steel needle valve. Stormwater was delivered through flexible tubing to the surface of the bioretention soil. A PVC t-spreader on the end of this flexible tubing was used to help minimize disturbance to the soil and more evenly spread semi-synthetic stormwater over the column surface area.

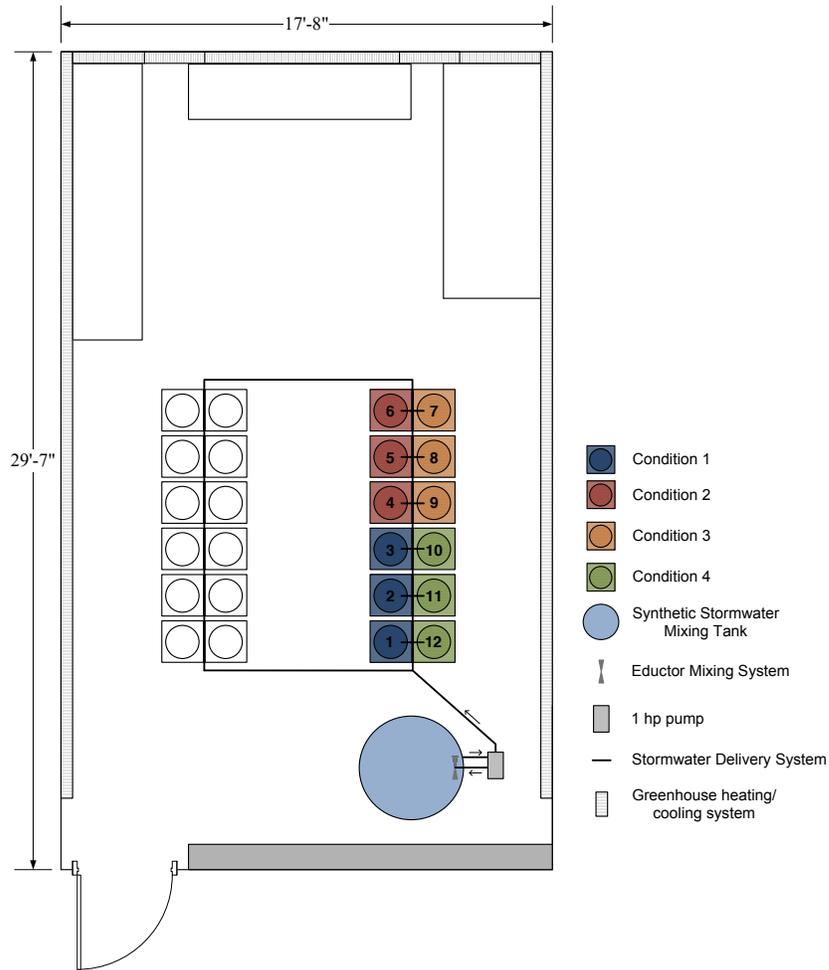


Figure 2. Greenhouse Experimental Setup

Semi-synthetic stormwater was mixed for 1.5 hours prior to running the experiment to ensure a homogenous mixture. Mesocosms were then loaded with approximately 45 liters of semi-synthetic stormwater over an average duration of 3.2 ± 0.25 hours. Effluent samples for each mesocosm were collected in 15-liter HDPE containers and kept on ice for the duration of the experiment. Mesocosms were allowed to gravity drain for approximately 1 hour after the storm event, at which time flow had slowed to a slow drip and roughly 41 liters of effluent water had been collected. At the conclusion of each experiment a 1-liter flow-weighted composite effluent sample was collected for all mesocosms. The same splitting technique was utilized on all effluent samples and randomly selected duplicate samples were analyzed to verify quality

control. A 1-liter grab sample of influent water from a randomly selected mesocosm was collected during the duration of the experiment. This sample was applied as the influent concentration for pollutant reduction analysis of all mesocosms. Samples were then preserved and stored according to Clean Water Act, Title 40, CFR Part 136, Table II.

Sample analysis was performed by a Washington State Department of Ecology certified laboratory. The samples were analyzed for total concentrations of nitrate+nitrite, ammonia, total nitrogen, ortho-phosphate, total phosphorus, total heavy metals, and dissolved heavy metals (copper, zinc, lead, and aluminum) utilizing the following methods respectively: EPA 353.2, 4500-NH3 C, COT-TN, EPA 365.1, and EPA 6020A. Additional stormwater constituents evaluated, but not of primary concern in this paper, include pH, total and dissolved organic carbon, and total suspended solids. Aluminum was evaluated as it is the main component of the water treatment residual used in the bioretention soil mixture. Table 4 gives a schedule of test runs and corresponding stormwater parameters evaluated for each.

Table 3. Mesocosm Test Schedule

Constituent Analyzed	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Nitrate + Nitrite	x	x	x	x
Total Nitrogen	x	x	x	x
Ortho-Phosphate	x	x	x	x
Total Phosphorus	x	x	x	x
Ammonia	x	x	x	x
Total Organic Carbon	-	-	x*	-
Dissolved Organic Carbon	-	-	x*	-
Dissolved Copper, Lead, Zinc, Aluminum	-	x	x*	x
Total Copper, Lead, Zinc, Aluminum	-	x	x*	x
Total Suspended Solids	-	-	-	x*
pH	x	x	x	x

x = influent water and all columns analyzed

x* = influent water and one replicate per testing condition was analyzed

- = analysis not performed

RESULTS AND DISCUSSION

Total effluent concentrations for both nitrate and ortho-phosphate are reported as an average value from three replicate mesocosms acquired for each test condition (Table 4). Standard deviations between these replicates were also calculated and are shown on Figures 3 and 6 in the form of error bars. Limited variability was seen between replicates for all test conditions as maximum standard deviations calculated for nitrate and ortho-phosphate were 0.074 and 0.018 mg/L, respectively. Variability also occurred between tests, which is due in part to varying influent concentrations.

Table 4. Influent and effluent concentrations (mg/L) for corresponding test dates

Test Date	12/14/2011		12/21/2011		12/28/2011		1/3/2012	
Constituent	Nitrate	Ortho-P	Nitrate	Ortho-P	Nitrate	Ortho-P	Nitrate	Ortho-P
Influent	0.403	0.344	0.667	0.388	0.737	0.350	0.415	0.378
Condition 1	0.119	0.113	0.324	0.131	0.353	0.136	0.178	0.145
Condition 2	0.271	0.102	0.707	0.088	0.833	0.086	0.422	0.095
Condition 3	0.309	0.073	0.636	0.075	0.711	0.082	0.338	0.096
Condition 4	0.147	0.136	0.291	0.139	0.333	0.147	0.179	0.160

Pollutant concentration reductions (in percent) referenced throughout this section were determined using the following equation:

Where: R = pollutant concentration reduction (percent)

C_i = flow-weighted influent pollutant concentration (mg/L)

C_e = flow-weighted effluent pollutant concentration (mg/L)

Utilization of this method slightly underestimates load removal as it does not account for the mass of pollutants in stormwater flow which is retained by the bioretention systems.

Nitrate Removal

Although laboratory analysis for nitrate included the nitrite fraction, nitrite can be assumed negligible as its fraction is typically very small when compared to nitrate. Influent concentrations for nitrate ranged from 0.40 to 0.74 mg/L. These values are representative of median first flush concentrations seen in many land use types including commercial, institutional, and residential (Maestre et al., 2004). Figure 3 shows a comparison of influent and effluent nitrate concentrations for each test condition and corresponding test date.

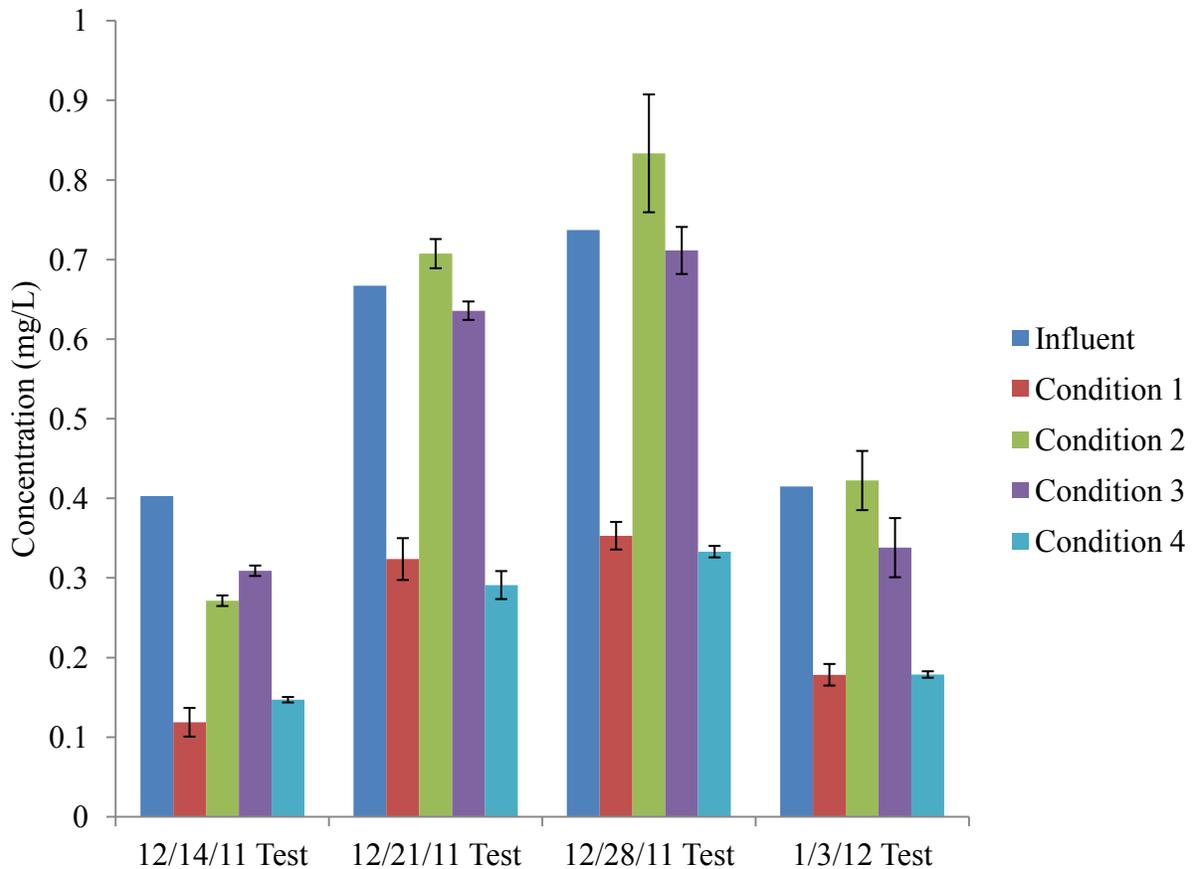


Figure 3. Nitrate concentration comparisons between test conditions and test dates.

Nitrate effluent concentrations were variable between test conditions. The highest removal rates were consistently seen from test conditions 1 and 4 in which saturation zones were included. Event and inter-event denitrification within these saturation zones facilitated nitrate

removal at levels up to 71 percent. The highest removal rates for all test conditions were seen on the 12/14/11 test date. Results from the remaining three test dates consistently showed nitrate removal between 52 and 57 percent. Improved attenuations on the 12/14/11 test date are thought to be a result of initially un-spiked stormwater within both the soil pores and saturation zones. This effectively provided greater dilution of stormwater running through the system. While this result may indicate that improved nitrate removal could occur if a longer inter-event period was utilized, research suggests that denitrification may approach completion in only 10 to 12 hours as compared to the 7 day inter-event period provided in this study (Whitmore and Hamilton, 2005).

Utilization of a saturation zone in a study conducted in Victoria, Australia showed nitrate reduction up to 99 percent (Zinger et al., 2007). This study implemented a mixture of fine sand infused with a cellulose base carbon source as the main substrate for denitrification. The upper half of this 36 inch system consisted of a sandy loam soil. Removal reduced to 70 percent when the saturation depth was lowered from 18 to 6 inches. Although influent nitrate concentrations and mesocosm surface area were similar to those seen in this study, Zinger et al. (2007) utilized a smaller design storm with a total volume of 25 liters. Improved nitrate removal exhibited by Zinger et al. (2007) is thought to be from utilization of both a smaller design storm and larger saturation depth.

A bioretention pilot study conducted by Kim et al. (2003) showed nitrate mass reduction between 70 to 80 percent with inclusion of a saturation zone in a Baltimore, Maryland based bioretention system. Use of an impermeable liner created a horizontal saturation flow distance of at least 20 inches. A newspaper carbon source was mixed with sand to create an acceptable substrate for denitrification. Total organic carbon levels in effluent samples were 5 mg/L or less. Test results showed nitrate removal of less than 10 percent without the inclusion of a

cellulose based carbon source. The bioretention soil mix utilized in this study consisted of a loamy sand. Although the hydraulic loading rate (12.36 in/hr) shown by Kim et al. (2003) was similar to that of this study, loading duration was almost twice as long and roughly 74 liters of stormwater was ran through the system. Additionally, the influent nitrate concentration utilized was much higher at 2.0 mg/L. An increase in saturation zone volume by a factor of roughly 1.7 times the size exhibited in this study, along with increased retention in the saturation zone, are both thought as primary contributors to better removal efficiencies shown by Kim et al. (2003) Accurate removal comparisons are hampered by extensive design differences shown between studies. An interesting finding presented by Kim et al. (2003) is that complete nitrate removal may be achieved in smaller storm events. Effluent nitrate concentrations in the first 2 hours of their storm event were below detection limits.

Removal rates in test conditions utilizing a saturation zone would seem to be very positive when considering the moderately high “first flush” influent concentrations and expedited hydraulic loading utilized in this study. A 6 month, 24 hour storm, from a relatively wet climate region, was applied to the mesocosms in just over 3 hours. Removal efficiencies suggest that the type-26 drainage layer is an acceptable substrate for denitrification to take place. They also indicate that the inclusion of compost and shredded cedar bark within the BSM provided a sufficient carbon source for denitrification. As no carbon source was mixed into the type-26 mineral aggregate, carbon was leached into this drainage layer during storm events. Effluent concentrations of total organic carbon (TOC) and dissolved organic carbon (DOC) analyzed on the 12/28/11 test date were 26.1 5.0 and 19.1 2.1 mg/L, respectively. There was not a significant increase in percent removal on storm events exhibiting lower influent concentrations. This indicates that inter-event denitrification, and subsequent dilution of

stormwater in the following event, played the predominant role in nitrate concentration reductions. Results presented by Zinger et al. (2007) and Kim et al. (2003) suggest that nitrate removal, through denitrification, may increase with smaller storm events or by utilization of a larger saturation zone.

Event based nitrate removal should play an increasing role in overall nitrate reductions as infiltration rates decrease, and retention time is ultimately increased. Research conducted by Lucas and Greenway (2011a, b) suggests that improved nitrate removal is possible, even without the inclusion of a saturation zone, when retention time is increased in systems displaying a coarse media, similar to the BSM utilized in this study. Results showed an improvement in nitrate removal from 17 percent to 50 percent when flow was slowed from a fraction of an hour to several hours with the use of an effluent control valve. The influent concentrations and saturated hydraulic conductivity (43 in/hr) exhibited in Lucas and Greenway (2011a, b) were 0.77 mg/L and 43 in/hr, respectively; both very similar to values shown in this study. Findings suggest that nitrate removal may even be possible in condition 2 where no saturation zone or vegetation was utilized. They also indicate that increased removal may be seen in storm events with slower hydraulic loading rates.

The *Carex Flacca* sedge established in test conditions 3 appeared to play a small, but significant, role in nitrate removal even with limited establishment. Nitrate reduction from plant uptake was seen at levels up to 19% on the 1/3/12 test date. Although test condition 4 also incorporated vegetation, uptake was not shown to be significant when comparing results to test condition 1 which also utilized a saturation zone but was barren of vegetation. Plant uptake in bioretention systems with limited established is thought to be less rapid than other removal mechanisms such as immobilization and denitrification (Lucas and Greenway, 2011b).

Denitrification in test condition 4 appears to have played an earlier and more significant role in nitrate removal, ultimately making plant uptake efficiency less pronounced. Uptake is expected to improve as the rhizosphere becomes extensively established within the system. Maximized removal of nitrate through vegetation uptake may not be obtained until two years of plant establishment in which greater than 90 percent removal can be seen (Lucas and Greenway, 2011b). Results from the 12/14/11 test showed nitrate concentration reduction in test condition 2 in which no vegetation or saturated zone was utilized. It is thought that initially un-spiked stormwater within the system's soil pores effectively diluted influent nitrate concentrations during the initial test. Alternatively, analysis on the remaining three tests showed that excess nitrate was flushed out from previous test events at rates up to 14 percent. These results correspond to findings published by Bratieres et al. (2008) and Lucas and Greenway (2008) in which lack of inter-event uptake by vegetation resulted in export of excess nitrate in the following event. Nitrate export ranged from 2 to 560 percent in the well established loamy sand and sandy loam soils exhibited in these studies. Results from Bratieres et al. (2008) indicate that high amounts of nitrate export, at levels corresponding to barren systems, are still possible in systems with less efficient vegetation.

A comparison of cumulative influent and effluent nitrate loading throughout the duration of this study are shown in Figure 4. There is a distinct improvement in nitrate removal from incorporation of a saturation zone in conditions 1 and 4. No difference can be seen in cumulative nitrate removal between condition 1 and 4 even though condition 4 utilized vegetation. Lack of both a saturation zone and vegetation are thought to account for little to no cumulative removal seen in condition 2. On the other hand, although condition 3 also did not exhibit a saturation zone, slight cumulative removal is thought to be contributed to uptake by vegetation. These

results emphasize the importance of a saturation zone has on nitrate removal during early establishment when plant removal is limited. As vegetation and microbial populations become more extensively established, nitrate removal should also increase.

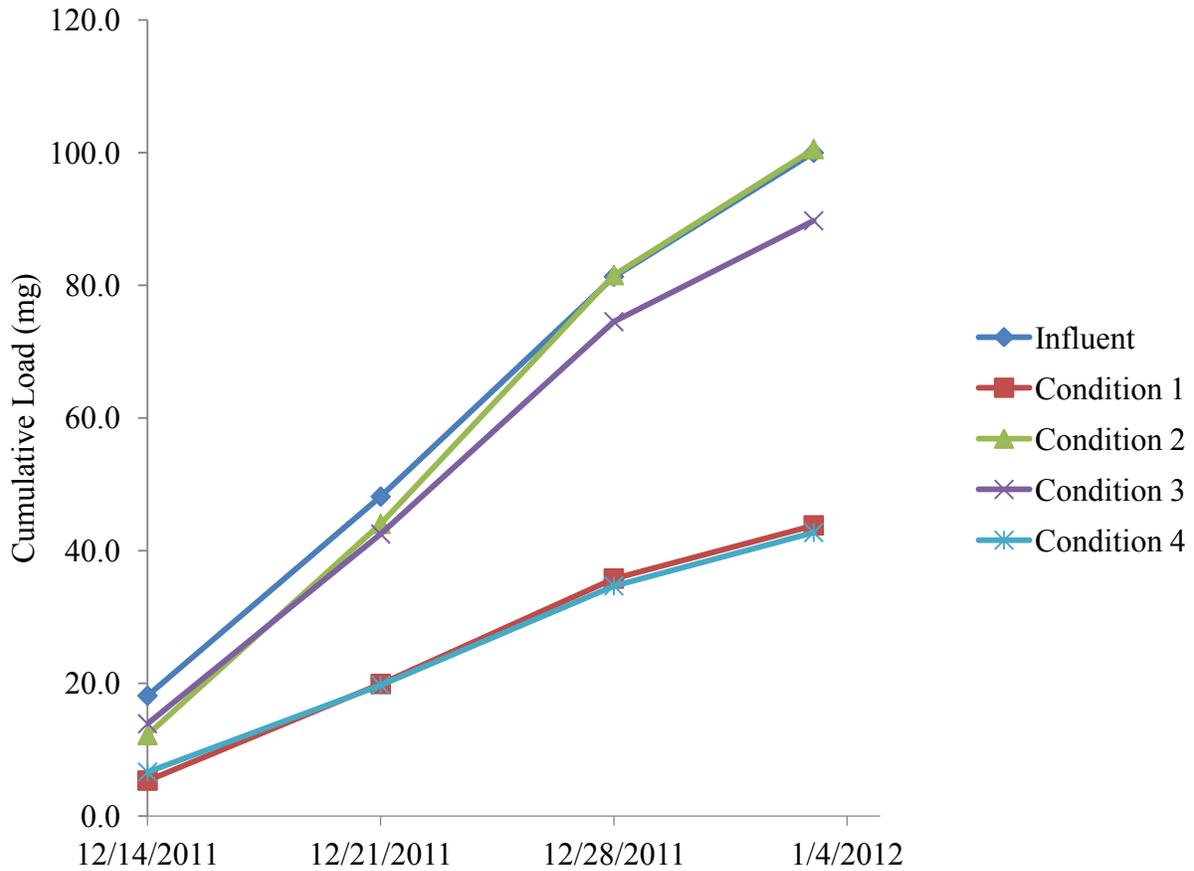


Figure 4. Cumulative influent and effluent nitrate load comparisons

Total nitrogen and ammonia concentrations were analyzed on influent and effluent samples for every test event. Influent and effluent ammonia concentrations were below the 0.07 mg/L detection limit for all test events and testing conditions. However, results show that total nitrogen was exported from every test condition during the duration of the experiment. Figure 5 shows a comparison of influent and effluent total nitrogen concentrations for each test condition and corresponding test date. All mesocosms appear to follow a general trend of decreased export over time. This tendency was also shown by Pitt et al. (1999) in which Cedar Grove Compost

was examined for its effect on soil infiltration in a compost-amendment soil application. Losses are expected to decrease as these systems become more established and infiltration rates decrease. While export of total nitrogen may be a concern in systems which utilize an under-drain, this is not a concern in systems designed for natural infiltration of stormwater into the ground.

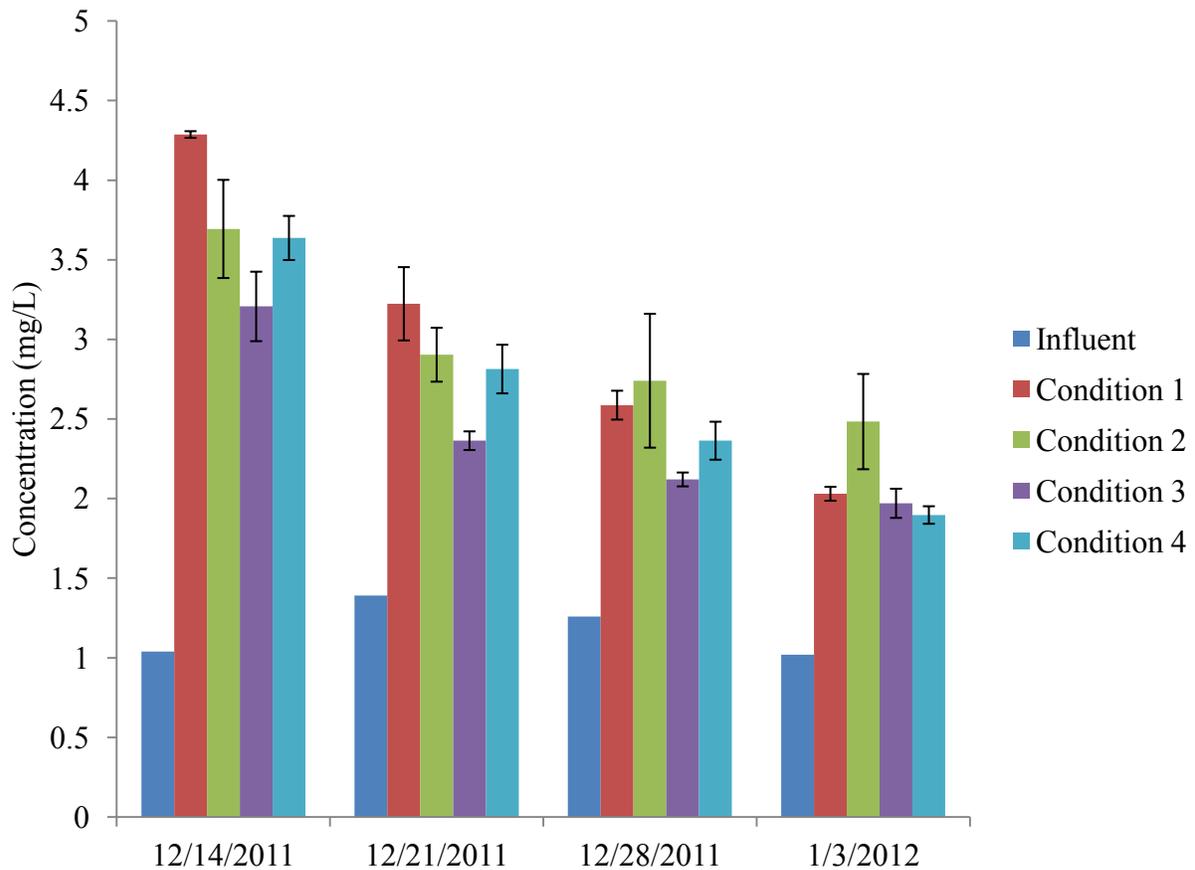


Figure 5. Total nitrogen concentration comparisons between test conditions and test dates.

Negligible ammonia concentrations along with nitrate removal efficiencies, found within effluent samples, together indicate that the majority of nitrogen exported from the mesocosms was in the organic form. These results show that the compost utilized in the bioretention soil mix is leaching organic nitrogen. Batch leaching analysis conducted on individual bioretention soil materials by the Center for Urban Waters (Tacoma, WA) confirmed these results

(unpublished data). Compost leaching of total nitrogen was found at levels up to roughly 14 mg/L (per 20 grams of material in 1 liter of water). This concentration is 10 times greater than the highest concentrations found within influent stormwater applied to all test conditions. The compost utilized within the system has an organic matter content of 45 to 65 percent (as determined by loss of ignition method). It was derived from materials consistent of a type 1 feedstock such as yard and garden waste, wood wastes, and pre-consumed vegetative food wastes. Organic nitrogen leaching from this compost is much less readily usable by biological processes (Pitt et al., 1999) and therefore not of great concern.

While slight nitrate removal was seen with the utilization of vegetation in condition 3 (no saturation zone), substantial leaching from a compost-amended soil used for bioretention was shown by Bratieres et al. (2008). A sandy loam soil amended with 10 percent leaf mulch-compost and 10 percent wood mulch was used as the BSM soil in this Australian study. Their system was planted with a *Carex* species and exhibited a media depth of approximately 28 inches. Results were reported after a 7 month establishment period, in which a twice weekly dosing regimen of 25 liters was conducted. Nitrate was exported at a rate of 158 percent with an influent concentration of 0.79 mg/L. These results stress the importance of selecting appropriate organic matter (compost) for utilization in bioretention soil mixtures; and further emphasize the need for localized testing. Initial results suggest that Cedar Grove compost is acceptable for use in bioretention soil mixtures in areas with nitrate limited aquatic systems.

Ortho-Phosphate Removal

A comparison of influent and effluent ortho-phosphate concentrations for each test condition and corresponding test date are shown in Figure 6.

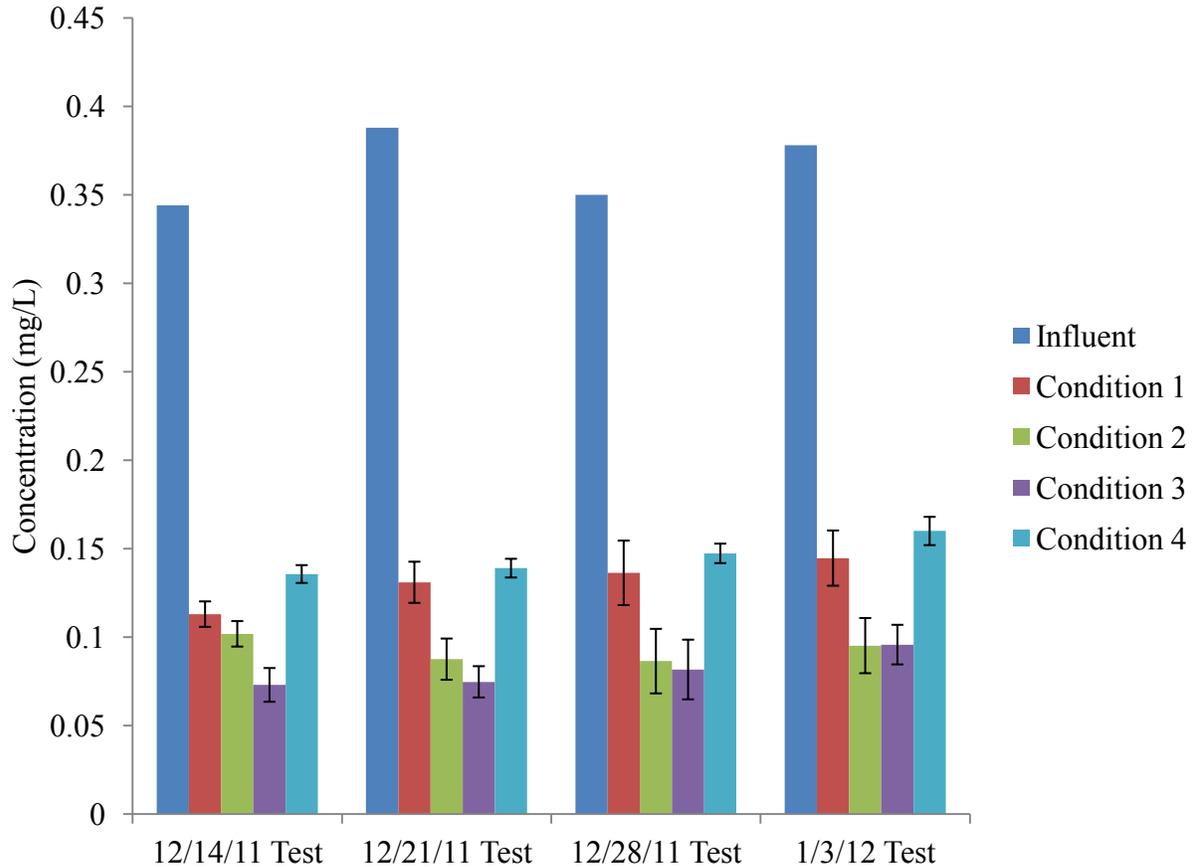


Figure 6. Phosphate concentration comparisons between test conditions and test date

Ortho-phosphate influent concentrations ranged from 0.34 to 0.39 mg/L. Median first flush values for all land uses typically range between 0.16 and 0.25 mg/L (Maestre et al., 2004), which is significantly lower. Even with these high influent concentrations, effluent concentrations were significantly reduced from all test conditions. Removal occurred at rates of 58 to 81 percent. While these results do not directly determine the specific contribution of ortho-phosphate sorption by the WTRs within the BSM, a study conducted at the Center for Urban Waters (Tacoma, WA) showed only modest removal at levels up to 38 percent in a 60% sand /

40% compost BSM utilizing the same media sources (unpublished data). This indicates that the aluminum based water treatment residuals can effectively enhance sorption of phosphate even when the bioretention system is subjected to an expedited hydraulic loading of high first flush influent concentrations.

Test conditions which did not incorporate a saturation zone (condition 2 and 3) consistently showed higher ortho-phosphate removal than those which did (condition 1 and 4). Removal from test conditions 2 and 3 ranged from 70 to 81 percent, whereas, removal from test conditions 1 and 4 ranged from 58 to 67 percent. These results indicate that the aluminum based water treatment residuals utilized within this study are slightly susceptible to desorption when incorporated in bioretention systems containing a saturation zone. Overall, the use of water treatment residuals appears to be an acceptable design method for enhanced removal of phosphate even when saturation is utilized for denitrification.

Ortho-phosphate reductions through water treatment residual utilization are comparable to those seen by Lucas and Greenway (2011). This study saw phosphate removal ranging from 81 to 92 percent at a high flow-weighted inflow concentration of 3.2 mg/L (used to evaluate accelerated loading). WTR was utilized at a level of 30 percent compared to 10 percent in this study. While it is unclear whether increased influent concentrations enhance phosphate adsorption capabilities of WTR, improved removal is expected with additional input of WTR to bioretention soil blends (O’Niell and Davis, 2010). Removal rates shown by Lucas and Greenway (2011) were given after 50 weeks of establishment in contrast to the limited establishment during this study. The fibrous coir peat, similar to shredded cedar bark, removed clogging potential that is possible with elevated fines content from inclusion of WTR.

Effluent data shows inconclusive results on the *Carex Flacca*'s ability to remove ortho-phosphate under early establishment conditions. Besides the 1/3/12 test, results showed that vegetated mesocosms slightly reduced ortho-phosphate when compared to test conditions which didn't incorporate a saturation zone. Alternatively, ortho-phosphate effluent levels were always slightly higher in vegetated mesocosms when comparing to test conditions that included a saturation zone. However, these trends are not conclusive as variability in uptake from these immature plant species has made removal differences insignificant. Research has suggested that modification of pH and concentrations of aluminum could allow plant roots to shift chemical equilibria which determine mobility and bioavailability of inorganic phosphate (Hinsinger, 2001). This phenomenon may result in either increased or decreased phosphate removal from bioretention systems. As the WTR utilized within the BSM contains high levels of aluminum, these effects will need to be analyzed after extensive establishment of these systems. Additionally, plant uptake is not expected to play a significant role in phosphate removal until root systems have been extensively established. Many studies have shown greater than 90 percent removal of phosphate in sandy loam and loamy sand systems with vegetation after several months of establishment (Lucas and Greenway 2008; Bratieres et al. 2008; Read et al., 2008). As with nitrate removal, removal rates are highly dependent on vegetation type and export is still possible in systems with inefficient plant species (Bratieres et al., 2008; Read et al., 2008).

A comparison of cumulative influent and effluent ortho-phosphate loading throughout the duration of this test are shown in Figure 7. There was a significant load reduction from all test conditions. Slightly better load reduction was seen in test conditions which did not include a saturated zone. As vegetation and microbial populations become more extensively established, phosphate removal should also increase.

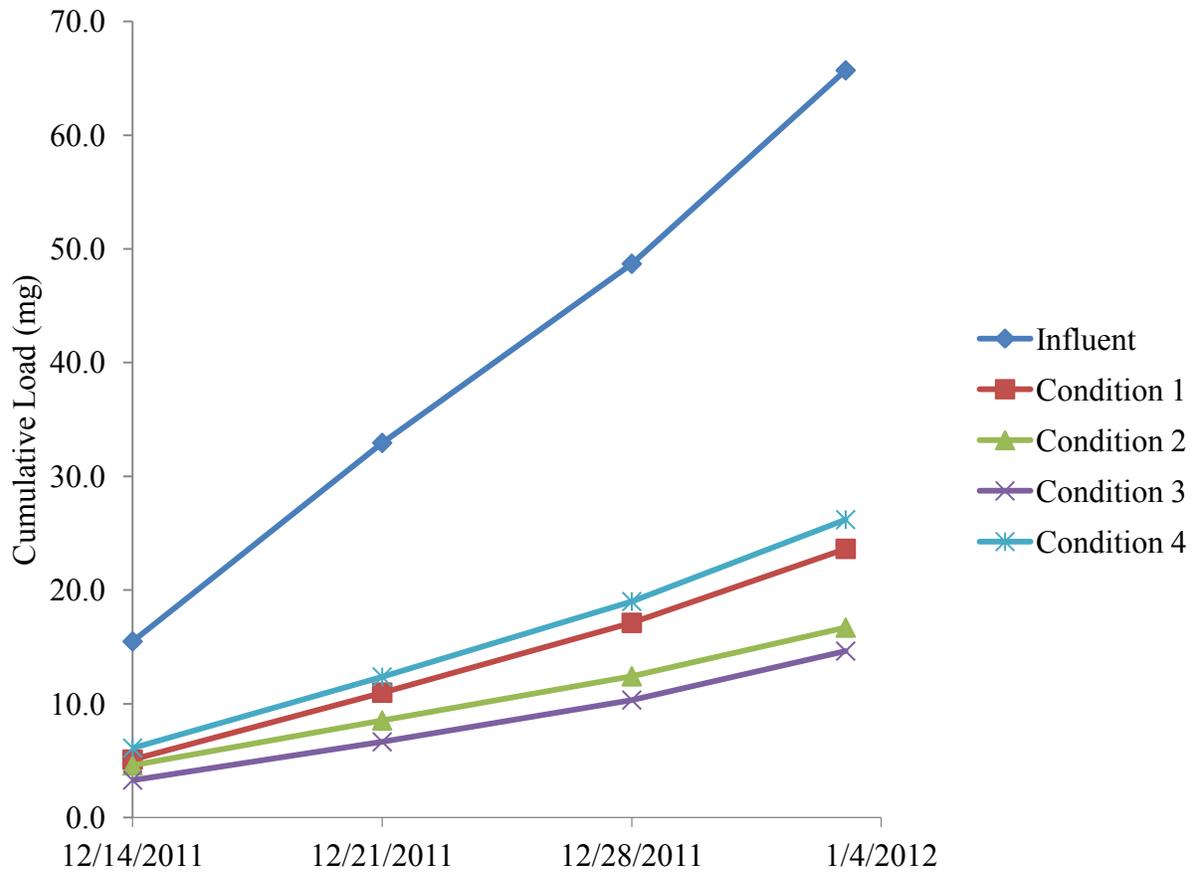


Figure 7. Cumulative influent and effluent phosphate load comparisons

Total phosphorus concentrations were also analyzed on influent and effluent samples for every test event. Figure 8 shows a comparison of influent and effluent total phosphorus concentrations for each test condition and corresponding test date. Results show initial export of total phosphorus from every test condition. All mesocosms appear to follow a general trend of decreased export over time. This tendency was also shown by Pitt et al. (1999) in which Cedar Grove compost was examined for its effect on soil infiltration in a compost-amendment soil application. By the 1/3/12 test run, there is a slight removal of total phosphorus from every test condition. Removal is expected to increase as these systems become more established and infiltration rates decrease. While export of total phosphorus may be a concern in systems which

utilize an under-drain, this is not a concern in systems designed for natural infiltration of stormwater into the ground.

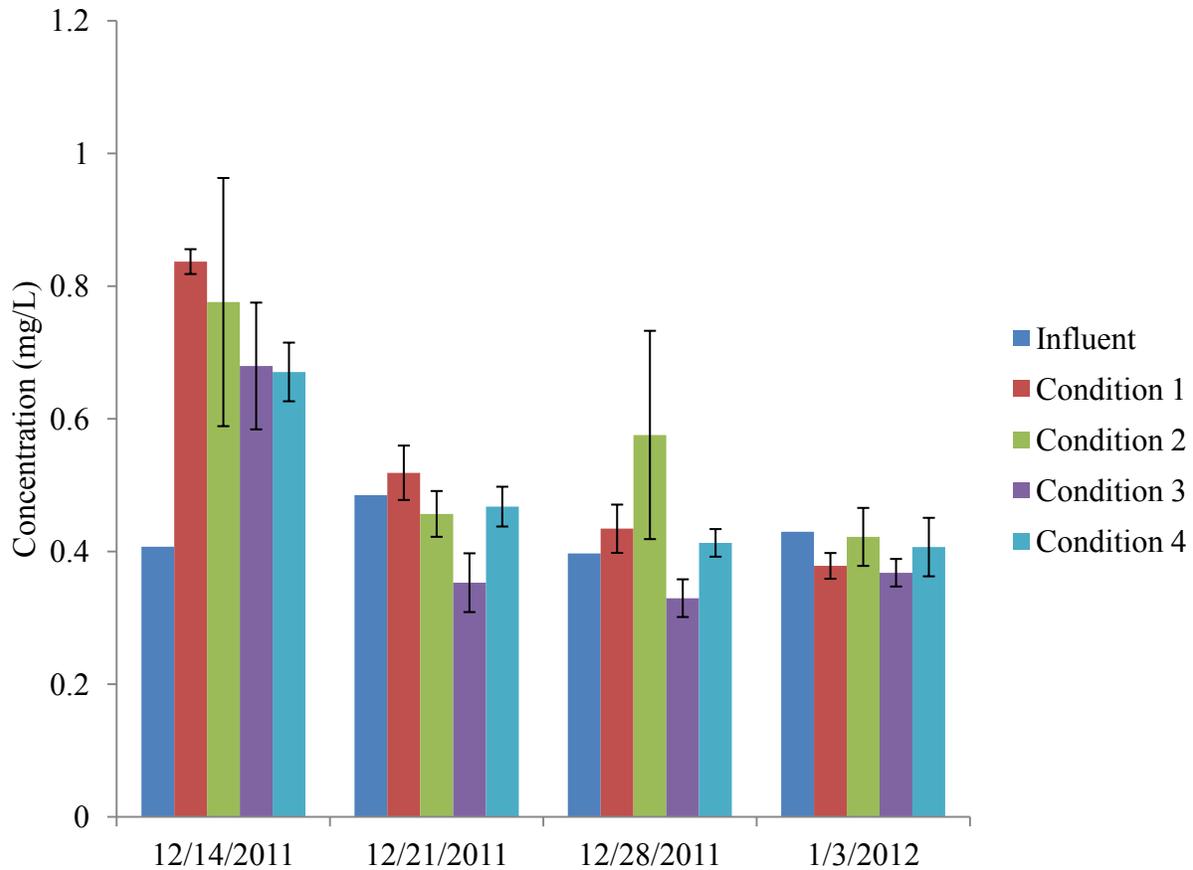


Figure 8. Total phosphorus concentration comparisons between test conditions and test dates.

Elevated standard deviations of results from test condition 2 on both the 12/14/2011 and 12/28/2011 test dates are thought to be a product of initial loading malfunctions. Random dislodgement of suspended sediment within the flow control value of two different mesocosms produced a substantial increase in initial hydraulic loading to these systems. Stormwater ponding was observed in these mesocosms for the first 10 to 15 minutes before valves were re-calibrated back to the desired loading rate. Variations in phosphorus leaching between mesocosms are shown to reduce by the following event. This increase in hydraulic loading does not appear to have played a significant role in export of total nitrogen and nitrate, along with the

phosphate adsorption, experienced by condition 2. These results indicate that initial total phosphorus leaching is highly dependent on hydraulic loading rate. It is unclear whether this phenomenon will take place after these systems are extensively established and leaching is exhausted.

Phosphate removal efficiencies found within effluent samples indicate that the majority of phosphorus exported from the mesocosms was in the organic form. These results show that the compost utilized in the bioretention soil mix is leaching organic phosphorus. Batch leaching analysis conducted on individual bioretention soil materials by the Center for Urban Waters (Tacoma, WA) confirmed these results (unpublished data). Compost leaching of total phosphorus was found at levels up to roughly 2.89 mg/L (per 20 grams of material in 1-liter of water). This concentration is 7 times greater than the highest concentrations found within influent stormwater applied to all test conditions. As discussed earlier, the compost utilized within the system has an organic matter content of 45 to 65 percent (as determined by loss of ignition method) and was derived from materials consistent of a type 1 feedstock. Organic phosphorus leaching from this compost is much less readily usable by biological processes (Pitt et al., 1999) and therefore not of great concern.

Leaching of phosphate from compost is not conclusive in this study as WTR utilization within the BSM appears to have effectively reduced phosphate concentrations in all test conditions. However, substantial leaching of phosphate from a compost-amended soil used for bioretention was shown by Bratieres et al. (2008). Phosphate was exported at a rate of 78 percent with an influent concentration of 0.127 mg/L. These results stress the importance of selecting appropriate organic matter (compost) for utilization in bioretention soil mixtures; and further emphasize the need for localized testing. Initial results suggest that Cedar Grove compost is

acceptable for use in bioretention soil mixtures that are amended with WTRs. Further analysis is needed on its efficiency to retain phosphate without the utilization of WTRs.

Influent Suspended Sediment

The semi-synthetic stormwater used within this study contained a small concentration of natural suspended sediment. Concentrations were shown to range between 4 and 20 mg/L. Typical concentrations of suspended solids within stormwater runoff range between 20 and 150 mg/L (Maestre et al., 2004). Sediment was not added to this mix as it promoted clogging of the stormwater delivery system. While addition of higher concentrations of suspended sediment is a concern for bioretention systems which exhibit already slow infiltrations rates, this sediment would prove to be a benefit to the system used in this study. As sediment settles on the top of the mesocosm, higher infiltration rates exhibited in this study should slow, ultimately providing greater retention times and improved nutrient removal (Hatt et al., 2008). Fibrous amendments such as shredded bark should still allow bioretention systems to maintain higher infiltration rates, even with high sediment loading, making them more efficient for a longer period of time (Lucas and Greenway, 2011a). Accumulation of fine particles found within suspended sediment may also provide suitable sites for biofilm in which microbial conversion and subsequent uptake of nutrients can be seen (Clark and Pitt, 1999).

Effluent Suspended Sediment (BSM Mobilization)

The type-26 drainage layer, recommended for use in bioretention systems containing under-drains, did not effectively retain bioretention soil within the mesocosms. Suspended sediment analysis on the 1/3/12 test date gave effluent concentrations of TSS as high as 154 mg/L. This level is greater than concentrations typically found in stormwater runoff (Maestre et al., 2004). With an influent concentration of only 4 mg/L, significant export of bioretention

sediment was observed. While soil immobilization occurred in all mesocosms, a significant difference was seen between test conditions containing a saturated zone (69 ± 6 mg/L) and those which did not (148 ± 9 mg/L). These results show that implementation of a saturation zone may enhance suspended solid removal from stormwater runoff. It is also likely that raised total nitrogen and total phosphorus concentrations found in effluent samples are directly related to this BSM immobilization. Suspended sediment can consist of a large percentage of structurally bound nitrogen and phosphorus (Kadlec and Wallace, 2009). Other studies have also shown a washout of fines from media in newly installed systems (Hsieh and Davis, 2005b). Although sediment immobilization should decrease as the system becomes established, findings suggest that further research on drainage layer composition is necessary specifically within systems that utilize an under-drain.

Infiltration Rates

The Washington State Department of Ecology requires a maximum infiltration rate of 12 in/hr for enhanced water quality treatment. Initial infiltration rates in typical bioretention systems are often expected to reduce by a factor of 4 as systems mature overtime. Primary mechanisms for this decreased infiltration rate include clogging of pores by suspended sediment, rearrangement of soil particles within the system, and natural settling which takes place overtime (Li and Davis, 2008). Early research has suggested that higher retention times seen with slower infiltration rates are necessary for suitable treatment of stormwater pollutants (Kadlec and Wallace, 2009; Hatt et al., 2008).

Recent research has suggested that enhanced treatment of total phosphorus, hydrocarbons, and heavy metals can be seen at much higher infiltration rates (Hsieh and Davis, 2005; Davis et. al., 2003). The study conducted by Hsieh and Davis (2005) observed infiltration

rates up to 22.44 in/hr, and Davis et al. (2003) measured infiltration rates up to 127.56 in/hr. Infiltration rates within this study were also fairly high at 47.9 – 8.0 in/hr. Results show that significant nitrate and phosphate removal is still possible with high infiltration rates when specific design features are included. As infiltration rates are thought to play an important role for nitrate and phosphate management, additional research is needed for defensible infiltration rate guidelines (Hinman, 2009).

There are many variables which could have played a role in the high infiltration rates seen within this study. Inclusion of both shredded bark and compost has been shown to increase stormwater infiltration by opening up flow paths within bioretention systems (O’Niell and Davis, 2010; Hatt et al, 2008; Pitt, et al., 1999b). Higher infiltration rates are also seen in bioretention systems where limited to no compaction is conducted during construction, specifically in the early establishment period. While preferential flow of water along the sides of the mesocosm is always a concern, it is an unlikely source for the high infiltration rates in this study as significant phosphate removal was shown in every test condition. Removal of phosphate is dependent on soil contact, and ultimately adsorption, thus preferential flow was unlikely.

Implications for Early Establishment

The limited establishment of only 7 weeks found within this study gives a fairly good example of how these bioretention systems perform immediately after installation. With little to no compaction found in the construction of bioretention systems, initial infiltration rates are often quite high and limited to no ponding is experienced. Although design features (t-spreader) were included in this study to more evenly disperse flow, stormwater appeared to take a direct path through the bioretention system. This pattern is present when soil infiltration rates are greater than applied loading rates in bioretention systems and are often seen in early

establishment. Utilization of both compost and shredded bark within the bioretention system may allow for slight soil compaction during construction. This should reduce initial infiltration rates and preferential flow patterns within the soil; ultimately allowing for improved nutrient removal.

Results of this study show that organic nitrogen and organic phosphorous are initially exported from systems utilizing compost within the soil mixture. Observations of the 12/14/2011 and 12/28/2011 test show that initial export of organic phosphorus is connected to hydraulic loading rate. While an increase in export of organic phosphorus was observed with amplified hydraulic loading, it does not appear to have played a significant role in export of total nitrogen and nitrate, along with phosphate adsorption. It is unclear whether this phenomenon will take place after these systems are extensively established and leaching is exhausted. Leaching of organic phosphorus appears to have been diminished by the end of the 1/3/2012 test date in which removal was seen in every test condition. At this point roughly 200 liters of water had been run through all mesocosms. Assuming an equal distribution of yearly precipitation totals (Tacoma, WA) over every day, this is equivalent to roughly 3 months of stormwater.

Plant removal of nutrients was limited as root growth was likely minimal during the short establishment period. Design features such as utilization of a saturation zone or WTR within the bioretention system are needed for improved nitrate and phosphate removal during this time. To fully understand removal capabilities of *Carex Flacca* within this bioretention soil mixture, a follow-up study is needed after plant systems and microbial populations have been established extensively. Even with minimal establishment, all *Carex Flacca* sedges appeared to be fairly healthy even after subjecting them to large quantities of water. Early indications show that the bioretention soil mix utilized in this study provides an adequate substrate for vegetation.

Observing the plant response to longer drying periods between events is also needed. Addition of the mulch layer will help keep moisture in the soil between storm events.

Competing Removal Mechanisms

Results of this study indicate that inclusion of a saturation zone is necessary for enhanced removal of nitrate, particularly in the early stages of establishment. It is also apparent that the use of water treatment residuals within bioretention soil mixtures is an acceptable design method for enhanced removal of phosphate. While good removal of both nitrate and phosphate was shown in systems utilizing both WTRs and a saturation zone, it appears that WTRs are slightly susceptible to desorption under anoxic conditions developed in saturation. Phosphate removal was shown to decrease from between 70 to 81 percent to between 58 and 67 percent when a saturation zone was utilized. While this reduction in removal efficiency may not pose a significant effect in nitrogen limited waters, this small decrease may have a significant impact on phosphorus limited waters. Only a modest increase in phosphate concentrations can result in significant eutrophication of these freshwater environments (USEPA, 2012). However, improved nitrate and phosphate removal is expected as vegetation and microbial populations become extensively established. This may counteract slight phosphate desorption experienced by aluminum based WTRs and allow for inclusion of a saturation zone within the system. Ultimately, individual receiving bodies of water need to be evaluated before inclusion of a saturation zone is specified.

Implications for Design

Augmenting the BSM with shredded cedar bark is expected to allow the system to maintain higher infiltrations rates than are seen with standard mixtures (Lucas and Greenway, 2011a). Higher infiltration rates may make this system more acceptable for urban environments

in which bioretention applications are limited as there is typically less room for extensive implementation. By this, a smaller bioretention system is needed to handle the water quality design storm (6 month, 24 hours).

Improved infiltration through the inclusion of both shredded cedar bark and compost may initially hinder a system's ability to further remove nutrients. Although flow is expected to slow overtime, use of an effluent control valve may be a means to better control retention times, and ultimately improve both stormwater quality and quantity (Lucas and Greenway, 2011a,b). However, implementing and maintaining such control valves may not be practical for many communities. Alternatively, use of design features such as a saturation zone and WTR can still provide enhanced treatment under these high infiltration rates.

While vegetation is usually included in bioretention for its aesthetic appeal, it is now being looked at as a specific design feature to improve nutrient removal. Vegetation is not expected to play a significant role in nutrient removal until extensive establishment has been achieved. Both a saturation zone and WTR can be used to augment removal during early stages of establishment. These design features can also enhance removal during seasons when plant uptake is less efficient (Lucas and Greenway, 2008).

Summary and Conclusions

This study was conducted to further evaluate the effects of various bioretention design features on removal of nitrate and ortho-phosphate from stormwater runoff. As a result of this study it was determined that:

1. Implementation of a saturation zone within systems incorporating a compost amended soil can effectively enhance nitrate removal. Inclusion of compost and shredded cedar bark within the BSM provides a sufficient carbon source for denitrification. A

- type-26 mineral aggregate, often specified for bioretention drainage layers, provides an acceptable substrate for denitrification to take place.
2. Aluminum based water treatment residuals can effectively remove ortho-phosphate even in a system exhibiting high infiltration rates. Use of this soil amendment should allow for reduction of phosphate to the maximum extent possible.
 3. Vegetation plays a small role in nitrate removal even under limited establishment. Export of nitrate can be seen in systems barren of both vegetation and a saturation zone. Initial vegetation uptake of ortho-phosphate is less apparent in systems utilizing WTRs. Extended establishment is required for definitive results of *Carex Flacca*'s effectiveness at removing both nitrate and ortho-phosphate.
 4. Even with limited establishment, significant nitrate and phosphate reductions are available from bioretention systems which utilize both a saturation zone and WTR's as design features. Slight improvement in ortho-phosphate removal is available in systems which do not incorporate a saturation zone as anoxic conditions may promote desorption. Results also show an export of total phosphorus and total nitrogen from the compost amended bioretention soil mixture. While export appears to decrease with an increase in hydraulic loading, this may pose concerns for bioretention systems which utilize an under-drain.

Results of this study represent what would be seen in an early establishment. A planned follow-up study will evaluate performance after significant establishment has been achieved.

Information provided will directly influence future design regulations required for bioretention utilization in Western Washington communities.

CHAPTER 3

HEAVY METAL REMOVAL

INTRODUCTION

A large sum of bioretention research has shown significant reductions in heavy metals from stormwater runoff (Davis et al., 2001, 2007; Hsieh and Davis, 2005a, b; Dietz and Clausen, 2005). Removal rates are often shown anywhere from 70 to 99 percent. Although these results are very promising, evaluation of heavy metal removal in newly derived bioretention soil blends is still required to further promote their use.

Copper, zinc, and lead are often considered three primary species of concern in stormwater runoff. These metals are highly toxic to aquatic species and readily available in the environment from vehicle components such as exhaust, brake linings, and tire and engine wear (Lancaster and Beutel, 2011). Heavy metals are typically removed in bioretention systems through filtration and rapid sorption processes (Davis et al., 2001, 2007; Hsieh and Davis, 2005a,b). Additionally, research has shown that most metal retention appears to occur in the upper layers of media (Davis et al., 2009).

Many soil properties are required for efficient adsorption of heavy metals. The cation exchange capacity (CEC) is of particular interest. The CEC is a measure of how many positively charged elements or cations a soil can retain. It is essentially an indicator of a soils potential to adsorb metals in urban runoff. The Washington State Department of Ecology requires soils to exhibit a CEC of at least 5 meq/100 grams of dry soil (Hinman, 2009). Compost amended soils have been shown to provide sufficient CEC's required for proper adsorption of many heavy metals (Pitt et al., 1999; Seelsaen et al., 2007;). Soil pH is also of interest when analyzing

potential for heavy metal removal as metals are often susceptible to desorption with decreasing pH. Metal adsorption is generally irreversible at a neutral pH (Clarke and Pitt, 1999).

Although not the main focus of this study, we also tested metals in the effluent of the bioretention columns. The objective of this part of the study is to verify heavy metal removal trends with the BSM utilized in this study

METHODS

Removal of both total and dissolved forms of lead, zinc, and copper were analyzed for all test conditions. Table 3 shows the metals concentrations added to the semi-synthetic rainwater mix, and Table 4 shows the mesocosm test schedule (see Experimental Methods in Chapter 2). As shown from this schedule, all mesocosm effluent samples were tested on the 12/21/2011 and 1/3/2012 test dates. Additionally, a limited test regime was conducted on the 12/28/2011 test date in which only effluent from one replicate mesocosm was analyzed for each test condition. This was conducted to examine any possible inconsistencies in removal that may have occurred between test dates. It was also used to evaluate possible trends in results. Pollutant concentration reductions (in percent) referenced throughout this section were determined using the same equation used for nutrients (see Results and Discussion in Chapter 2).

RESULTS AND DISCUSSION

Zinc Removal

Zinc removal was shown to be relatively high for all test conditions on every test date. Total zinc and dissolved zinc were consistently removed at rates close to 89 and 97 percent, respectively. Figure 9 shows a comparison of average influent and effluent zinc concentrations for all test dates.

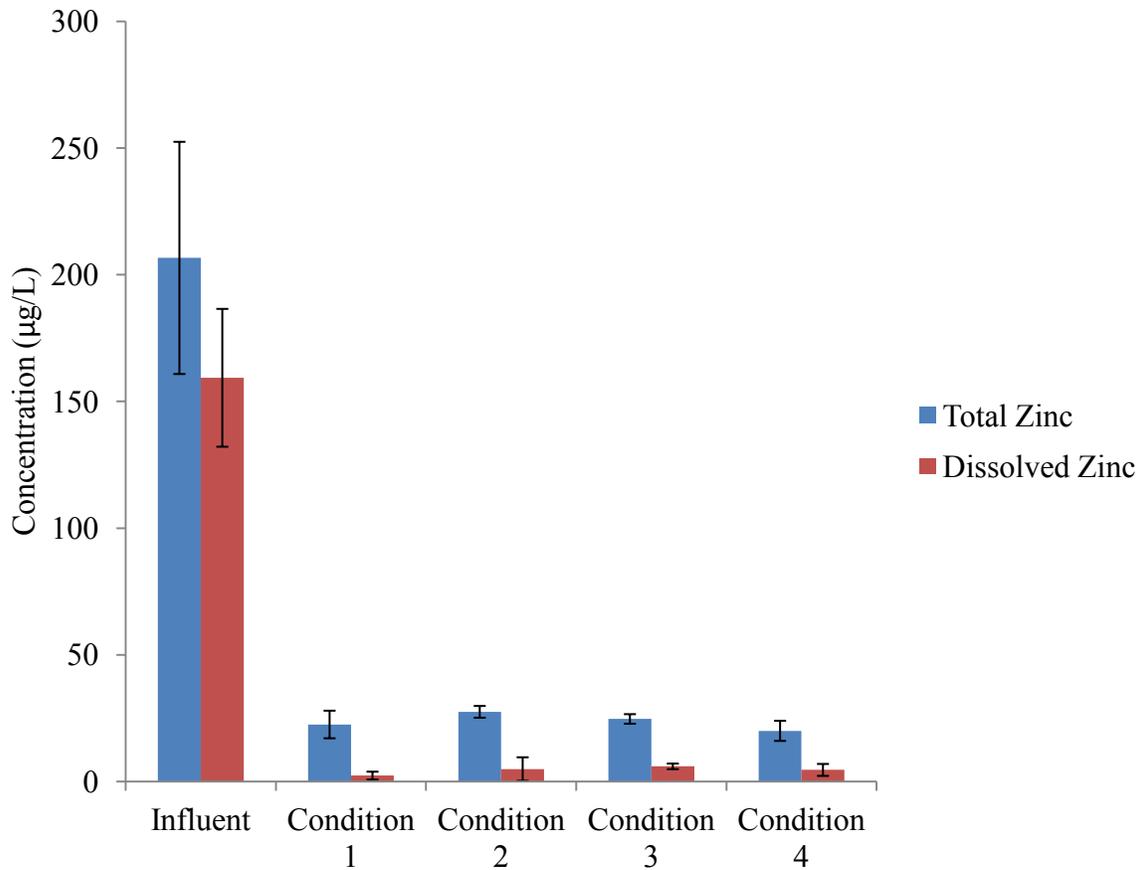


Figure 9. Average influent and effluent zinc concentrations for all test dates.

Lead Removal

Significant removal of both total lead and dissolved lead was shown for all test conditions on every test date. Reduction of total lead was shown to be between 55 and 70 percent while reduction of dissolved lead was between 56 and 94 percent. No trends in removal were seen between test conditions. Figure 10 shows a comparison of average influent and effluent lead concentrations for all test dates.

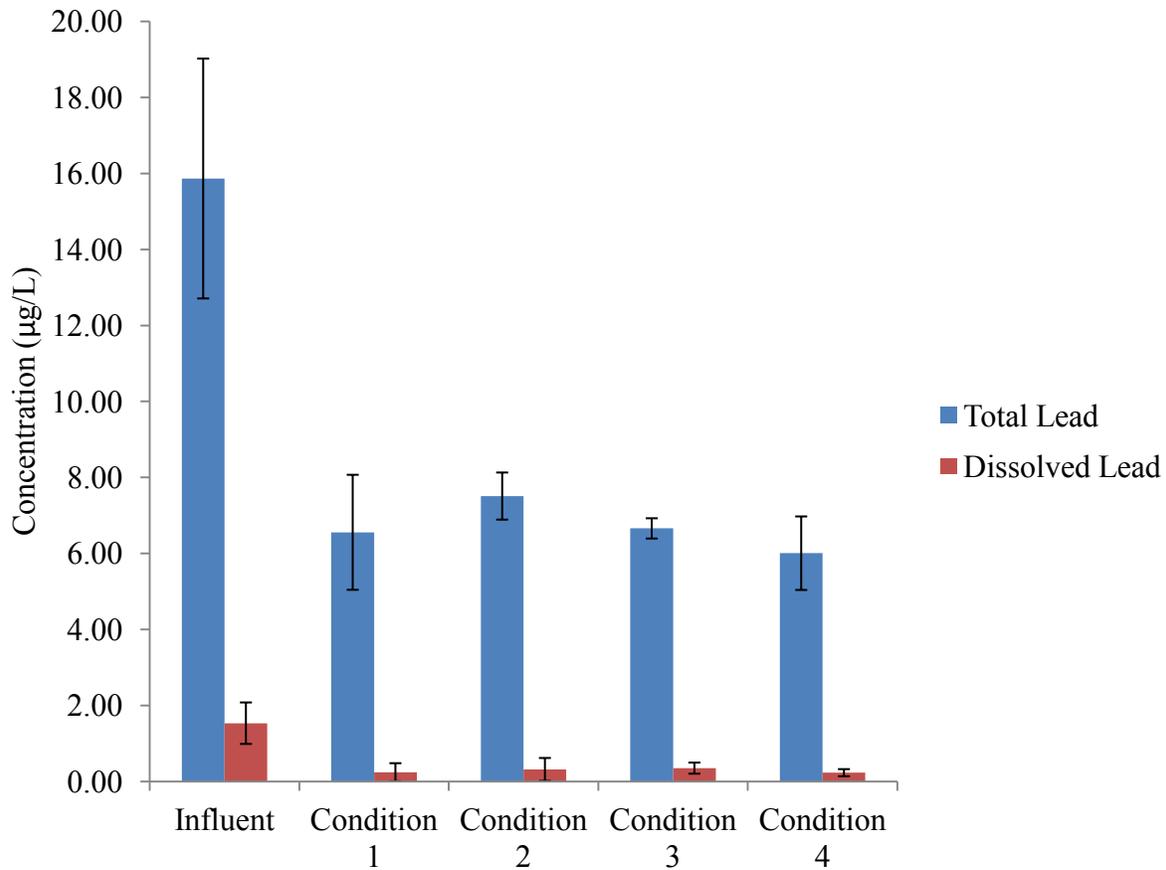


Figure 10. Average influent and effluent lead concentrations for all test dates.

Copper Removal/Export

Slight export of total copper was seen for all test conditions on every test date. Reduction of total copper was shown to be between -8 and -36 percent. Results for dissolved copper were slightly better with a reduction in concentration shown in some effluent samples. Removal ranged between -26 and 11 percent. No trends in removal/export were seen between test conditions. Figure 11 shows a comparison of average influent and effluent copper concentrations for all test dates.

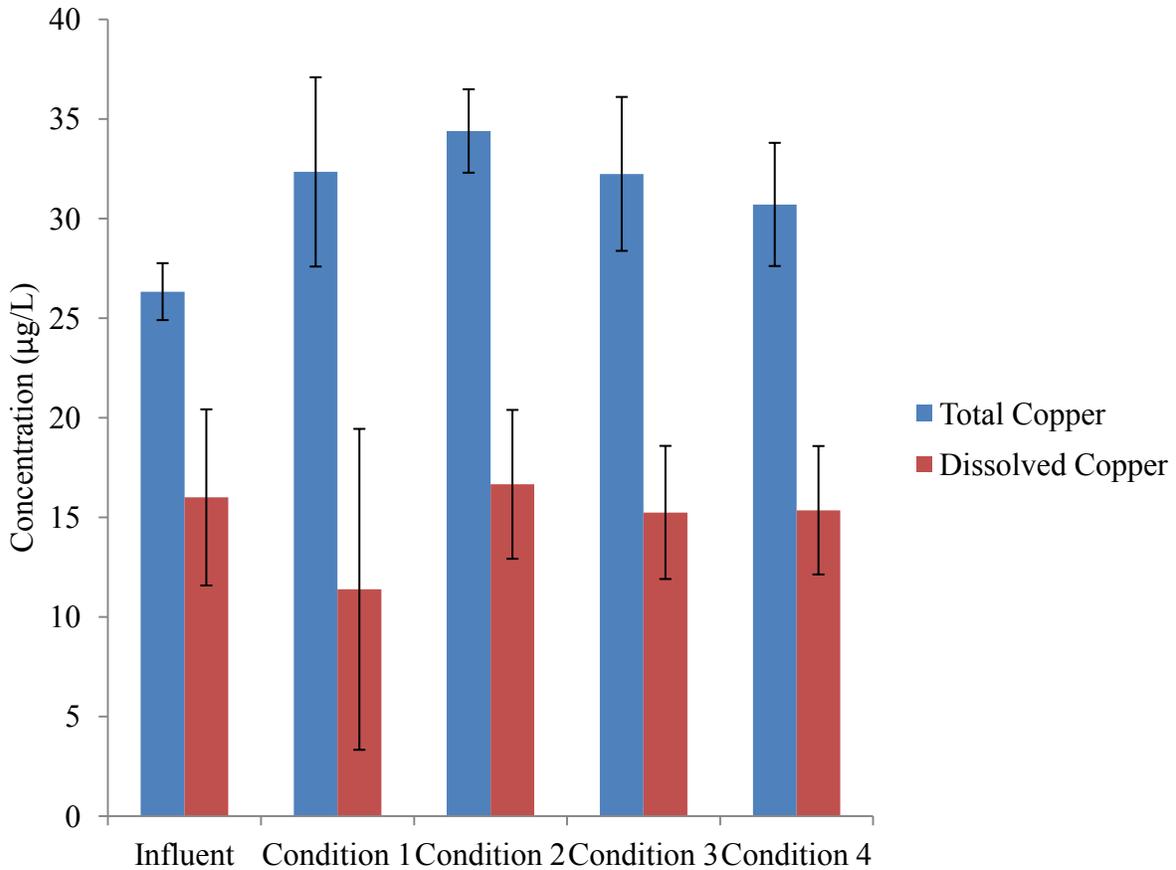


Figure 11. Average influent and effluent copper concentrations for all test dates.

It is also likely that raised total and dissolved copper concentrations found in effluent samples are directly related to immobilization of the BSM through the system. Suspended sediment can consist of a large percentage of structurally bound copper (Kadlec and Wallace, 2009). Recent research conducted (Arnold, 2005) suggests that toxicity of copper in aquatic systems is directly related to dissolved organic carbon (DOC) concentrations. Copper toxicity has been shown to be minimal when a 12:1 ratio of DOC to Copper is established in water systems. Effluent concentrations of DOC analyzed on the 12/28/11 test date were on average 26.1 ± 5.0 mg/L, which equates to a DOC:Cu ratio of roughly 2300. These results indicate while copper is initially leaching from the BSM, it does not pose a toxic hazard to aquatic species. These results were verified by a study conducted at the Washington State University

Extension Center (unpublished data). Percent survival of *Daphnia* (commonly used in toxicology evaluations) from effluent through a system with BSM specifications similar to this study showed a 100 percent survival rate after an exposure of 48 hours. Tests conducted with influent water low in DOC gave a 0 percent survival rate after this same 48 hour exposure.

Aluminum Mobilization

Total and dissolved aluminum was also analyzed in this study as it is the primary constituent in the water treatment residual used for phosphate removal. Substantial export of aluminum was found in the effluent samples of all test conditions. However, this is thought to be from immobilization of bioretention soil as elevated suspended solids concentrations were found in effluent samples. Figure 12 shows a comparison of average influent and effluent aluminum concentrations for all test dates.

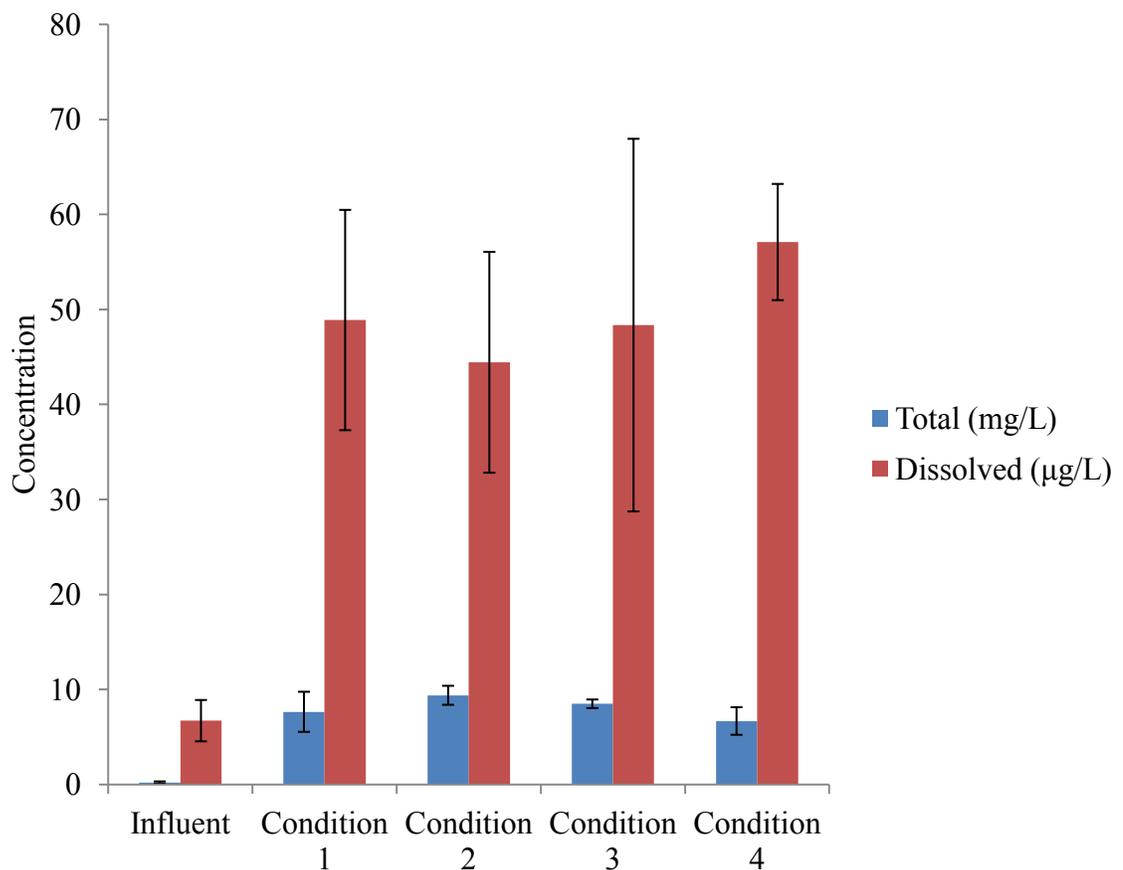


Figure 12. Average influent and effluent aluminum concentrations for all test dates.

Studies have shown only minimal leaching of aluminum from water treatment residuals when proper restraint of bioretention soil is implemented (Lucas and Greenway, 2011). Even with the high degree of immobilization found within this study, aluminum is not thought to be significantly toxic to aquatic species. The highest concentration of dissolved aluminum found within effluent samples (0.062 mg/L) was still below EPA standards for both acute, 0.75 mg/L, and chronic, 0.087 mg/L, toxicity (Lucas and Greenway, 2011). Results also show a gradual decline in export of aluminum during the duration of the experiment.

Implications for Early Establishment

While removal rates of zinc and lead were shown to be quite high during initial establishment of the system, export of copper is also shown. Leaching of copper is expected to diminish as more stormwater is delivered through the system. However, a high ratio of dissolved organic carbon to copper within effluent samples may make this copper less toxic to aquatic species. Further research is needed to confirm this phenomenon. Additionally inclusion of mulch within the system should further enhance already significant levels of removal of these heavy metals.

Implications for Design

Results of zinc and lead removal are consistent with reduction levels reported in many other bioretention studies. However, significant reductions of copper were also seen in these same studies. It appears that export of suspended sediment (BSM immobilization) found within this study may account for raised concentrations of copper found within effluent samples. While export of suspended sediment, and therefore copper, is expected to decrease overtime, further analysis will need to be conducted to verify these trends.

Toxicity of heavy metals is a function of water hardness. While Washington State has not developed toxicity criteria for lead, both zinc and copper measurements can be evaluated per WAC 173-201A-240. If a water hardness of 25 mg/L (Western Washington median value) is assumed, acute and chronic toxicity criteria for total zinc are 35 and 32 µg/L, respectively. Likewise, acute and chronic toxicity criteria for dissolved copper are 4.6 and 3.5 µg/L, respectively. By these criteria, effluent values for dissolved zinc in every test condition are significantly below both acute and chronic levels. On the other hand, effluent values for dissolved copper are still well above acute toxicity levels. However, the ratio of dissolved organic carbon to copper experienced by all test conditions may inhibit the toxicity of this copper to aquatic species. Further research should be conducted to evaluate this occurrence.

Research has shown enhanced metal reductions with the utilization of both saturation zone and WTR design features (Blecken et al., 2009; Mahmoud, 2011). This enhancement could further promote the utilization of these features in bioretention design. However, early results from this study are not conclusive. The possibility of these phenomena will need to be evaluated after extensive establishment of these systems.

Summary and Conclusion

The main purpose of this study was to further evaluate the effects of various bioretention design features on removal of nitrate and ortho-phosphate from stormwater runoff. However, removal efficiency of the BSM to filter and adsorb heavy metals was also analyzed. As a result of this study it was determined that the BSM utilized in this study can effectively remove both total and dissolved forms of zinc and lead even under relatively fast infiltration rates. However, both total and dissolved copper was leached from this BSM. Further evaluation of effluent DOC values indicate that the BSM DOC:Cu ratio may inhibit toxicity of this copper.

Results of this study represent what would be seen in an early establishment. A planned follow-up study will evaluate performance after significant establishment has been achieved.

Information provided will directly influence future design regulations required for bioretention utilization in Western Washington communities.

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APPENDIX

LABORATORY RESULTS



09 January 2012

Dr Joel Baker
UW Tacoma
326 East D Street
Tacoma, WA 98421

Subject: Soil Media

Enclosed are the analytical results for samples collected 12/14/2011.

A detailed Quality Control Data Review is included with the sample results for your review.

If you have any questions concerning this report, call me at (253)502-2130. Please note that the samples associated with this report will be discarded **3 months** from the date of this report unless notified.

Sincerely,

Lou A. Zboralski
Assistant Division Manager
Environmental Services Laboratory

cc. John Pelerine

Environmental Services Laboratory | 326 East D Street | Tacoma, Washington 98421-1801 | (253) 591-5588

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled
Cistern Influent	T112103-01	Water	14-Dec-11 04:00
Cistern Column 1	T112103-02	Water	14-Dec-11 04:00
Cistern Column 2	T112103-03	Water	14-Dec-11 04:00
Cistern Column 3	T112103-04	Water	14-Dec-11 04:00
Cistern Column 4	T112103-05	Water	14-Dec-11 04:00
Cistern Column 5	T112103-06	Water	14-Dec-11 04:00
Cistern Column 6	T112103-07	Water	14-Dec-11 04:00
Cistern Column 7	T112103-08	Water	14-Dec-11 04:00
Cistern Column 8	T112103-09	Water	14-Dec-11 04:00
Cistern Column 9	T112103-10	Water	14-Dec-11 04:00
Cistern Column 10	T112103-11	Water	14-Dec-11 04:00
Cistern Column 11	T112103-12	Water	14-Dec-11 04:00
Cistern Column 12	T112103-13	Water	14-Dec-11 04:00


Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

CONTRACT LABS

No contract labs were used to analyze these samples.

CHAIN OF CUSTODY

Standard Chain of Custody forms were filled out for these samples.

METHODS

The samples were analyzed according to EPA methods 6020A for Total and dissolved Metals, 353.2 for Nitrate/Nitrite, 365.1 for Ortho Phosphate, SM 4500-NH3-C for Ammonia, and COT-TN for Total Nitrogen.

SAMPLE STORAGE, PRESERVATION, & HOLDING TIMES

The samples were preserved and stored according to 40 CFR Part 136 Table II.

METHOD DETECTION LIMITS

All analytes are reported to the Method Detection Limit (MDL). Values greater than the MDL and less than the Practical Quantitation Limit (Reporting Limit or PQL) are reported for your information. Values may be qualified as estimated (J) as not as precise as values reported greater than the PQL (the low standard or 3 - 5 times the MDL).

METHOD BLANKS

Method blanks were analyzed at the required frequencies of the methods. There was a minimum of one Method Blank for each analytical method. All blank values were less than the Practical Quantitation Limits, or less than 1/5 of the level in the samples.

LABORATORY CONTROL SAMPLES

Laboratory Control Samples were analyzed with these samples for all parameters. The recoveries for all associated LCS were within the project limits.

DUPLICATE SAMPLE ANALYSIS

Duplicate analysis was performed with these samples. Relative percent differences were within the laboratory's limits.

DATA AVAILABILITY

All data associated with the samples contained in this report are archived at the Environmental Services Laboratory and are available upon request.

Center for Urban Waters - Environmental Services Lab

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.


Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Influent
T112103-01 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.403	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	1.04	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.344	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Aluminum, Dissolved	11.4	10.0	0.890	ug/L	03-Jan-12	03-Jan-12	6020A
Aluminum	93.6	10.0	1.02	ug/L	16-Dec-11	03-Jan-12	6020A
Arsenic, Dissolved	0.411	0.200	0.041	ug/L	03-Jan-12	03-Jan-12	6020A
Arsenic	0.515	0.500	0.0420	ug/L	16-Dec-11	03-Jan-12	6020A
Cadmium, Dissolved	0.143J	0.200	0.039	ug/L	03-Jan-12	03-Jan-12	6020A
Cadmium	0.0661J	0.500	0.0250	ug/L	16-Dec-11	03-Jan-12	6020A
Copper, Dissolved	18.8	0.200	0.038	ug/L	03-Jan-12	03-Jan-12	6020A
Copper	31.5	1.00	0.0400	ug/L	16-Dec-11	03-Jan-12	6020A
Lead, Dissolved	3.00	0.200	0.026	ug/L	03-Jan-12	03-Jan-12	6020A
Lead	14.3	1.00	0.120	ug/L	16-Dec-11	03-Jan-12	6020A
Nickel, Dissolved	0.488	0.200	0.017	ug/L	03-Jan-12	03-Jan-12	6020A
Nickel	0.641	1.00	0.0190	ug/L	16-Dec-11	03-Jan-12	6020A
Phosphorus	407	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A
Zinc, Dissolved	133	0.200	0.075	ug/L	03-Jan-12	03-Jan-12	6020A
Zinc	171	1.00	0.590	ug/L	16-Dec-11	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.


Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 1
T112103-02 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.100	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	4.28	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.101	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	858	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 2
T112103-03 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.136	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	4.31	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.127	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	822	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By 

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 3
T112103-04 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.120	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	4.27	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.111	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	831	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

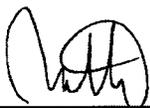
Reported:
09-Jan-12 14:20

Cistern Column 4
T112103-05 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.277	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	4.04	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.109	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	992	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

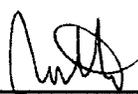
UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 09-Jan-12 14:20
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Cistern Column 5
T112103-06 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.264	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	3.59	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.102	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	665	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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 Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 6
T112103-07 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.273	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	3.45	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.0946	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	671	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

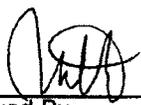


Reviewed By

UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 09-Jan-12 14:20
---	---	-------------------------------------

Cistern Column 7
T112103-08 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.302	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	3.40	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.0715	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	696	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Reviewed By 

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

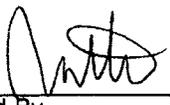
Reported:
09-Jan-12 14:20

Cistern Column 8
T112103-09 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.310	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	2.97	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.0643	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	577	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By 

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 9
T112103-10 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.315	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	3.25	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.0832	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	766	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

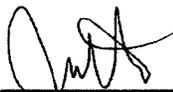
UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 10
T112103-11 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.145	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	3.79	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.131	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	712	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A



UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 11
T112103-12 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.151	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	3.52	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.141	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	624	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Cistern Column 12
T112103-13 (Water)
14-Dec-11 04:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	15-Dec-11	15-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.145	0.010	0.007	mg/L	15-Dec-11	15-Dec-11	EPA 353.2
Total Nitrogen	3.60	0.20	0.05	mg/L	20-Dec-11	20-Dec-11	COT-TN
Phosphate, Ortho	0.135	0.0100	0.0031	mg/L	15-Dec-11	15-Dec-11	365.1
Metals							
Phosphorus	676	100	48.0	ug/L	03-Jan-12	03-Jan-12	6020A



UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

**CONVENTIONAL - Quality Control
Environmental Services Laboratory**

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
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Batch 1151041 - Distillation

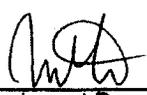
Blank (1151041-BLK1)				Prepared & Analyzed: 15-Dec-11					
Ammonia as N	ND	0.50	mg/L						
LCS (1151041-BS1)				Prepared & Analyzed: 15-Dec-11					
Ammonia as N	9.78	0.50	mg/L	10.0		98	79-127		

Batch 1151042 - Conventionals No-Prep

Blank (1151042-BLK1)				Prepared & Analyzed: 15-Dec-11					
Phosphate, Ortho	ND	0.0100	mg/L						
Duplicate (1151042-DUP1)				Source: T112103-01 Prepared & Analyzed: 15-Dec-11					
Phosphate, Ortho	0.350	0.0100	mg/L		0.344			2	20
Reference (1151042-SRM1)				Prepared & Analyzed: 15-Dec-11					
Phosphate, Ortho	0.151	0.0100	mg/L	0.156		97	90-110		

Batch 1151054 - Conventionals No-Prep

Blank (1151054-BLK1)				Prepared & Analyzed: 15-Dec-11					
Nitrate+Nitrite as N	0.009	0.010	mg/L						
Duplicate (1151054-DUP1)				Source: T112103-01 Prepared & Analyzed: 15-Dec-11					
Nitrate+Nitrite as N	0.405	0.010	mg/L		0.403			0.5	20
Reference (1151054-SRM1)				Prepared & Analyzed: 15-Dec-11					
Nitrate+Nitrite as N	1.00	0.010	mg/L	1.08		93	90-110		


Reviewed By

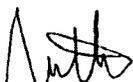
UW Tacoma
 326 East D Street
 Tacoma WA, 98421

Project: Soil Media
 Project Number: ENV-03007-04-04
 Project Manager: Dr Joel Baker

Reported:
 09-Jan-12 14:20

CONVENTIONAL - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1152023 - Conventionals No-Prep										
Blank (1152023-BLK1)										
Total Nitrogen	ND	0.20	mg/L							Prepared & Analyzed: 20-Dec-11
Duplicate (1152023-DUP1)										
Total Nitrogen	1.09	0.20	mg/L		1.04			5	20	Source: T112103-01 Prepared & Analyzed: 20-Dec-11
Reference (1152023-SRM1)										
Total Nitrogen	2.74	0.20	mg/L	2.60		105	75-125			Prepared & Analyzed: 20-Dec-11



 Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Metals - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
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Batch 1151043 - 3005A

Blank (1151043-BLK1)

Prepared: 16-Dec-11 Analyzed: 03-Jan-12

Aluminum	2.68	10.0	ug/L						J
Arsenic	ND	0.500	ug/L						
Cadmium	ND	0.500	ug/L						
Copper	0.0630	1.00	ug/L						J
Lead	ND	1.00	ug/L						
Nickel	ND	1.00	ug/L						
Zinc	ND	1.00	ug/L						

LCS (1151043-BS1)

Prepared: 16-Dec-11 Analyzed: 03-Jan-12

Aluminum	981	10.0	ug/L	920		107	80-120		
Arsenic	71.8	0.500	ug/L	66.0		109	80-120		
Cadmium	216	0.500	ug/L	212		102	80-120		
Copper	275	1.00	ug/L	255		108	80-120		
Lead	688	1.00	ug/L	668		103	80-120		
Nickel	875	1.00	ug/L	816		107	80-120		
Zinc	169	1.00	ug/L	159		106	80-120		

Batch 1201008 - Filtered

Blank (1201008-BLK1)

Prepared & Analyzed: 03-Jan-12

Aluminum, Dissolved	0.908	10.0	ug/L						J
Arsenic, Dissolved	ND	0.200	ug/L						
Cadmium, Dissolved	ND	0.200	ug/L						
Copper, Dissolved	ND	0.200	ug/L						
Lead, Dissolved	ND	0.200	ug/L						
Nickel, Dissolved	ND	0.200	ug/L						
Zinc, Dissolved	ND	0.200	ug/L						

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Metals - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
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Batch 1201008 - Filtered

LCS (1201008-BS1)				Prepared & Analyzed: 03-Jan-12					
Aluminum, Dissolved	1000	10.0	ug/L	1000		100	80-120		
Arsenic, Dissolved	47.3	0.200	ug/L	50.0		95	80-120		
Cadmium, Dissolved	24.4	0.200	ug/L	25.0		98	80-120		
Copper, Dissolved	123	0.200	ug/L	125		99	80-120		
Lead, Dissolved	14.9	0.200	ug/L	15.0		99	80-120		
Nickel, Dissolved	199	0.200	ug/L	200		100	80-120		
Zinc, Dissolved	99.3	0.200	ug/L	100		99	80-120		

Batch 1201013 - * DEFAULT PREP *****

Blank (1201013-BLK1)				Prepared & Analyzed: 03-Jan-12					
Phosphorus	ND	100	ug/L						

LCS (1201013-BS1)				Prepared & Analyzed: 03-Jan-12					
Phosphorus	4890	100	ug/L	5000		98	80-120		

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
09-Jan-12 14:20

Notes and Definitions

J The result is an estimated concentration.

DET Analyte DETECTED

ND Analyte NOT DETECTED at or above the reporting limit

NR Not Reported

dry Sample results reported on a dry weight basis

RPD Relative Percent Difference



Chain of Custody Record

Page 1 of 1

SAP Accounting		Project Name		Analysis/# of Containers		Samples Sent to:	
Lab #	Date	Time	Matrix	Grid	Composite	Sample ID	PO#
7112103		WSU-Puyallup Column Study		Brian Hite, Eric Palmer			
1	12-14	4am	water	X		Cistern Influent	
2						Column 1	
3						Column 2	
4						Column 3	
5						Column 4	
6						Column 5	
7						Column 6	
8						Column 7	
9						Column 8	
10						Column 9	
11						Column 10	
12						Column 11	
13						Column 13	
14							
15							
16							
Relinquished By (Signature):		Date/Time		Received By (Signature):		Date/Time	
Relinquished By (Signature):		Date/Time		Received for Analysis By (Signature):		Date/Time	
				Received for Laboratory By (Signature):		Date/Time	
				Remarks			

11-20-11
BC

Total Containers: 5
NO₃-NO₂, NH₃, TP, ICP
TN
SRP
Total metals: Al, As, Cd, Cu, Ni, Pb, Zn, Dissolved metals: Al, As, Cd, Cu, Ni, Pb, Zn

12-14 2pm
Remarks: Changed T Phos 365.4 to TP 6020A. Bill E



25 January 2012

Dr Joel Baker
UW Tacoma
326 East D Street
Tacoma, WA 98421

Subject: Soil Media

Enclosed are the analytical results for samples collected 12/21/2011.

A detailed Quality Control Data Review is included with the sample results for your review.

If you have any questions concerning this report, call me at (253)502-2130. Please note that the samples associated with this report will be discarded **3 months** from the date of this report unless notified.

Sincerely,

Assistant Division Manager
Environmental Services Laboratory

cc.

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled
Column 1	T112148-01	Water	21-Dec-11 12:00
Column 2	T112148-02	Water	21-Dec-11 12:00
Column 3	T112148-03	Water	21-Dec-11 12:00
Column 4	T112148-04	Water	21-Dec-11 12:00
Column 5	T112148-05	Water	21-Dec-11 12:00
Column 6	T112148-06	Water	21-Dec-11 12:00
Column 7	T112148-07	Water	21-Dec-11 12:00
Column 8	T112148-08	Water	21-Dec-11 12:00
Column 9	T112148-09	Water	21-Dec-11 12:00
Column 10	T112148-10	Water	21-Dec-11 12:00
Column 11	T112148-11	Water	21-Dec-11 12:00
Column 12	T112148-12	Water	21-Dec-11 12:00
Column DUP	T112148-13	Water	21-Dec-11 12:00
Cistern Influent	T112148-14	Water	21-Dec-11 12:00
DI Rinsate	T112148-15	Water	21-Dec-11 12:00

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

CONTRACT LABS

No contract labs were used to analyze these samples.

CHAIN OF CUSTODY

Standard Chain of Custody forms were filled out for these samples.

SAMPLE STORAGE, PRESERVATION, & HOLDING TIMES

The samples were preserved and stored according to 40 CFR Part 136 Table II.

METHOD DETECTION LIMITS

All analytes are reported to the Method Detection Limit (MDL). Values greater than the MDL and less than the Practical Quantitation Limit (Reporting Limit or PQL) are reported for your information. Values may be qualified as estimated (J) as not as precise as values reported greater than the PQL (the low standard or 3 - 5 times the MDL).

METHOD BLANKS

Method blanks were analyzed at the required frequencies of the methods. There was a minimum of one Method Blank for each analytical method. All blank values were less than the Practical Quantitation Limits, or less than 1/5 of the levels in the samples **except for Total Aluminum. Sample T112148-15 (DI Rinseate) is flagged as undetected (U) since it is less than 5X the blank value**

LABORATORY CONTROL SAMPLES

Laboratory Control Samples were analyzed with these samples for all parameters. The recoveries for all associated LCS were within the project limits.

DUPLICATE SAMPLE ANALYSIS

Duplicate analysis was performed with these samples. Relative percent differences were within the laboratory's limits.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE ANALYSIS

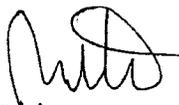
Matrix Spike and/or Matrix Spike Duplicate analysis was performed with these samples. The recoveries were within the project limits. The spike level for aluminum was less than the amount in the sample which resulted in a high recovery.

ICP SERIAL DILUTIONS

The Column 1 sample (T112148-01) analyzed at a five-fold dilution for Total Metals. The percent differences of the diluted samples when compared to the undiluted samples were less than 10% for the analytes with concentrations greater than 50 times the method detection limit.

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UW Tacoma
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Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

DATA AVAILABILITY

All data associated with the samples contained in this report are archived at the Environmental Services Laboratory and are available upon request.

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Column 1
T112148-01 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.294	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	3.46	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.121	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	83.6	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	10200	10.0	1.00	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.9	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	35.7	1.00	0.400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.238	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	8.85	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	559	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	3.60	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	30.3	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

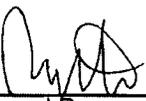
Reported:
25-Jan-12 11:39

Column 2
T112148-02 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.333	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	3.00	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.138	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	57.7	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	9610	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	13.0	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	35.0	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.215	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	7.90	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	477	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	2.81	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	27.4	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

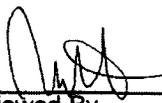
Reported:
25-Jan-12 11:39

Column 3
T112148-03 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.344	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	3.21	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.134	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	45.5	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	9920	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	13.4	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	35.4	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.091J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	7.85	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	520	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	2.30	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	27.0	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Column 4
T112148-04 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.693	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.76	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.101	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	56.6	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	9830	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	11.8	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	31.1	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.129J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	7.86	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	473	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	1.99	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	28.2	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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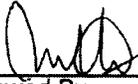
UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 25-Jan-12 11:39
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Column 5
T112148-05 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.701	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	3.09	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.0811	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	56.9	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	11500	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.9	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	36.6	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.110J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	8.90	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	480	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	1.96	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	32.9	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Column 6
T112148-06 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.728	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.86	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.0806	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	33.8	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	10200	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.5	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	34.0	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.114J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	7.75	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	417	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	2.13	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	29.3	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Column 7
T112148-07 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.634	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.43	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.0751	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	40.7	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	10100	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.7	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	30.5	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.220	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	6.78	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	394	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	3.08	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	25.4	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Column 8
T112148-08 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.648	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.34	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.0657	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	91.3	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	8540	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.4	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	30.2	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	1.08	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	6.74	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	306	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	16.7	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	25.8	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Column 9
T112148-09 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.625	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.32	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.0834	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	45.9	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	7890	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	11.4	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	28.7	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.102J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	6.36	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	359	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	1.22	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	23.1	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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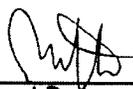
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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Column 10
T112148-10 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.311	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.68	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.141	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	35.5	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	8580	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	11.8	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	33.1	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.116J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	7.01	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	467	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	3.14	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	24.3	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A


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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

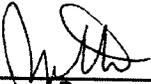
Reported:
25-Jan-12 11:39

Column 11
T112148-11 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.284	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.78	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.133	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	63.4	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	7310	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.6	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	32.0	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.169J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	6.45	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	438	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	4.41	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	21.6	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.


Reviewed By _____

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Column 12
T112148-12 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.278	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.98	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.143	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	83.9	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	9020	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.4	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	33.5	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.139J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	7.62	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	498	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	2.58	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	26.4	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

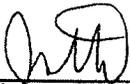
Reported:
25-Jan-12 11:39

Column DUP
T112148-13 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.700	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	2.75	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.103	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	45.1	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	12600	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.3	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	34.1	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.155J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	8.24	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	464	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	2.96	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	31.2	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By _____

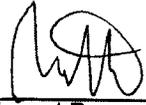
UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 25-Jan-12 11:39
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Cistern Influent
T112148-14 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.667	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	1.39	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.388	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	9.17J	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	166	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	12.6	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	26.0	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	2.07	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	18.3	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	485	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	173	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	249	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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 Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

DI Rinsate
T112148-15 (Water)
21-Dec-11 12:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	22-Dec-11	22-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.009J	0.010	0.007	mg/L	22-Dec-11	22-Dec-11	EPA 353.2
Total Nitrogen	0.05	0.20	0.05	mg/L	22-Dec-11	23-Dec-11	COT-TN
Phosphate, Ortho	0.0048J	0.0100	0.0031	mg/L	22-Dec-11	22-Dec-11	365.1
Metals							
Aluminum, Dissolved	1.79J	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	1.02U	10.0	1.02	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	0.086J	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	0.0400U	1.00	0.0400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.026U	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	0.120U	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	48.0U	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	0.382	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	0.590U	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
 326 East D Street
 Tacoma WA, 98421

Project: Soil Media
 Project Number: ENV-03007-04-04
 Project Manager: Dr Joel Baker

Reported:
 25-Jan-12 11:39

CONVENTIONAL - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC %REC	%REC Limits	RPD	RPD Limit	Notes
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Batch 1152035 - Distillation

Blank (1152035-BLK1)	Prepared & Analyzed: 22-Dec-11									
Ammonia as N	ND	0.50	mg/L							
LCS (1152035-BS1)	Prepared & Analyzed: 22-Dec-11									
Ammonia as N	9.78	0.50	mg/L	10.0		98	79-127			

Batch 1152036 - Conventionals No-Prep

Blank (1152036-BLK1)	Prepared & Analyzed: 22-Dec-11									
Phosphate, Ortho	ND	0.0100	mg/L							
Duplicate (1152036-DUP1)	Source: T112148-01 Prepared & Analyzed: 22-Dec-11									
Phosphate, Ortho	0.122	0.0100	mg/L		0.121			0.8	20	
Reference (1152036-SRM1)	Prepared & Analyzed: 22-Dec-11									
Phosphate, Ortho	0.154	0.0100	mg/L	0.156		99	90-110			

Batch 1152040 - Conventionals No-Prep

Blank (1152040-BLK1)	Prepared & Analyzed: 22-Dec-11									
Nitrate+Nitrite as N	ND	0.010	mg/L							
Duplicate (1152040-DUP1)	Source: T112148-01 Prepared & Analyzed: 22-Dec-11									
Nitrate+Nitrite as N	0.295	0.010	mg/L		0.294			0.3	20	
Reference (1152040-SRM1)	Prepared & Analyzed: 22-Dec-11									
Nitrate+Nitrite as N	1.07	0.010	mg/L	1.08		99	90-110			

Center for Urban Waters - Environmental Services Lab

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 Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

CONVENTIONAL - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
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Batch 1152045 - Conventionals No-Prep

Blank (1152045-BLK1)

Prepared: 22-Dec-11 Analyzed: 23-Dec-11

Total Nitrogen ND 0.20 mg/L

Duplicate (1152045-DUP1)

Source: T112148-01

Prepared: 22-Dec-11 Analyzed: 23-Dec-11

Total Nitrogen 3.36 0.20 mg/L 3.46 3 20

Reference (1152045-SRM1)

Prepared: 22-Dec-11 Analyzed: 23-Dec-11

Total Nitrogen 2.65 0.20 mg/L 2.60 102 75-125

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
 326 East D Street
 Tacoma WA, 98421

Project: Soil Media
 Project Number: ENV-03007-04-04
 Project Manager: Dr Joel Baker

Reported:
 25-Jan-12 11:39

Metals - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
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Batch 1152039 - 3005A

Blank (1152039-BLK1)		Prepared: 04-Jan-12 Analyzed: 12-Jan-12							
Aluminum	1.10	10.0	ug/L						
Copper	ND	1.00	ug/L						
Lead	ND	1.00	ug/L						
Zinc	ND	1.00	ug/L						

LCS (1152039-BS1)		Prepared: 04-Jan-12 Analyzed: 12-Jan-12							
Aluminum	1030	10.0	ug/L			80-120			
Copper	254	1.00	ug/L			80-120			
Lead	770	1.00	ug/L			80-120			
Zinc	166	1.00	ug/L			80-120			

Duplicate (1152039-DUP1)		Source: T112148-01		Prepared: 04-Jan-12 Analyzed: 12-Jan-12					
Aluminum	9680	10.0	ug/L		10200		5	20	
Copper	35.4	1.00	ug/L		35.7		0.8	20	
Lead	8.65	1.00	ug/L		8.85		2	20	
Zinc	29.5	1.00	ug/L		30.3		3	20	

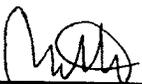
Matrix Spike (1152039-MS1)		Source: T112148-01		Prepared: 04-Jan-12 Analyzed: 12-Jan-12					
Aluminum	12200	10.0	ug/L	400	10200	515	70-130		
Copper	429	1.00	ug/L	400	35.7	98	70-130		
Lead	411	1.00	ug/L	400	8.85	101	70-130		
Zinc	428	1.00	ug/L	400	30.3	99	70-130		

Batch 1201014 - 3005A

Blank (1201014-BLK1)		Prepared: 03-Jan-12 Analyzed: 10-Jan-12							
Phosphorus	98.4	100	ug/L						

Center for Urban Waters - Environmental Services Lab

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 Reviewed By _____

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Metals - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
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Batch 1201014 - 3005A

LCS (1201014-BS1)

Prepared: 03-Jan-12 Analyzed: 10-Jan-12

Phosphorus	4560	100	ug/L	5000		91	80-120			
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Batch 1201023 - Filtered

Blank (1201023-BLK1)

Prepared & Analyzed: 12-Jan-12

Aluminum, Dissolved	ND	10.0	ug/L							
Copper, Dissolved	ND	0.200	ug/L							
Lead, Dissolved	ND	0.200	ug/L							
Zinc, Dissolved	ND	0.200	ug/L							

LCS (1201023-BS1)

Prepared & Analyzed: 12-Jan-12

Aluminum, Dissolved	974	10.0	ug/L	1000		97	80-120			
Copper, Dissolved	116	0.200	ug/L	125		93	80-120			
Lead, Dissolved	14.5	0.200	ug/L	15.0		97	80-120			
Zinc, Dissolved	96.0	0.200	ug/L	100		96	80-120			

Duplicate (1201023-DUP1)

Source: T112148-01

Prepared & Analyzed: 12-Jan-12

Aluminum, Dissolved	83.4	10.0	ug/L		83.6			0.3	20	
Copper, Dissolved	13.2	0.200	ug/L		12.9			3	20	
Lead, Dissolved	0.245	0.200	ug/L		0.238			3	20	
Zinc, Dissolved	3.97	0.200	ug/L		3.60			10	20	

Matrix Spike (1201023-MS1)

Source: T112148-01

Prepared & Analyzed: 12-Jan-12

Aluminum, Dissolved	195	10.0	ug/L	100	83.6	111	70-130			
Copper, Dissolved	102	0.200	ug/L	100	12.9	89	70-130			
Lead, Dissolved	94.9	0.200	ug/L	100	0.238	95	70-130			
Zinc, Dissolved	99.3	0.200	ug/L	100	3.60	96	70-130			

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:39

Notes and Definitions

J The result is an estimated concentration.

DET Analyte DETECTED

ND Analyte NOT DETECTED at or above the reporting limit

NR Not Reported

dry Sample results reported on a dry weight basis

RPD Relative Percent Difference



Chain of Custody Record

Page 1 of 1

SAP Accounting		Project Name			Analysis / # of Containers					Samples Sent to:			
Samplers (Print)		WSU-Puyallup Column Study											
Work Order	Date	Time	Matrix	Grb	Composite	Sample ID	Total Containers	Dissolved metals Cu, Pb, Zn, Al	Total metals Cu, Pb, Zn, Al	SRP	TN	NO ₃ , NO ₂ , NH ₃ , TP	Remarks
1112-139	12-21	12am	water	X		Column 1	5	X	X	X	X	X	
- 2						Column 2	5						
- 3						Column 3	5						
- 4						Column 4	5						
- 5						Column 5	5						
- 6						Column 6	5						
- 7						Column 7	5						
- 8						Column 8	5						
- 9						Column 9	5						
- 10						Column 10	5						
- 11						Column 11	5						
- 12						Column 12	5						
- 13						Column Duplicate	5						
- 14						Cistern Influent	5						
- 15						DI Rinse	5						
- 16													
Relinquished By (Signature):		Date/Time		Received By (Signature):		Date/Time		Relinquished By (Signature):		Date/Time		Received for Laboratory By (Signature):	
										12-21-11		1500 Bill Esmerin	
Relinquished By (Signature):		Date/Time		Received for Analysis By (Signature):		Date/Time		Remarks					



25 January 2012

Dr Joel Baker
UW Tacoma
326 East D Street
Tacoma, WA 98421

Subject: Soil Media

Enclosed are the analytical results for samples collected 12/27/2011.

A detailed Quality Control Data Review is included with the sample results for your review.

If you have any questions concerning this report, call me at (253)502-2130. Please note that the samples associated with this report will be discarded **3 months** from the date of this report unless notified.

Sincerely,

Assistant Division Manager
Environmental Services Laboratory

cc.

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled
Column 1	T112196-01	Water	27-Dec-11 18:00
Column 2	T112196-02	Water	27-Dec-11 18:00
Column 3	T112196-03	Water	27-Dec-11 18:00
Column 4	T112196-04	Water	27-Dec-11 18:00
Column 5	T112196-05	Water	27-Dec-11 18:00
Column 6	T112196-06	Water	27-Dec-11 18:00
Column 7	T112196-07	Water	27-Dec-11 18:00
Column 8	T112196-08	Water	27-Dec-11 18:00
Column 9	T112196-09	Water	27-Dec-11 18:00
Column 10	T112196-10	Water	27-Dec-11 18:00
Column 11	T112196-11	Water	27-Dec-11 18:00
Column 12	T112196-12	Water	27-Dec-11 18:00
Cistern Influent	T112196-13	Water	27-Dec-11 18:00

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

CONTRACT LABS

No contract labs were used to analyze these samples.

CHAIN OF CUSTODY

Standard Chain of Custody forms were filled out for these samples.

SAMPLE STORAGE, PRESERVATION, & HOLDING TIMES

The samples were preserved and stored according to 40 CFR Part 136 Table II.

METHOD DETECTION LIMITS

All analytes are reported to the Method Detection Limit (MDL). Values greater than the MDL and less than the Practical Quantitation Limit (Reporting Limit or PQL) are reported for your information. Values may be qualified as estimated (J) as not as precise as values reported greater than the PQL (the low standard or 3 - 5 times the MDL).

METHOD BLANKS

Method blanks were analyzed at the required frequencies of the methods. There was a minimum of one method blank for each analytical method. All blank values were less than the Practical Quantitation Limit.

LABORATORY CONTROL SAMPLES

Laboratory Control Samples were analyzed with these samples for all parameters. The recoveries for all associated LCS were within the project limits.

DUPLICATE SAMPLE ANALYSIS

Duplicate analysis was performed with these samples. Relative percent differences were within the laboratory's limits.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE ANALYSIS

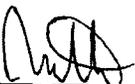
Matrix Spike and/or Matrix Spike Duplicate analysis was performed with these samples. The recoveries were within the project limits. The spike level for aluminum was less than the amount in the sample which resulted in a high recovery.

DATA AVAILABILITY

All data associated with the samples contained in this report are archived at the Environmental Services Laboratory and are available upon request.

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

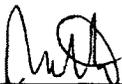
Reported:
25-Jan-12 11:03

Column 1
T112196-01 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.334	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.69	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Dissolved Organic Carbon	17.9	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM5310B
Total Organic Carbon	32.9	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM 5310B
Phosphate, Ortho	0.132	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Aluminum, Dissolved	42.2	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	7260	10.0	1.00	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	19.0	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	34.8	1.00	0.400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.569	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	6.25	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	476	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	3.38	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	21.8	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Column 2
T112196-02 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.357	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.55	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.144	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	418	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A

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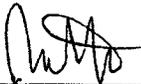


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UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 25-Jan-12 11:03
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Column 3
T112196-03 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.368	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.52	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.133	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	409	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A



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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Column 4
T112196-04 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.760	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.31	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Dissolved Organic Carbon	18.1	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM5310B
Total Organic Carbon	20.9	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM 5310B
Phosphate, Ortho	0.107	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Aluminum, Dissolved	31.2	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	8630	10.0	1.00	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	19.4	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	36.7	1.00	0.400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.168J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	6.94	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	418	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	2.42	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	26.5	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Tacoma WA, 98421

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Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Column 5
T112196-05 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.832	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.79	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.0722	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	577	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A

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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

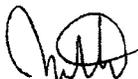
Reported:
25-Jan-12 11:03

Column 6
T112196-06 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.908	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	3.15	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.0801	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	732	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A

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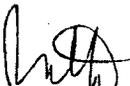


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Column 7
T112196-07 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.683	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.14	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Dissolved Organic Carbon	18.2	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM5310B
Total Organic Carbon	24.5	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM 5310B
Phosphate, Ortho	0.0744	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Aluminum, Dissolved	25.7	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	7770	10.0	1.00	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	18.8	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	34.6	1.00	0.400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.187J	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	6.15	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	298	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	4.80	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	23.2	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A



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Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Column 8
T112196-08 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.742	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.15	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.0697	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	353	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A

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Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Column 9
T112196-09 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.709	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.07	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.101	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	338	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A

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Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Column 10
T112196-10 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.341	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.46	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Dissolved Organic Carbon	22.3	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM5310B
Total Organic Carbon	26.1	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM 5310B
Phosphate, Ortho	0.150	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Aluminum, Dissolved	60.3	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	6170	10.0	1.00	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	18.7	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	32.1	1.00	0.400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	0.328	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	5.89	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	426	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	7.26	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	19.6	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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Project Manager: Dr Joel Baker

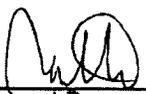
Reported:
25-Jan-12 11:03

Column 11
T112196-11 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.331	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.40	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.141	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	389	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A

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Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Column 12
T112196-12 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.327	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	2.23	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Phosphate, Ortho	0.151	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Phosphorus	424	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A

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Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Cistern Influent
T112196-13 (Water)
27-Dec-11 18:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	29-Dec-11	29-Dec-11	4500-NH3 C
Nitrate+Nitrite as N	0.737	0.010	0.007	mg/L	29-Dec-11	29-Dec-11	EPA 353.2
Total Nitrogen	1.26	0.20	0.05	mg/L	30-Dec-11	30-Dec-11	COT-TN
Dissolved Organic Carbon	3.28	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM5310B
Total Organic Carbon	3.09	1.00	0.13	mg/L	30-Dec-11	30-Dec-11	SM 5310B
Phosphate, Ortho	0.350	0.0100	0.0031	mg/L	29-Dec-11	29-Dec-11	365.1
Metals							
Aluminum, Dissolved	5.04J	10.0	0.890	ug/L	12-Jan-12	12-Jan-12	6020A
Aluminum	88.2	10.0	1.00	ug/L	04-Jan-12	12-Jan-12	6020A
Copper, Dissolved	21.0	0.200	0.038	ug/L	12-Jan-12	12-Jan-12	6020A
Copper	27.9	1.00	0.400	ug/L	04-Jan-12	12-Jan-12	6020A
Lead, Dissolved	1.55	0.200	0.026	ug/L	12-Jan-12	12-Jan-12	6020A
Lead	12.3	1.00	0.120	ug/L	04-Jan-12	12-Jan-12	6020A
Phosphorus	397	100	48.0	ug/L	03-Jan-12	10-Jan-12	6020A
Zinc, Dissolved	177	0.200	0.075	ug/L	12-Jan-12	12-Jan-12	6020A
Zinc	213	1.00	0.590	ug/L	04-Jan-12	12-Jan-12	6020A

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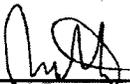
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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

CONVENTIONAL - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
Batch 1153030 - Distillation									
Blank (1153030-BLK1)					Prepared & Analyzed: 29-Dec-11				
Ammonia as N	ND	0.50	mg/L						
LCS (1153030-BS1)					Prepared & Analyzed: 29-Dec-11				
Ammonia as N	9.89	0.50	mg/L	10.0		99	79-127		
Batch 1153033 - Conventionals No-Prep									
Blank (1153033-BLK1)					Prepared & Analyzed: 29-Dec-11				
Phosphate, Ortho	ND	0.0100	mg/L						
Duplicate (1153033-DUP1)					Source: T112196-01 Prepared & Analyzed: 29-Dec-11				
Phosphate, Ortho	0.133	0.0100	mg/L		0.132		0.8	20	
Reference (1153033-SRM1)					Prepared & Analyzed: 29-Dec-11				
Phosphate, Ortho	0.156	0.0100	mg/L	0.156		100	90-110		
Batch 1153043 - Conventionals No-Prep									
Blank (1153043-BLK1)					Prepared & Analyzed: 29-Dec-11				
Nitrate+Nitrite as N	ND	0.010	mg/L						
Duplicate (1153043-DUP1)					Source: T112196-01 Prepared & Analyzed: 29-Dec-11				
Nitrate+Nitrite as N	0.335	0.010	mg/L		0.334		0.3	20	
Reference (1153043-SRM1)					Prepared & Analyzed: 29-Dec-11				
Nitrate+Nitrite as N	1.12	0.010	mg/L	1.08		104	90-110		


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326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

CONVENTIONAL - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC %REC	%REC Limits	RPD RPD	RPD Limit	Notes
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Batch 1153046 - Conventionals No-Prep

Blank (1153046-BLK1) Prepared & Analyzed: 30-Dec-11

Total Nitrogen 0.06 0.20 mg/L

Reference (1153046-SRM1) Prepared & Analyzed: 30-Dec-11

Total Nitrogen 2.87 0.20 mg/L 2.60 110 75-125

Batch 1153047 - Conventionals No-Prep

Blank (1153047-BLK1) Prepared & Analyzed: 30-Dec-11

Dissolved Organic Carbon 0.61 1.00 mg/L

Total Organic Carbon 0.61 1.00 mg/L

LCS (1153047-BS1) Prepared & Analyzed: 30-Dec-11

Dissolved Organic Carbon 9.76 1.00 mg/L 10.0 98 85-115

Total Organic Carbon 9.76 1.00 mg/L 10.0 98 85-115

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Project: Soil Media
 Project Number: ENV-03007-04-04
 Project Manager: Dr Joel Baker

Reported:
 25-Jan-12 11:03

Metals - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD Limit	Notes
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Batch 1152039 - 3005A

Blank (1152039-BLK1)		Prepared: 04-Jan-12 Analyzed: 12-Jan-12							
Aluminum	1.10	10.0	ug/L						J
Copper	ND	1.00	ug/L						
Lead	ND	1.00	ug/L						
Zinc	ND	1.00	ug/L						

LCS (1152039-BS1)		Prepared: 04-Jan-12 Analyzed: 12-Jan-12							
Aluminum	1030	10.0	ug/L			80-120			
Copper	254	1.00	ug/L			80-120			
Lead	770	1.00	ug/L			80-120			
Zinc	166	1.00	ug/L			80-120			

Batch 1201022 - * DEFAULT PREP *****

Blank (1201022-BLK1)		Prepared: 03-Jan-12 Analyzed: 10-Jan-12							
Phosphorus	89.1	100	ug/L						

LCS (1201022-BS1)		Prepared: 03-Jan-12 Analyzed: 10-Jan-12							
Phosphorus	4370	100	ug/L	5000		87	80-120		

Batch 1201023 - Filtered

Blank (1201023-BLK1)		Prepared & Analyzed: 12-Jan-12							
Aluminum, Dissolved	ND	10.0	ug/L						
Copper, Dissolved	ND	0.200	ug/L						
Lead, Dissolved	ND	0.200	ug/L						
Zinc, Dissolved	ND	0.200	ug/L						


 Reviewed By _____

UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 25-Jan-12 11:03
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Metals - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
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Batch 1201023 - Filtered

LCS (1201023-BS1)	Prepared & Analyzed: 12-Jan-12									
Aluminum, Dissolved	974	10.0	ug/L	1000		97	80-120			
Copper, Dissolved	116	0.200	ug/L	125		93	80-120			
Lead, Dissolved	14.5	0.200	ug/L	15.0		97	80-120			
Zinc, Dissolved	96.0	0.200	ug/L	100		96	80-120			

Center for Urban Waters - Environmental Services Lab

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UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 11:03

Notes and Definitions

J The result is an estimated concentration.

DET Analyte DETECTED

ND Analyte NOT DETECTED at or above the reporting limit

NR Not Reported

dry Sample results reported on a dry weight basis

RPD Relative Percent Difference



Chain of Custody Record

Send Results & Invoice to:
Environmental Services Laboratory
326 East D Street
Tacoma, WA 98421
(253) 502-2130
PO#:

SAP Accounting		Project Name		Analysis/# of Containers		Samples Sent to:									
Samplers (Print)		Date	Time	Matrix	Grab	Composite	Sample ID								
KM ² 28 DEC 11 Work Order T112196-01		12-27	6pm	water	X		Column 1								
		02					Column 2								
		03					Column 3								
		04					Column 4								
		05					Column 5								
		06					Column 6								
		07					Column 7								
		08					Column 8								
		09					Column 9								
		10					Column 10								
		11					Column 11								
		12					Column 13								
		13					Eastern Influent								
		14													
		15													
		16													
Relinquished By (Signature):		Date/Time		Received By (Signature):		Date/Time		Relinquished By (Signature):		Date/Time		Received for Laboratory By (Signature):			
												12-28 140		Ken Nelson 13:40	
Relinquished By (Signature):		Date/Time		Received for Analysis By (Signature):		Date/Time		Remarks							



25 January 2012

Dr Joel Baker
UW Tacoma
326 East D Street
Tacoma, WA 98421

Subject: Soil Media

Enclosed are the analytical results for samples collected 01/02/2012.

A detailed Quality Control Data Review is included with the sample results for your review.

If you have any questions concerning this report, call me at (253)502-2130. Please note that the samples associated with this report will be discarded **3 months** from the date of this report unless notified.

Sincerely,

Assistant Division Manager
Environmental Services Laboratory

cc.

Environmental Services Laboratory | 326 East D Street | Tacoma, Washington 98421-1801 | (253) 591-5588

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled
Column 1	T201021-01	Water	02-Jan-12 17:00
Column 2	T201021-02	Water	02-Jan-12 17:00
Column 3	T201021-03	Water	02-Jan-12 17:00
Column 4	T201021-04	Water	02-Jan-12 17:00
Column 5	T201021-05	Water	02-Jan-12 17:00
Column 6	T201021-06	Water	02-Jan-12 17:00
Column 7	T201021-07	Water	02-Jan-12 17:00
Column 8	T201021-08	Water	02-Jan-12 17:00
Column 9	T201021-09	Water	02-Jan-12 17:00
Column 10	T201021-10	Water	02-Jan-12 17:00
Column 11	T201021-11	Water	02-Jan-12 17:00
Column 12	T201021-12	Water	02-Jan-12 17:00
Column DUP	T201021-13	Water	02-Jan-12 17:00
Column INF	T201021-14	Water	02-Jan-12 17:00

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

CONTRACT LABS

No contract labs were used to analyze these samples.

CHAIN OF CUSTODY

Standard Chain of Custody forms were filled out for these samples.

SAMPLE STORAGE, PRESERVATION, & HOLDING TIMES

The samples were preserved and stored according to 40 CFR Part 136 Table II.

METHOD DETECTION LIMITS

All analytes are reported to the Method Detection Limit (MDL). Values greater than the MDL and less than the Practical Quantitation Limit (Reporting Limit or PQL) are reported for your information. Values may be qualified as estimated (J) as not as precise as values reported greater than the PQL (the low standard or 3 - 5 times the MDL).

METHOD BLANKS

Method blanks were analyzed at the required frequencies of the methods. There was a minimum of one Method Blank for each analytical method. All blank values were less than the Practical Quantitation Limits **except dissolved aluminum. Sample T201021-14 is flagged as estimated (J) as it was less than 5X the blank level.**

LABORATORY CONTROL SAMPLES

Laboratory Control Samples were analyzed with these samples for all parameters. The recoveries for all associated LCS were within the project limits.

DUPLICATE SAMPLE ANALYSIS

Duplicate analysis was performed with these samples. Relative percent differences were within the laboratory's limits.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE ANALYSIS

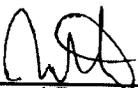
Matrix Spike and/or Matrix Spike Duplicate analysis was performed with these samples. The recoveries were within the project limits.

DATA AVAILABILITY

All data associated with the samples contained in this report are archived at the Environmental Services Laboratory and are available upon request.

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Column 1
T201021-01 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.92	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.164	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	2.05	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.141	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	47.2	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	6060	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	13.1	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	27.2	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.194J	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	5.52	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	388	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	3.65	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	18.0	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Column 2
T201021-02 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.191	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	1.98	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.152	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	37.8	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	5640	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	13.6	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	27.2	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.288	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	5.06	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	391	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	2.16	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	17.3	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Column 3
T201021-03 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.180	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	2.06	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.141	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	41.5	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	5530	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	13.6	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	26.2	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.174J	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	5.08	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	356	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	2.98	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	16.9	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

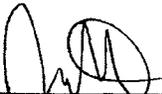
Reported:
25-Jan-12 10:34

Column 4
T201021-04 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.411	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	2.14	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.113	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	45.0	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	7240	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	17.0	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	28.8	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	1.22	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	6.51	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	373	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	17.5	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	21.5	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 25-Jan-12 10:34
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Column 5
T201021-05 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.431	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	2.62	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.0887	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	55.0	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	9430	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	19.8	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	34.4	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.236	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	7.84	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	457	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	3.33	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	27.5	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

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326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Column 6
T201021-06 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.425	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	2.69	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.0839	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	59.0	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	10300	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	17.7	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	34.6	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.532	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	7.91	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	436	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	9.90	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	28.4	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Column 7
T201021-07 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.342	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	1.99	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.0838	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	86.5	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	8250	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	12.1	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	30.2	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.286	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	6.17	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	380	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	4.20	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	23.4	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

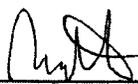
Reported:
25-Jan-12 10:34

Column 8
T201021-08 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.299	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	1.87	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.106	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	61.6	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	7610	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	16.6	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	29.5	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.729	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	6.47	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	380	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	12.2	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	21.5	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

Center for Urban Waters - Environmental Services Lab

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Reviewed By

UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

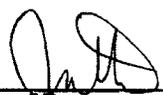
Reported:
25-Jan-12 10:34

Column 9
T201021-09 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.373	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	2.05	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.0975	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	32.0	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	8070	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	15.6	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	31.0	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.170J	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	6.59	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	344	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	1.78	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	23.3	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

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UW Tacoma
326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Column 10
T201021-10 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.178	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	1.84	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.168	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	54.7	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	5770	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	15.1	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	27.3	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.276	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	5.24	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	444	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	3.53	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	16.6	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

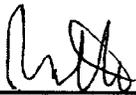
Reported:
25-Jan-12 10:34

Column 11
T201021-11 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.07U	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.183	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	1.95	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.152	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	54.6	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	5170	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	14.5	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	27.0	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.169J	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	4.90	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	358	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	2.92	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	15.2	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

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Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

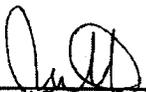
Reported:
25-Jan-12 10:34

Column 12
T201021-12 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.92	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.175	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	1.91	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.160	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	40.8	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	5660	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	15.7	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	27.2	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.217	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	5.17	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	418	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	2.57	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	16.8	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

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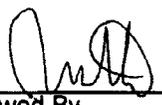
UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 25-Jan-12 10:34
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Column DUP
T201021-13 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	11.2	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.181	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	2.05	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.168	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	247	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	5640	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	12.7	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	28.1	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.901	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	5.36	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	420	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	4.52	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	17.0	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

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326 East D Street
Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Column INF
T201021-14 (Water)
02-Jan-12 17:00

Analyte	Result	PQL	MDL	Units	Prepared	Analyzed	Method
CONVENTIONAL							
Ammonia as N	0.72	0.50	0.07	mg/L	04-Jan-12	04-Jan-12	4500-NH3 C
Nitrate+Nitrite as N	0.415	0.010	0.007	mg/L	05-Jan-12	05-Jan-12	EPA 353.2
Total Nitrogen	1.02	0.20	0.05	mg/L	04-Jan-12	04-Jan-12	COT-TN
Phosphate, Ortho	0.378	0.0100	0.0031	mg/L	04-Jan-12	04-Jan-12	365.1
Metals							
Aluminum, Dissolved	5.91J	10.0	0.890	ug/L	13-Jan-12	13-Jan-12	6020A
Aluminum	323	10.0	1.02	ug/L	04-Jan-12	13-Jan-12	6020A
Copper, Dissolved	14.4	0.200	0.038	ug/L	13-Jan-12	13-Jan-12	6020A
Copper	25.1	1.00	0.0400	ug/L	04-Jan-12	13-Jan-12	6020A
Lead, Dissolved	0.980	0.200	0.026	ug/L	13-Jan-12	13-Jan-12	6020A
Lead	17.0	1.00	0.120	ug/L	04-Jan-12	13-Jan-12	6020A
Phosphorus	430	100	48.0	ug/L	09-Jan-12	11-Jan-12	6020A
Zinc, Dissolved	128	0.200	0.075	ug/L	13-Jan-12	13-Jan-12	6020A
Zinc	158	1.00	0.590	ug/L	04-Jan-12	13-Jan-12	6020A

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UW Tacoma 326 East D Street Tacoma WA, 98421	Project: Soil Media Project Number: ENV-03007-04-04 Project Manager: Dr Joel Baker	Reported: 25-Jan-12 10:34
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CONVENTIONAL - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
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Batch 1201024 - Distillation

Blank (1201024-BLK1)				Prepared & Analyzed: 04-Jan-12					
Ammonia as N	ND	0.50	mg/L						
LCS (1201024-BS1)				Prepared & Analyzed: 04-Jan-12					
Ammonia as N	9.92	0.50	mg/L	10.0		99	79-127		

Batch 1201026 - Conventionals No-Prep

Blank (1201026-BLK1)				Prepared & Analyzed: 04-Jan-12					
Total Nitrogen	ND	0.20	mg/L						
Duplicate (1201026-DUP1)				Source: T201021-01 Prepared: 04-Jan-12 Analyzed: 05-Jan-12					
Total Nitrogen	2.02	0.20	mg/L		2.05			2	20
Reference (1201026-SRM1)				Prepared & Analyzed: 04-Jan-12					
Total Nitrogen	2.63	0.20	mg/L	2.60		101	75-125		

Batch 1201031 - Conventionals No-Prep

Blank (1201031-BLK1)				Prepared & Analyzed: 04-Jan-12					
Phosphate, Ortho	ND	0.0100	mg/L						
Duplicate (1201031-DUP2)				Source: T201021-01 Prepared & Analyzed: 04-Jan-12					
Phosphate, Ortho	0.142	0.0100	mg/L		0.141			0.7	20
Reference (1201031-SRM1)				Prepared & Analyzed: 04-Jan-12					
Phosphate, Ortho	0.357	0.0100	mg/L	0.357		100	90-110		


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Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

CONVENTIONAL - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 1201035 - Conventionals No-Prep										
Blank (1201035-BLK1) Prepared & Analyzed: 05-Jan-12										
Nitrate+Nitrite as N	ND	0.010	mg/L							
Duplicate (1201035-DUP2) Source: T201021-01 Prepared & Analyzed: 05-Jan-12										
Nitrate+Nitrite as N	0.169	0.010	mg/L		0.164			3	20	
Reference (1201035-SRM1) Prepared & Analyzed: 05-Jan-12										
Nitrate+Nitrite as N	1.10	0.010	mg/L	1.08		102	90-110			

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Tacoma WA, 98421

Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

**Metals - Quality Control
Environmental Services Laboratory**

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC Limits	RPD	RPD Limit	Notes
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Batch 1201015 - 3005A

Blank (1201015-BLK1)		Prepared: 04-Jan-12 Analyzed: 13-Jan-12							
Aluminum	ND	10.0	ug/L						
Copper	ND	1.00	ug/L						
Lead	ND	1.00	ug/L						
Zinc	ND	1.00	ug/L						

LCS (1201015-BS1)		Prepared: 04-Jan-12 Analyzed: 13-Jan-12							
Aluminum	1050	10.0	ug/L	920		114	80-120		
Copper	263	1.00	ug/L	255		103	80-120		
Lead	725	1.00	ug/L	668		109	80-120		
Zinc	168	1.00	ug/L	159		106	80-120		

Batch 1202022 - Filtered		Prepared & Analyzed: 13-Jan-12							
Blank (1202022-BLK1)									
Aluminum, Dissolved	1.54	10.0	ug/L						
Copper, Dissolved	ND	0.200	ug/L						
Lead, Dissolved	ND	0.200	ug/L						
Zinc, Dissolved	ND	0.200	ug/L						

LCS (1202022-BS1)		Prepared & Analyzed: 13-Jan-12							
Aluminum, Dissolved	991	10.0	ug/L	1000		99	80-120		
Copper, Dissolved	116	0.200	ug/L	125		93	80-120		
Lead, Dissolved	14.4	0.200	ug/L	15.0		96	80-120		
Zinc, Dissolved	94.6	0.200	ug/L	100		95	80-120		

Batch 1202023 - *** DEFAULT PREP ***		Prepared: 09-Jan-12 Analyzed: 11-Jan-12							
Blank (1202023-BLK1)									
Phosphorus	ND	100	ug/L						

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326 East D Street
Tacoma WA, 98421

Project: **Soil Media**
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Metals - Quality Control
Environmental Services Laboratory

Sample ID Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC %REC	%REC Limits	RPD	RPD Limit	Notes
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Batch 1202023 - * DEFAULT PREP *****

Blank (1202023-BLK2)		Prepared: 09-Jan-12 Analyzed: 11-Jan-12								
Phosphorus	ND	100	ug/L							
LCS (1202023-BS1)		Prepared: 09-Jan-12 Analyzed: 11-Jan-12								
Phosphorus	4610	100	ug/L	5000		92	80-120			
LCS (1202023-BS2)		Prepared: 09-Jan-12 Analyzed: 11-Jan-12								
Phosphorus	4950	100	ug/L	5000		99	80-120			

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Project: Soil Media
Project Number: ENV-03007-04-04
Project Manager: Dr Joel Baker

Reported:
25-Jan-12 10:34

Notes and Definitions

J The result is an estimated concentration.

DET Analyte DETECTED

ND Analyte NOT DETECTED at or above the reporting limit

NR Not Reported

dry Sample results reported on a dry weight basis

RPD Relative Percent Difference

STATISTICAL ANALYSIS OF RESULTS

12/14/11 Test Results

Basic Statistics

Constituent (Unit)	Influent	Condition 1		Condition 2		Condition 3		Condition 4	
		Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev
Nitrate+Nitrite as N (mg/L)	0.403	0.119	0.018	0.271	0.007	0.309	0.007	0.147	0.003
Phosphate, Ortho (mg/L)	0.344	0.113	0.013	0.102	0.007	0.073	0.010	0.136	0.005
Total Nitrogen (mg/L)	1.04	4.287	0.021	3.693	0.308	3.207	0.218	3.637	0.139
Total Phosphorus (mg/L)	0.407	0.837	0.019	0.776	0.187	0.680	0.096	0.671	0.044

Pollutant Load Reduction

Constituent	Condition 1	Condition 2	Condition 3	Condition 4
Nitrate+Nitrite as N	70.6%	32.7%	23.3%	63.5%
Phosphate, Ortho	67.2%	70.4%	78.8%	60.6%
Total Nitrogen	-312.2%	-255.1%	-208.3%	-249.7%
Total Phosphorus	-105.7%	-90.7%	-67.0%	-64.8%

Condition 1 - Columns 1,2,3

Condition 2 - Columns 4,5,6

Condition 3 - Columns 7,8,9

Condition 4 - Columns 10, 11, 12

12/21/11 Test Results

Basic Statistics

Constituent (Unit)	Influent	Condition 1				Condition 2				Condition 3				Condition 4			
		Mean	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev			
Nitrate+Nitrite as N (mg/L)	0.667	0.324	0.026	0.707	0.018	0.636	0.012	0.291	0.018								
Phosphate, Ortho (mg/L)	0.388	0.131	0.009	0.088	0.012	0.075	0.009	0.139	0.005								
Total Nitrogen (mg/L)	1.39	3.223	0.230	2.903	0.169	2.363	0.059	2.813	0.153								
Total Phosphorus (mg/L)	0.485	0.519	0.041	0.457	0.035	0.353	0.044	0.468	0.030								
Aluminum, Dissolved (ug/L)	9.17	62.3	19.5	49.1	13.3	59.3	27.8	60.9	24.3								
Aluminum (ug/L)	166	9910	295	10510	877	8843	1136	8303	888								
Copper, Dissolved (ug/L)	12.6	13.1	0.265	12.4	0.557	12.2	0.681	12.3	0.416								
Copper (ug/L)	26	35.4	0.351	33.9	2.8	29.8	1.0	32.9	0.8								
Lead, Dissolved (ug/L)	2.07	0.181	0.079	0.118	0.010	0.467	0.534	0.141	0.027								
Lead (ug/L)	18.3	8.20	0.563	8.17	0.635	6.63	0.232	7.03	0.585								
Zinc, Dissolved (ug/L)	173	2.90	0.655	2.03	0.091	7.00	8.452	3.38	0.938								
Zinc (ug/L)	249	28.2	1.801	30.1	2.458	24.8	1.457	24.1	2.406								

Pollutant Load Reduction

Constituent	Condition 1 - Columns 1,2,3			
	Condition 1	Condition 2	Condition 3	Condition 4
Nitrate+Nitrite as N	51.5%	-6.0%	4.7%	56.4%
Phosphate, Ortho	66.2%	77.4%	80.7%	64.2%
Total Nitrogen	-131.9%	-108.9%	-70.0%	-102.4%
Total Phosphorus	-6.9%	5.8%	27.2%	3.6%
Aluminum, Dissolved	-579.0%	-435.4%	-546.7%	-564.5%
Aluminum	-5869.9%	-6231.3%	-5227.3%	-4902.0%
Copper, Dissolved	-4.0%	1.6%	3.4%	2.6%
Copper	-36.0%	-30.4%	-14.6%	-26.4%
Lead, Dissolved	91.2%	94.3%	77.4%	93.2%
Lead	55.2%	55.4%	63.8%	61.6%
Zinc, Dissolved	98.3%	98.8%	96.0%	98.0%
Zinc	88.7%	87.9%	90.1%	90.3%

Condition 1 - Columns 1,2,3
 Condition 2 - Columns 4,5,6
 Condition 3 - Columns 7,8,9
 Condition 4 - Columns 10, 11, 12

12/28/11 Test Results

Basic Statistics

Constituent (Unit)	Influent		Condition 1		Condition 2		Condition 3		Condition 4	
	Mean	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev	
Nitrate+Nitrite as N (mg/L)	0.737	0.353	0.017	0.833	0.074	0.711	0.030	0.333	0.007	
Phosphate, Ortho (mg/L)	0.35	0.136	0.007	0.086	0.018	0.082	0.017	0.147	0.006	
Total Nitrogen (mg/L)	1.26	2.587	0.091	2.740	0.420	2.120	0.044	2.363	0.119	
Total Phosphorus (mg/L)	0.397	0.434	0.036	0.576	0.157	0.330	0.028	0.413	0.021	
Aluminum, Dissolved (ug/L)*	5.04	42.2		31.2		25.7		60.3		
Aluminum (ug/L)*	88.2	7260		8630		7770		6170		
Copper, Dissolved (ug/L)*	21	19.0		19.4		18.8		18.7		
Copper (ug/L)*	27.9	34.8		36.7		34.6		32.1		
Lead, Dissolved (ug/L)*	1.55	0.569		0.168		0.187		0.328		
Lead (ug/L)*	12.3	6.25		6.94		6.15		5.89		
Zinc, Dissolved (ug/L)*	177	3.38		2.42		4.80		7.26		
Zinc (ug/L)*	213	21.8		26.5		23.2		19.6		
Dissolved Organic Carbon (mg/L)*	3.28	17.9		18.1		18.2		22.3		
Total Organic Carbon (mg/L)*	3.09	32.9		20.9		24.5		26.1		

*Represents effluent value for single column tested per condition

Pollutant Load Reduction

Constituent	Condition 1	Condition 2	Condition 3	Condition 4	
Nitrate+Nitrite as N	52.1%	-13.1%	3.5%	54.8%	Condition 1 - Columns 1,2,3
Phosphate, Ortho	61.0%	75.3%	76.7%	57.9%	Condition 2 - Columns 4,5,6
Total Nitrogen	-105.3%	-117.5%	-68.3%	-87.6%	Condition 3 - Columns 7,8,9
Total Phosphorus	-9.4%	-45.0%	17.0%	-4.0%	Condition 4 - Columns 10, 11, 12
Aluminum, Dissolved	-737.3%	-519.0%	-409.9%	-1096.4%	
Aluminum	-8131.3%	-9684.6%	-8709.5%	-6895.5%	
Copper, Dissolved	9.5%	7.6%	10.5%	11.0%	
Copper	-24.7%	-31.5%	-24.0%	-15.1%	
Lead, Dissolved	63.3%	89.2%	87.9%	78.8%	
Lead	49.2%	43.6%	50.0%	52.1%	
Zinc, Dissolved	98.1%	98.6%	97.3%	95.9%	
Zinc	89.8%	87.6%	89.1%	90.8%	

1/3/12 Test Results

Basic Statistics

Constituent (Unit)	Influent	Condition 1				Condition 2				Condition 3				Condition 4			
		Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev		
Nitrate+Nitrite as N (mg/L)	0.415	0.178	0.014	0.422	0.010	0.338	0.037	0.179	0.004								
Phosphate, Ortho (mg/L)	0.378	0.145	0.006	0.095	0.016	0.096	0.011	0.160	0.008								
Total Nitrogen (mg/L)	1.02	2.030	0.044	2.483	0.299	1.970	0.092	1.897	0.055								
Total Phosphorus (mg/L)	0.43	0.378	0.019	0.422	0.044	0.368	0.021	0.407	0.044								
Aluminum, Dissolved (ug/L)	5.91	42.2	4.7	53.0	7.2	60.0	27.3	50.0	8.0								
Aluminum (ug/L)	323	5743	280	8990	1577	7977	330	5533	319								
Copper, Dissolved (ug/L)	14.4	13.4	0.289	18.2	1.457	14.8	2.363	15.1	0.600								
Copper (ug/L)	25.1	26.9	0.577	32.6	3.3	30.2	0.8	27.2	0.2								
Lead, Dissolved (ug/L)	0.98	0.219	0.061	0.663	0.505	0.395	0.295	0.221	0.054								
Lead (ug/L)	17	5.22	0.260	7.42	0.789	6.41	0.216	5.10	0.180								
Zinc, Dissolved (ug/L)	128	2.93	0.746	10.24	7.091	6.06	5.453	3.01	0.486								
Zinc (ug/L)	158	17.4	0.557	25.8	3.751	22.7	1.069	16.2	0.872								

Pollutant Load Reduction

Constituent	Condition 1	Condition 2	Condition 3	Condition 4	Condition 1 - Columns 1,2,3	Condition 2 - Columns 4,5,6	Condition 3 - Columns 7,8,9	Condition 4 - Columns 10, 11, 12
Nitrate+Nitrite as N	57.0%	-1.8%	18.6%	56.9%				
Phosphate, Ortho	61.7%	74.8%	74.7%	57.7%				
Total Nitrogen	-99.0%	-143.5%	-93.1%	-85.9%				
Total Phosphorus	12.0%	1.9%	14.4%	5.4%				
Aluminum, Dissolved	-613.5%	-796.8%	-915.8%	-746.6%				
Aluminum	-1678.1%	-2683.3%	-2369.6%	-1613.1%				
Copper, Dissolved	6.7%	-26.2%	-2.5%	-4.9%				
Copper	-7.0%	-29.9%	-20.5%	-8.2%				
Lead, Dissolved	77.7%	32.4%	59.7%	77.5%				
Lead	69.3%	56.4%	62.3%	70.0%				
Zinc, Dissolved	97.7%	92.0%	95.3%	97.7%				
Zinc	89.0%	83.7%	85.6%	89.7%				

Nitrate Concentration (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	0.403	0.667	0.737	0.415
Condition 1	0.119	0.324	0.353	0.178
Condition 2	0.271	0.707	0.833	0.422
Condition 3	0.309	0.636	0.711	0.338
Condition 4	0.147	0.291	0.333	0.179

Nitrate Standard Deviation For Each Test Event (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Condition 1	0.018	0.026	0.017	0.014
Condition 2	0.007	0.0183	0.0740	0.0372
Condition 3	0.0066	0.0116	0.0296	0.0372
Condition 4	0.0035	0.0176	0.0072	0.0040

Nitrate Load (mg)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	18.1	30.0	33.2	18.7
Condition 1	5.3	14.6	15.9	8.0
Condition 2	12.2	31.8	37.5	19.0
Condition 3	13.9	28.6	32.0	15.2
Condition 4	6.6	13.1	15.0	8.0

Cumulative Load Removal (mg)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	18.1	48.2	81.3	100.0
Condition 1	5.3	19.9	35.8	43.8
Condition 2	12.2	44.0	81.5	100.5
Condition 3	13.9	42.5	74.5	89.7
Condition 4	6.6	19.7	34.7	42.7

Influent Volume (L)	45
Effluent Volume (L)	45

* Actual Effluent Volume was around 41 Liters
 (Used conservative number for possible variation in inflow volume between columns)

Ortho-Phosphate Concentration (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	0.344	0.388	0.35	0.378
Condition 1	0.113	0.131	0.136	0.145
Condition 2	0.102	0.088	0.086	0.095
Condition 3	0.073	0.075	0.082	0.096
Condition 4	0.136	0.139	0.147	0.160

Ortho-Phosphate Standard Deviation For Each Test Event (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Condition 1	0.013	0.009	0.007	0.006
Condition 2	0.007	0.0116	0.0182	0.0156
Condition 3	0.0095	0.0089	0.0169	0.0112
Condition 4	0.0050	0.0053	0.0055	0.0080

Ortho-Phosphate Load (mg)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	15.5	17.5	15.8	17.0
Condition 1	5.1	5.9	6.1	6.5
Condition 2	4.6	3.9	3.9	4.3
Condition 3	3.3	3.4	3.7	4.3
Condition 4	6.1	6.3	6.6	7.2

Cumulative Load Removal (mg)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	15.5	32.9	48.7	65.7
Condition 1	5.1	11.0	17.1	23.6
Condition 2	4.6	8.5	12.4	16.7
Condition 3	3.3	6.6	10.3	14.6
Condition 4	6.1	12.4	19.0	26.2

Influent Volume (L) 45
 Effluent Volume (L) 45

* Actual Effluent Volume was around 41 Liters
 (Used conservative number for possible variation in inflow volume between columns)

Total Nitrogen Concentration (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	1.04	1.390	1.26	1.02
Condition	4.287	3.223	2.587	2.030
Condition	3.693	2.903	2.740	2.483
Condition	3.207	2.363	2.120	1.970
Condition	3.637	2.813	2.363	1.897

Total Phosphorus Concentration (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Influent	0.407	0.485	0.397	0.43
Condition 1	0.837	0.519	0.434	0.378
Condition 2	0.776	0.457	0.576	0.422
Condition 3	0.680	0.353	0.330	0.368
Condition 4	0.671	0.468	0.413	0.407

Total Nitrogen StdDev (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Condition	0.021	0.230	0.091	0.044
Condition	0.308	0.169	0.420	0.2994
Condition	0.218	0.059	0.044	0.0917
Condition	0.139	0.153	0.119	0.0551

Total Phosphorus StdDev (mg/L)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Condition 1	0.019	0.041	0.036	0.019
Condition 2	0.187	0.035	0.157	0.0437
Condition 3	0.096	0.044	0.028	0.0208
Condition 4	0.044	0.030	0.021	0.0441

Total Nitrogen Export (Percent)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Condition	-312%	-132%	-105%	-99%
Condition	-255%	-109%	-117%	-143%
Condition	-208%	-70%	-68%	-93%
Condition	-250%	-102%	-88%	-86%

Total Phosphorus Export/Removal (Percent)

	12/14/2011	12/21/2011	12/28/2011	1/3/2012
Condition 1	-106%	-7%	-9%	12%
Condition 2	-91%	6%	-45%	2%
Condition 3	-67%	27%	17%	14%
Condition 4	-55%	4%	-4%	5%

Zinc Concentration (µg/L)

	Total	Dissolved
Influent	207	159
Condition 1	22.5	3.1
Condition 2	27.5	4.9
Condition 3	24.7	6.0
Condition 4	20.0	4.5

Lead Concentration (µg/L)

	Total	Dissolved
Influent	15.87	1.53
Condition 1	6.56	0.32
Condition 2	7.51	0.32
Condition 3	6.66	0.35
Condition 4	6.01	0.23

Copper Concentration (µg/L)

	Total	Dissolved
Influent	26	16
Condition 1	32.3	15.2
Condition 2	34.4	16.7
Condition 3	32.2	15.2
Condition 4	30.7	15.4

Aluminum Concentration

	Total (mg/L)	Dissolved (µg/L)
Influent	0	7
Condition 1	7.6	48.9
Condition 2	9.4	44.4
Condition 3	8.5	48.3
Condition 4	6.7	57.1

Zinc StDev (µg/L)

	Total	Dissolved
Influent	46	27
Condition 1	5.4	0.3
Condition 2	2.3	4.6
Condition 3	1.9	1.1
Condition 4	4.0	2.4

Lead StDev (µg/L)

	Total	Dissolved
Influent	3.16	0.55
Condition 1	1.51	0.21
Condition 2	0.62	0.30
Condition 3	0.27	0.15
Condition 4	0.97	0.09

Copper StDev (µg/L)

	Total	Dissolved
Influent	1	4
Condition 1	4.8	3.3
Condition 2	2.1	3.7
Condition 3	3.9	3.3
Condition 4	3.1	3.2

Aluminum StDev (µg/L)

	Total	Dissolved
Influent	0	2
Condition 1	2.1	11.6
Condition 2	1.0	11.6
Condition 3	0.5	19.6
Condition 4	1.5	6.1

1/3/2012 TestTSS Results

Notes: Test performed on flow-weighted composite samples used for nutrient and metal analysis.

Test performed at UW Tacoma Lab at Center for Urban Waters

Column #	Filter #	dry filter + dish	dry filtrate + filter + dish	dry weight (g)	dry weight (mg)	total vol (l)	tss (mg/l)	Average TSS (mg/L)
2	1	2.25903	2.2609	0.00187	1.87	0.025	74.80	73.20
2	2	2.23801	2.2398	0.00179	1.79	0.025	71.60	
5	3	2.22923	2.23318	0.00395	3.95	0.025	158.00	154.20
5	4	2.22555	2.22931	0.00376	3.76	0.025	150.40	
8	5	2.21132	2.21479	0.00347	3.47	0.025	138.80	141.20
8	6	2.21768	2.22127	0.00359	3.59	0.025	143.60	
11	7	2.18907	2.19069	0.00162	1.62	0.025	64.80	65.40
11	8	2.28456	2.28621	0.00165	1.65	0.025	66.00	
cistern	9	2.27051	2.27066	0.00015	0.15	0.025	6.00	4.00
cistern	10	2.24188	2.24193	5E-05	0.05	0.025	2.00	

PROCEDURES AND EXPERIMENTAL DATA

Mesocosm BSM Packing Information

12in Drainage Layer

Type-26 Drainage Material Used
 3-Liter Container (g) 5580

Total Volume Per Column (Liter) 30
 Total Weight Per Column (g) 55800

Notes: Compacted with half-moon tamper to 1ft mark
 Put 3-9Liter Buckets in each Column, Compacted With Tamper. Added additional 3-liter container and tamped to 1-ft mark

24in BSM

3-liter container (g) 3600 *graduated for volume and used to measure weight
 9-liter bucket (g) 10800 *Each 9-liter bucket is equivalent to 1-layer

Layer-1

Placed cardboard slots in place on sides of Soil Sampling Pipe with 1/2" clearance on sides
 Placed 1-Liter of Type-26 Drainage around Soil Sampling Pipe
 Dumped 3-liter container of BSM Soil Mix on each side of slots. Removed slots dumped 3-liter BSM Soil Mix on top over T-26
 Tamped Layer, measured final level

Layer 2-8

Dumped 9-liter bucket in, leveled layer off, measured soil level from top, tamped layer, measured final layer soil level

Layer	Pre-Compact Level (in)	Post-Compact Level (in)	
1	27.5	28	
2	24.5	25	
3	21.5	22	
4	18.5	19	
5	15.5	16	*Compaction Extender Added
6	12.5	13	
7	9.5	10	
8	6.5	7	

Notes: 3in layers with 0.5in compaction on each layer
 All columns within 1/4" of each other (between 24-3/4 and 25 inches)

Initial Column Soil

Volume (liter) 72
 Mass (g) 86400

*Remaining soil for each column sealed in individual 4 gal buckets

Soil Tamper Specs

Weight (lb) 10
 Area (in²) 160
 Air Flow Holes Area (in²) 5.0 (16-0.5 in diameter holes, 38-0.25in diameter holes)
 Drop Height (in) 18
 Number of Drops/Layer 4
 Side Clearance 1/8" +or-
 Packing Extender Same diameter as Mesocosm

*Tampering regime used to help reduced natural settlement and rid column soil of large voids

Natural Settlement/Leaching Test (See Additional Info On Other Sheet)

42 liters of DI water through all columns to settle soil and leach column

Vegetation Planting/Additional Soil (See Additional Info On Other Sheet)

After settling/leaching test planted vegetation and filled up columns to 24in mark with additional soil (roughly 3.5-4 liters new soil added in each column)
 Ran additional 3 liters of Di Water through (1 liter per day on Mon (planted plants 10/24/11), Tue, Wed)
 Thursday Started 0.5 liter per day column watering routine with Kalkus roof runoff

Natural Settling Information

Settling/leaching Test

Ran 42 liters of DI water through top of column (at a rate to reach 6in ponding by final loading)

Closed bottom drainage valve until all water placed in (filled up to about top of drainage layer)

Collected first 30 liters of effluent (majority of flow, only small drips after this)

10 Liter Cubitainers used

Collected 270 ml from each cubitainer (measured in 1 liter graduated cylinder)

- 1) Shake and mix cubitainer, pour 90 ml into graduated cylinder
- 2) Close lid, Shake and mix cubitainer, pour 90 ml into graduated cylinder
- 3) Close lid, Shake and mix cubitainer, pour 90 ml into graduated cylinder

All columns settled within 1.75 to 2 inches

34 liters came out (so soil took in about 8 liters of water)

6 week plant establishment period also used as additional media settling period

Pre-12/14/11 Test Total Watering

	Liters	Water Source	
Soil Settling/Leaching	42	DI	
Planting water	3	DI	
6 week plant establish	16	Kalkus Cistern	
Infiltration Test (11/28/11)	42	Mesocosm Cistern (non spiked levels)	Used to initially Condition Saturated Zone
Practice Test Run 1 (12/5/11)	24	Mesocosm Cistern (non spiked levels)	Additional Saturated Zone Conditioning
Practice Test Run 2 (12/7/11)	30	Mesocosm Cistern (non spiked levels)	Additional Saturated Zone Conditioning
Total Water Pre-Testing	157	Approx 150-160 liters	
Tacoma Yearly Rainfall (in)	36.9		
Drainage Area (in ²)	2492		
Runoff Ratio	0.9		
Yearly Runoff Input	1356		
Percent of Yearly Runoff	11.6%	Pre-Testing	

Test Run Watering

Test Run 1 (12/13/11)	45	
Test Run 2 (12/20/11)	45	
Test Run 3 (12/27/11)	45	
Test Run 4 (12/3/12)	45	
Percent of Yearly Runoff	24.8%	Total
Infiltration Test (1/11/12)	42	
Percent of Yearly Runoff	27.9%	Total

Vegetation Planting

Plant Species/Specs

Carex Flacca (Carex Glauca), 'Blue Zinger'

Tufted bluish-gray, grassy foliage

Grows 10-18in tall, 12-16in wide, evergreen ground cover (optimal for raingards to look attractive year round)

Tolerable to both saturated and drought conditions (see literature, optimal for raingardens)

Blooming Nursery, Inc. Cornelius, OR (regionally available)

Find article on root system or possibility of improved nutrient uptake from sedge, native to coastal regions (sandy soils)

Low maintenance and tolerable to sunny, part-shade, and shady environments

Transplanting

Mature Sedge was cut into similar densities and transplanted into a 60sand/40compost (same materials as in column soil blend) in 4 in rectangular pots

Mainly done for prepare for using same sedge in all columns (only ended up applying vegetation in 6 columns)

Pre-Column Planting

Established in pots for 2 weeks outside then moved inside greenhouse for 2 weeks

Watered with greenhouse tap water

Cleaned dead stuff off plants before planting in columns

Cleaned fertilizer balls off top

Column Planting

After settling/leaching test, same planting pot placed in column with additional soil (quantity estimate based on settlement test observations)

1 Liter of DI water ran on top of new soil with empty planting pot placed in center of column

6 like density carex flacca sedges where cleaned of all there dead growth

Empty pots removed from columns and carex sedges where placed in slots (procedure used to help diminish possible large voids in soil from transplanting)

Additional soil added to get to 24in soil mark

All Columns watered with 1 liter DI water

*See column packing for further details

Plant Establishment Pre Test Run #1

7 weeks

Greenhouse Conditions

Watering Regime

Watered all columns with 0.5 liters of Kalkus Hall Roof Runoff for 7 week establishment period (4.84 mm water a day per mesocosm)
Uniformly spread water through entire column surface area
Used shower head to diminish disturbance to soil

Greenhouse Temp

Green house temperature set to stay between 62-72 degrees F
Recommendation by WSU lead horticulturist (optimum to improve growth rate)

Green House Lighting

Lighting kept on all columns for 14 hours a day for duration of study (As recommended by Rita Hummel, WSU Hort)

Column Specs

Material: PVC

Diameter: 14-3/8inches +/- 1/16 inch

Area: 162.3 in²

Pneumatically sanded inside of pvc columns to increase surface roughness and thus prevent preferential flow along side walls

Material Specs

Component	Supplier	Specification
Compost	Cedar Grove Composting Maple Valley, WA	Type 1 Feedstock
Sand	Walrath Trucking, Inc. Tacoma, WA	See Gradation
WTR	Anachortes Water Treatment Plant Anachortes, WA	Aluminum Based
Cedar Bark	Swansons Bark and Wood Products Longview, WA	Shredded
Drainage Layer	Walrath Trucking, Inc. Tacoma, WA	Type-26
Vegetation	Blooming Nursery, Inc. Cornelius, OR	Carex Flacca Grassy Foliage

Additional Compost Specification

Organic matter content between 45-65% as determined by loss of ignition test method

pH between 5.5 and 8

Carbon:nitrogen ratio between 20:1 and 25:1 for most landscapes.

Maximum electrical conductivity of 6 mmhos/cm

Moisture content range between 35 and 50%

No viable weed seeds

Manufactured inert material (plastic, concrete, ceramics, etc.) should be less than 1% on a dry weight or volume basis (As required by WAC 173-350-220)

See WAC 173-350-220 for additional information and heavy metal limits

Bioretention Sand Gradation

Sieve Size	Percent Passing
3/8"	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-5

Type-26 Drainage Layer Gradation

Sieve Size	Percent Passing
3/4"	100
1/4"	30-60
#8	20-50
#50	3-10
#200	0-1

Initial Infiltration Test Procedure (11/28/11)

-60 liters of water ran through column before test
 No saturated condition established

Columns 1-6 (no plants)

Closed all valves on all columns (bottom of column still open to atmosphere by riser pipe)
 Filled columns with 27 liters of water (~1in ponding above soil level) from top and let saturate overnight
 Put additional 15 liters of water in column to fill to 6 in ponding depth

Columns 7-12 (no plants)

Closed all valves on column and left 24" height riser pipe valve open (half of soil column)
 Filled columns with 18 liters of water from top and let saturate overnight (did not want to kill plants with overnight saturation)
 About 1 liter of water came out of riser pipe
 Filled additional 10 liters in column through bottom/Top (50/50 split) to get 1in ponding
 Filled additional 15 liters on top to get 6 inch ponding depth
 Let column stand for 3.5 hours + before infiltration test

Approx. 42 liters put in column to get to 6 inch ponding depth

Initial Infiltration Test Results (Falling Head Permeability Test)

Area (in²) 162.3
 L (in) 24

Column	Ponding Depth (in)	Time (sec)	Delta T (sec)	k (in/hr)
Column 1				
6	0			
5	62	62		47.2
4	123	61		49.7
3	186	63		49.9
2	249	63		51.8
1	313	64		52.9
0	380	67		52.6
		Avg		50.7
Column 2				
6	0			
5	50	50		58.6
4	101	51		59.4
3	153	52		60.4
2	208	55		59.3
1	262	54		62.8
0	320	58		60.8
		Avg		60.2
Column 3				
6	0			
5	55	55		53.3
4	110	55		55.1
3	165	55		57.1
2	221	56		58.2
1	281	60		56.5
0	345	64		55.1
		Avg		55.9
Column 4				
6	0			
5	57	57		51.4
4	111	54		56.1
3	167	56		56.1
2	225	58		56.2
1	284	59		57.4
0	351	67		52.6
		Avg		55.0
Column 5				
6	0			
5	66	66		44.4
4	132	66		45.9
3	202	70		44.9
2	271	69		47.3
1	342	71		47.7
0	416	74		47.7
		Avg		46.3
Column 6				
6	0			
5	52	52		56.3
4	106	54		56.1
3	160	54		58.2
2	217	57		57.2
1	277	60		56.5
0	343	66		53.4
		Avg		56.3
Column 7				
6	0			
5	85	85		34.5
4	172	87		34.8
3	261	89		35.3
2	356	95		34.3
1	446	90		37.7
0	545	99		35.6
		Avg		35.4
Column 8				
6	0			
5		82		35.7
4		80		37.9
3		89		35.3
2		90		36.2
1		92		36.8
0		85		41.5
		Avg		37.2
Column 9				
6	0			
5		63		46.5
4		64		47.4
3		64		49.1
2		66		49.4
1		70		48.4
0		65		54.3
		Avg		49.2
Column 10				
6	0			
5		67		43.7
4		67		45.3
3		72		43.6
2		74		44.1
1		78		43.4
0		74		47.7
		Avg		44.6
Column 11				
6	0			
5		66		44.4
4		70		43.3
3		73		43.0
2		75		43.5
1		78		43.4
0		74		47.7
		Avg		44.2
Column 12				
6	0			
5		75		39.1
4		76		39.9
3		80		39.3
2		84		38.8
1		85		39.9
0		83		42.5
		Avg		39.9
	Total Avg			47.9
	STDEV			8.0

Design Storm By Drainage Area Ratio
 Column Area (in²) 163
 Drainage Area Ratio 1 to 15
 Runoff Ratio 0.9

6 Month 24-hr Storm
 Seattle Tacoma
 1.32 1.21
 Storm Runoff (Liter) 47 44

Peak Flow Requirement (100%)			Flow Volume Reduction (91%)			Quality Treatment		
Contributing Area (in ²)	2508		Contributing Area (in ²)	2700		Contributing Area (in ²)	6230.77	
Column Area (in ²)	163		Column Area (in ²)	162		Column Area (in ²)	162	
Percent Sizing (%)	6.5		Percent Sizing (%)	6.0		Percent Sizing (%)	2.6 for 6in ponding	
Runoff Ratio	0.9		Runoff Ratio	0.9		Runoff Ratio	0.9	
6 Month 24-hr Storm (in)			6 Month 24-hr Storm (in)			6 Month 24-hr Storm (in)		
	Tacoma			Tacoma			Tacoma	
	1.21			1.21			1.21	
Storm Runoff (Liter)	45		Storm Runoff (Liter)	48		Storm Runoff (Liter)	111	
75% capture (Liter)	33.5							
Mean Annual Storm (in)			Mean Annual Storm (in)			Mean Annual Storm (in)		
	Sea-Tac			Sea-Tac			Sea-Tac	
	0.49			0.49			0.49	
Storm Runoff (Liter)	18		Storm Runoff (Liter)	19		Storm Runoff (Liter)	45	

*Ran approx 45 liters of water through columns, collected approx 40-42 liters of water (~13.75liter bucket*3)

Cistern Water Baseline (pre-spiked stormwater)

Jens Lab Results (11/2/11)			LID Test Influent (11/2/11)	
Total	Limit		Total	Microgram
Nitrate/Nitrite (mg/liter)	0.3			
Ammonia (mg/liter)	0.022			
Total Phosphorus (mg/liter)	0.066		0.063	
SRP (mg/liter)	U	0.1	0.027	
Dissolved Zinc (mg/liter)	0.11		0.079	79
Dissolved Copper (mg/liter)	0.002		0.0023	2.3
Dissolved Lead (mg/liter)	U	0.02	N/A	
Total Zinc (mg/liter)	0.12		0.099	99
Total Copper (mg/liter)	0.005		0.0048	4.8
Total Lead (mg/liter)	U	0.02	N/A	

Stormwater Studies/Tape Requirements

TAPE (2011)			NSQDS				
Low	High		All Land Use Composite	All Land Use First Flush	High All		
Nitrate/Nitrite (mg/liter)	N/A	N/A	Nitrate/Nitrite (mg/liter)	0.7	1.05	1.6	Commercial First Flush
Ammonia (mg/liter)	N/A	N/A	Ammonia (mg/liter)	0.52	0.8	1.3	Commercial First Flush
Total Phosphorus (mg/liter)	0.1	0.5	Total Phosphorus (mg/liter)	0.28	0.41	0.49	Commercial First Flush
Dissolved Zinc (mg/liter)	0.02	0.3	Dissolved Zinc (mg/liter)	0.125	0.2	0.75	Institutional First Flush
Dissolved Copper (mg/liter)	0.005	0.02	Dissolved Copper (mg/liter)	0.015	0.02	0.031	Industrial First Flush
Dissolved Lead (mg/liter)	N/A	N/A	Dissolved Lead (mg/liter)	0.013	0.02	0.028	Commercial First Flush
			Total Nitrogen (mg/liter)	1.6	1.95	3.61	Industrial First Flush

Synthetic Blend

Needed To Add To Blend

Nitrate/Nitrite (mg/liter)	0.95	*0.1 from cistern results from 11/22/11
Ammonia (mg/liter)	0.778	
Total Phosphorus (mg/liter)	0.347	
Dissolved Zinc (mg/liter)	0.09	
Dissolved Copper (mg/liter)	0.018	
Dissolved Lead (mg/liter)	0.02	

Spiking Calcs

Totals Water (gal) 300
 Total Water (liter) 1135.624 3.79 Liters Per Gallon

Total Chemicals to Add	mg Needed	Compound	MW Compound	MW Element	Faction	nitrate fraction	mg nitrate added
Copper Copper Sulfate	20.4	51.34	159.61	63.546	0.40		
Zinc Zinc Chloride	102.2	213.07	136.3	65.38	0.48	0.19	6.80
Lead Lead Nitrate	22.7	36.31	331.21	207.2	0.63		
Nitrate Potassium Nitrate	1056.1	1710.95	101.1	62.005	0.61		
Ammonia Ammonium Chloride	883.5	2619.91	53.49	18.0385	0.34		
Total P Potassium Phosphate	394.1	564.31	136	94.97	0.70		

*math wrong on phosphate
 see richards calcs

**see richards calcs on nitrate also
 made some adjustments after run #1

Test Preparation and Procedures

Cleaning

1. Clean all 15-Liter HDPE buckets and 1-Liter HDPE Containers with Liquinox laboratory soap and DI water
2. Triple DI Rinse
3. Acid wash all 15-Liter HDPE buckets and 1-Liter HDPE Containers (in 1:10 ratio HCL:DI water bath)
4. Triple DI Rinse
5. Let containers air dry for a few days
6. Triple acid wash saturation zone sampling hoses

Greenhouse Setup

Fill 300 gallon mixing tank with stormwater runoff by pumping from LID collection cisterns
Place saturation zone sampling hoses on 12 inch effluent spout
Spike and mix stormwater for approx. 1 hour before test event

Test Event Procedure

Purge stormwater delivery system with newly mixed semi-synthetic stormwater
Place 15 liter HDPE bucket underneath effluent valve for all mesocosms (in large plastic container and surround with ice)
Saturation zone sampling ports have a hose which runs into the 15 liter bucket
Open influent valves to all mesocosms (use of double valve system allows for turning on and off without adjusting flow)
Turn delivery pump on and start stopwatch
Verify influent flowrate for each mesocosm throughout experiment and adjust accordingly.
After first HDPE bucket fills up to 13.75 Liter mark, close valve, and replace with clean empty HDPE bucket
Collect a 1-liter flow-weighted composit sample from first HDPE Bucket (see procedure below)
Collect a 1-liter flow-weighted composit sample from second HDPE Bucket (see procedure below)
Turn off influent valve after approx. 45 liters has been delivered to each mesocosm
Let effluent flow drip into final HDPE bucket until 13.75 liter mark is achieved (approx 1 to 1.5 hours after test)
Collect a 1-liter flow-weighted composit sample from third HDPE Bucket (see procedure below)
Select two random mesocosms to collect 2 1-liter samples from the beginning of the test and from the end of the test.

Subsampling

Effluent water from each HDPE bucket is mixed by dumping water into another 15 liter HDPE bucket (1 mixing bucket per mesocosm)
This water is dumped back and forth at least twice before a 1-liter widemouth HDPE bottle is quickly submerged into bucket and filled
At the end of each test every mesocosm has three 1-liter containers filled with flow-weighted effluent water.
These 1-liter containers are then poured back into the empty mixing bucket of the designated mesocosm and sloshed around
While the 3 liters of flow-weighted effluent is still mixing around a final 1-liter flow-weighted effluent container was submerged and filled
The two influent 1-liter containers were subsampled in the same fashion but only 2 liters was available
All samples 1-liter HDPE effluent samples were labeled, placed in a refrigerator, and stored below 4 deg C overnight

Quality Control

Sanitized gloves were utilized during the duration of the experiment. Hands were washed with DI water between handling of containers
A DI rinsate following the same procedure was conducted on one of the experiments to evaluate any possible contamination
Random Duplicate samples were analyze on two of the test events to verify proper mixing was achieved

pH

HACH pH probe was calibrated before each test event for evaluation of pH
pH was tested in additional effluent of each mesocosm after 1-liter flow-weighted sample was obtained (HDPE mixing buckets were kept on ice during this time)
pH was measured within 15 minutes of obtaining final 1-liter flow-weighted effluent sample
A calibration check was performed at the end of the experiment to verify probe remained calibrated during test

Transfer of Subsamples to UWT for Prep

1 Liter HDPE bottles were transferred to UW-Tacoma lab following morning for sample preparation/preservation
Samples were analyzed by lab within required time-limits to ensure quality of data

12/14/11 Test General Notes

Cistern filled to 300 gal mark from mesocosm cistern a few days before
spiked cistern and mixed for 1.5 hours before test

cleared cistern line by running ~30 liters through system

green house kept at 43 deg F

Test started at 6pm, finished at 4am

Cistern at 300gal initial and drained to just below 150gal at end of test

Influent loading time range was 2.75-3.5 hrs

12/21/11 Test General Notes

Cistern completely emptied and perged of previous water

Cistern filled to 300 gal mark from mesocosm cistern a few days before spiked cistern and mixed for 1.5 hours before test

cleared cistern line by running ~30 liters through system

Greenhouse kept at 47 deg F

Test started at 3pm, finished at 1am

Cistern at 300gal initial and drained to just below 150gal at end of test

~45 liter loading time

	Hours
Column 1	3.75
Column 2	3.5
Column 3	3
Column 4	3.25
Column 5	3.5
Column 6	3.5
Column 7	3.5
Column 8	3.5
Column 9	3.5
Column 10	3.25
Column 11	3
Column 12	3.25

*Time when influent shutoff, approximated based on water level in final sampling bucket

12/28/11 Test General Notes

100 gal of cistern from previous test reused for this test
Cistern filled to 300 gal mark from mesocosm cistern a few days before
spiked cistern at 2/3 previous rate for 300 gal and mixed for 1.5 hours before test
cleared cistern line by running ~30 liters through system
green house kept at 43 deg F
Test started at 11am
Cistern at 300gal initial and drained to just below 150gal at end of test

~45 liter loading time

	Hours	
Column 1	3.25	
Column 2	3	
Column 3	3.25	
Column 4	3	
Column 5	3.5	* Initial loading to fast - ponding was seen in column - bucket filled to 7 liters in 15 to 20 minutes before slowing valve down
Column 6	3.5	* Initial loading to fast - ponding was seen in column - bucket filled to 10 liters before slowing valve down (faster of the two)
Column 7	3	
Column 8	3	
Column 9	3	
Column 10	2.75	
Column 11	2.75	
Column 12	3	

*Time when influent shutoff, approximated based on water level in final sampling bucket

1/3/12 Test General Notes

Cistern completely emptied and purged of old water before test run

Cistern filled to 300 gal mark from mesocosm cistern a few days before
spiked cistern at 2/3 previous rate for 300 gal and mixed for 1.5 hours before test
cleared cistern line by running ~30 liters through system

green house kept at 50 deg C

Test started at 10am

Cistern at 300gal initial and drained to just below 150gal at end of test

~45 liter loading time

	Hours
Column 1	3.25
Column 2	3.25
Column 3	3.25
Column 4	3
Column 5	3.5
Column 6	3
Column 7	3
Column 8	3
Column 9	3
Column 10	3
Column 11	3
Column 12	3

*Time when influent shutoff, approximated based on water level in final sampling bucket

the Regional Administrator, to the Alternate Test Procedure Program Coordinator, Washington, DC, for technical review and recommendations for action on the variance application. Upon receipt of the recommendations from the Alternate Test Procedure Program Co-

ordinator, the Regional Administrator may grant a variance applicable to the specific discharge to the applicant. A decision to approve or deny a variance will be made within 90 days of receipt of the application by the Regional Administrator.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter No./name	Container ¹	Preservation ^{2,3}	Maximum holding time ⁴
Table IA—Bacterial Tests:			
1-5. Coliform, total, fecal, and <i>E. coli</i>	PA, G	Cool, <10°C, 0.0008% Na ₂ S ₂ O ₃ ⁵	6 hours. ^{22,23}
6. Fecal streptococci	PA, G	Cool, <10°C, 0.0008% Na ₂ S ₂ O ₃ ⁵	6 hours. ²²
7. Enterococci	PA, G	Cool, <10°C, 0.0008% Na ₂ S ₂ O ₃ ⁵	6 hours. ²²
8. Salmonella	PA, G	Cool, <10°C, 0.0008% Na ₂ S ₂ O ₃ ⁵	6 hours. ²²
Table IA—Aquatic Toxicity Tests:			
9-11. Toxicity, acute and chronic	P, FP, G	Cool, ≤6°C ¹⁸	36 hours.
Table IB—Inorganic Tests:			
1. Acidity	P, FP, G	Cool, ≤6°C ¹⁸	14 days.
2. Alkalinity	P, FP, G	Cool, ≤6°C ¹⁸	14 days.
4. Ammonia	P, FP, G	Cool, ≤6°C ¹⁸ , H ₂ SO ₄ to pH<2	28 days.
9. Biochemical oxygen demand	P, FP, G	Cool, ≤6°C ¹⁸	48 hours.
10. Boron	P, FP, or Quartz	HNO ₃ to pH<2	6 months.
11. Bromide	P, FP, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous.	P, FP, G	Cool, ≤6°C ¹⁸	48 hours.
15. Chemical oxygen demand	P, FP, G	Cool, ≤6°C ¹⁸ , H ₂ SO ₄ to pH<2	28 days.
16. Chloride	P, FP, G	None required	28 days.
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes.
21. Color	P, FP, G	Cool, ≤6°C ¹⁸	48 hours.
23-24. Cyanide, total or available (or CATC).	P, FP, G	Cool, ≤6°C ¹⁸ , NaOH to pH>12 ⁶ , reducing agent ⁵ .	14 days.
25. Fluoride	P	None required	28 days.
27. Hardness	P, FP, G	HNO ₃ or H ₂ SO ₄ to pH<2	6 months.
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes.
31, 43. Kjeldahl and organic N	P, FP, G	Cool, ≤6°C ¹⁸ , H ₂ SO ₄ to pH<2	28 days.
Table IB—Metals:⁷			
18. Chromium VI	P, FP, G	Cool, ≤6°C ¹⁸ , pH = 9.3-9.7 ²⁰	28 days.
35. Mercury (CVAA)	P, FP, G	HNO ₃ to pH<2	28 days.
35. Mercury (CVAFS)	FP, G; and FP-lined cap ¹⁷ .	5 mL/L 12N HCl or 5 mL/L BrCl ¹⁷ .	90 days. ¹⁷
3, 5-8, 12, 13, 19, 20, 22, 26, 29, 30, 32-34, 36, 37, 45, 47, 51, 52, 58-60, 62, 63, 70-72, 74, 75. Metals, except boron, chromium VI, and mercury.	P, FP, G	HNO ₃ to pH<2, or at least 24 hours prior to analysis ¹⁹ .	6 months.
38. Nitrate	P, FP, G	Cool, ≤6°C ¹⁸	48 hours.
39. Nitrate-nitrite	P, FP, G	Cool, ≤6°C ¹⁸ , H ₂ SO ₄ to pH<2	28 days.
40. Nitrite	P, FP, G	Cool, ≤6°C ¹⁸	48 hours.
41. Oil and grease	G	Cool to ≤6°C ¹⁸ , HCl or H ₂ SO ₄ to pH<2.	28 days.
42. Organic Carbon	P, FP, G	Cool to ≤6°C ¹⁸ , HCl, H ₂ SO ₄ , or H ₃ PO ₄ to pH<2.	28 days.
44. Orthophosphate	P, FP, G	Cool, ≤6°C ¹⁸	Filter within 15 minutes; Analyze within 48 hours.
46. Oxygen, Dissolved Probe	G, Bottle and top	None required	Analyze within 15 minutes.
47. Winkler	G, Bottle and top	Fix on site and store in dark	8 hours.
48. Phenols	G	Cool, ≤6°C ¹⁸ , H ₂ SO ₄ to pH<2	28 days.
49. Phosphorous (elemental)	G	Cool, ≤6°C ¹⁸	48 hours.
50. Phosphorous, total	P, FP, G	Cool, ≤6°C ¹⁸ , H ₂ SO ₄ to pH<2	28 days.
53. Residue, total	P, FP, G	Cool, ≤6°C ¹⁸	7 days.
54. Residue, Filterable	P, FP, G	Cool, ≤6°C ¹⁸	7 days.
55. Residue, Nonfilterable (TSS)	P, FP, G	Cool, ≤6°C ¹⁸	7 days.
56. Residue, Settleable	P, FP, G	Cool, ≤6°C ¹⁸	48 hours.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container ¹	Preservation ^{2,3}	Maximum holding time ⁴
57. Residue, Volatile	P, FP, G	Cool, ≤6 °C ¹⁸	7 days.
61. Silica	P or Quartz	Cool, ≤6 °C ¹⁸	28 days.
64. Specific conductance	P, FP, G	Cool, ≤6 °C ¹⁸	28 days.
65. Sulfate	P, FP, G	Cool, ≤6 °C ¹⁸	28 days.
66. Sulfide	P, FP, G	Cool, ≤6 °C ¹⁸ , add zinc acetate plus sodium hydroxide to pH>9.	7 days.
67. Sulfite	P, FP, G	None required	Analyze within 15 minutes.
68. Surfactants	P, FP, G	Cool, ≤6 °C ¹⁸	48 hours.
69. Temperature	P, FP, G	None required	Analyze.
73. Turbidity	P, FP, G	Cool, ≤6 °C ¹⁸	48 hours.
Table IC—Organic Tests ⁹			
13, 18–20, 22, 24–28, 34–37, 39–43, 45–47, 56, 76, 104, 105, 108–111, 113. Purgeable Halocarbons.	G, FP-lined septum ...	Cool, ≤6 °C ¹⁸ , 0.008% Na ₂ S ₂ O ₃ ⁵ .	14 days.
6, 57, 106. Purgeable aromatic hydrocarbons.	G, FP-lined septum ...	Cool, ≤6 °C ¹⁸ , 0.008% Na ₂ S ₂ O ₃ ⁵ , HCl to pH 2 ⁹ .	14 days. ⁹
3, 4. Acrolein and acrylonitrile	G, FP-lined septum ...	Cool, ≤6 °C ¹⁸ , 0.008% Na ₂ S ₂ O ₃ ⁵ , pH to 4–5 ¹⁰ .	14 days. ¹⁰
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols ¹¹ .	G, FP-lined cap	Cool, ≤6 °C ¹⁸ , 0.008% Na ₂ S ₂ O ₃ ⁵ .	7 days until extraction, 40 days after extraction.
7, 38. Benzidines ^{11, 12}	G, FP-lined cap	Cool, ≤6 °C ¹⁸ , 0.008% Na ₂ S ₂ O ₃ ⁵ .	7 days until extraction, ¹³
14, 17, 48, 50–52. Phthalate esters ¹¹ .	G, FP-lined cap	Cool, ≤6 °C ¹⁸	7 days until extraction, 40 days after extraction.
82–84. Nitrosamines ^{11, 14}	G, FP-lined cap	Cool, ≤6 °C ¹⁸ , store in dark, 0.008% Na ₂ S ₂ O ₃ ⁵ .	7 days until extraction, 40 days after extraction.
88–94. PCBs ¹¹	G, FP-lined cap	Cool, ≤6 °C ¹⁸	1 year until extraction, 1 year after extraction.
54, 55, 75, 79. Nitroaromatics and isophorone ¹¹ .	G, FP-lined cap	Cool, ≤6 °C ¹⁸ , store in dark, 0.008% Na ₂ S ₂ O ₃ ⁵ .	7 days until extraction, 40 days after extraction.
1, 2, 5, 8–12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons ¹¹ .	G, FP-lined cap	Cool, ≤6 °C ¹⁸ , store in dark, 0.008% Na ₂ S ₂ O ₃ ⁵ .	7 days until extraction, 40 days after extraction.
15, 16, 21, 31, 87. Haloethers ¹¹ ...	G, FP-lined cap	Cool, ≤6 °C ¹⁸ , 0.008% Na ₂ S ₂ O ₃ ⁵ .	7 days until extraction, 40 days after extraction.
29, 35–37, 63–65, 107. Chlorinated hydrocarbons ¹¹ .	G, FP-lined cap	Cool, ≤6 °C ¹⁸	7 days until extraction, 40 days after extraction.
60–62, 66–72, 85, 86, 95–97, 102, 103. CDDs/CDFs ¹¹ .	G	Cool, ≤6 °C ¹⁸ , 0.008% Na ₂ S ₂ O ₃ ⁵ , pH<9.	1 year.
Aqueous Samples: Field and Lab Preservation.	G	Cool, ≤6 °C ¹⁸	7 days.
Solids and Mixed-Phase Samples: Field Preservation.	G	Cool, ≤6 °C ¹⁸	24 hours.
Tissue Samples: Field Preservation	G	Freeze, ≤ -10 °C	1 year.
Solids, Mixed-Phase, and Tissue Samples: Lab Preservation.	G		
Table ID—Pesticides Tests:			
1–70. Pesticides ¹¹	G, FP-lined cap	Cool, ≤6 °C ¹⁸ , pH 5–9 ¹⁵	7 days until extraction, 40 days after extraction.
Table IE—Radiological Tests:			
1–5. Alpha, beta, and radium	P, FP, G	HNO ₃ to pH<2	6 months.
Table IH—Bacterial Tests:			
1. <i>E. coli</i>	PA, G	Cool, <10 °C, 0.0008% Na ₂ S ₂ O ₃ ⁵ .	6 hours. ²²
2. Enterococci	PA, G	Cool, <10 °C, 0.0008% Na ₂ S ₂ O ₃ ⁵ .	6 hours. ²²
Table IH—Protozoan Tests:			
8. Cryptosporidium	LDPE; field filtration ..	0–8 °C	96 hours. ²¹

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container ¹	Preservation ^{2,3}	Maximum holding time ⁴
9. Giardia	LDPE; field filtration ..	0–8 °C	96 hours. ²¹

¹ "P" is polyethylene; "FP" is fluoropolymer (polytetrafluoroethylene (PTFE; Teflon®), or other fluoropolymer, unless stated otherwise in this Table II; "G" is glass; "PA" is any plastic that is made of a sterilizable material (polypropylene or other autoclavable plastic); "LDPE" is low density polyethylene.

² Except where noted in this Table II and the method for the parameter, preserve each grab sample within 15 minutes of collection. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), refrigerate the sample at 5°C during collection unless specified otherwise in this Table II or in the method(s). For a composite sample to be split into separate aliquots for preservation and/or analysis, maintain the sample at 5°C, unless specified otherwise in this Table II or in the method(s), until collection, splitting, and preservation is completed. Add the preservative to the sample container prior to sample collection when the preservative will not compromise the integrity of a grab sample, a composite sample, or an aliquot split from a composite sample; otherwise, preserve the grab sample, composite sample, or aliquot split from a composite sample within 15 minutes of collection. If a composite measurement is required but a composite sample would compromise sample integrity, individual grab samples must be collected at prescribed time intervals (e.g., 4 samples over the course of a day, at 6-hour intervals). Grab samples must be analyzed separately and the concentrations averaged. Alternatively, grab samples may be collected in the field and composited in the laboratory if the compositing procedure produces results equivalent to results produced by arithmetic averaging of the results of analysis of individual grab samples. For examples of laboratory compositing procedures, see EPA Method 1664A (oil and grease) and the procedures at 40 CFR 141.34(f)(14)(iv) and (v) (volatile organics).

³ When any sample is to be shipped by common carrier or sent via the U.S. Postal Service, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO₃) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H₂SO₄) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

⁴ Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before the start of analysis and still be considered valid (e.g., samples analyzed for fecal coliforms may be held up to 6 hours prior to commencing analysis). Samples may be held for longer periods only if the permittee or monitoring laboratory has data on file to show that, for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under § 136.3(e). For a grab sample, the holding time begins at the time of collection. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), the holding time begins at the time of the end of collection of the composite sample. For a set of grab samples composited in the field or laboratory, the holding time begins at the time of collection of the last grab sample in the set. Some samples may not be stable for the maximum time period given in the table. A permittee or monitoring laboratory is obligated to hold the sample for a shorter time if it knows that a shorter time is necessary to maintain sample stability. See § 136.3(e) for details. The date and time of collection of an individual grab sample is the date and time at which the sample is collected. For a set of grab samples to be composited, and that are all collected on the same calendar date, the date of collection is the date on which the samples are collected. For a set of grab samples to be composited, and that are collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14–15. For a composite sample collected automatically on a given date, the date of collection is the date on which the sample is collected. For a composite sample collected automatically, and that is collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14–15.

⁵ Add a reducing agent only if an oxidant (e.g., chlorine) is present. Reducing agents shown to be effective are sodium thiosulfate (Na₂S₂O₃), ascorbic acid, sodium arsenite (NaAsO₂), or sodium borohydride (NaBH₄). However, some of these agents have been shown to produce a positive or negative cyanide bias, depending on other substances in the sample and the analytical method used. Therefore, do not add an excess of reducing agent. Methods recommending ascorbic acid (e.g., EPA Method 335.4) specify adding ascorbic acid crystals, 0.1–0.6 g, until a drop of sample produces no color on potassium iodide (KI) starch paper, then adding 0.06 g (60 mg) for each liter of sample volume. If NaBH₄ or NaAsO₂ is used, 25 mg/L NaBH₄ or 100 mg/L NaAsO₂ will reduce more than 50 mg/L of chlorine (see method "Kelada-01" and/or Standard Method 4500-CN- for more information). After adding reducing agent, test the sample using KI paper, a test strip (e.g. for chlorine, SenSafe™ Total Chlorine Water Check 480010) moistened with acetate buffer solution (see Standard Method 4500-Cl.C.3e), or a chlorine/oxidant test method (e.g., EPA Method 330.4 or 330.5), to make sure all oxidant is removed. If oxidant remains, add more reducing agent. Whatever agent is used, it should be tested to assure that cyanide results are not affected adversely.

⁶ Sample collection and preservation: Collect a volume of sample appropriate to the analytical method in a bottle of the material specified. If the sample can be analyzed within 48 hours and sulfide is not present, adjust the pH to > 12 with sodium hydroxide solution (e.g., 5% w/v), refrigerate as specified, and analyze within 48 hours. Otherwise, to extend the holding time to 14 days and mitigate interferences, treat the sample immediately using any or all of the following techniques, as necessary, followed by adjustment of the sample pH to > 12 and refrigeration as specified. There may be interferences that are not mitigated by approved procedures. Any procedure for removal or suppression of an interference may be employed, provided the laboratory demonstrates that it more accurately measures cyanide. Particulate cyanide (e.g., ferric ferrocyanide) or a strong cyanide complex (e.g., cobalt cyanide) are more accurately measured if the laboratory holds the sample at room temperature and pH > 12 for a minimum of 4 hours prior to analysis, and performs UV digestion or dissolution under alkaline (pH=12) conditions, if necessary.

(1) Sulfur: To remove elemental sulfur (S₈), filter the sample immediately. If the filtration time will exceed 15 minutes, use a larger filter or a method that requires a smaller sample volume (e.g., EPA Method 335.4 or Lachat Method 01). Adjust the pH of the filtrate to > 12 with NaOH, refrigerate the filter and filtrate, and ship or transport to the laboratory. In the laboratory, extract the filter with 100 mL of 5% NaOH solution for a minimum of 2 hours. Filter the extract and discard the solids. Combine the 5% NaOH-extracted filtrate with the initial filtrate, lower the pH to approximately 12 with concentrated hydrochloric or sulfuric acid, and analyze the combined filtrate. Because the detection limit for cyanide will be increased by dilution by the filtrate from the solids, test the sample with and without the solids procedure if a low detection limit for cyanide is necessary. Do not use the solids procedure if a higher cyanide concentration is obtained without it. Alternatively, analyze the filtrates from the sample and the solids separately, add the amounts determined (in µg or mg), and divide by the original sample volume to obtain the cyanide concentration.

(2) Sulfide: If the sample contains sulfide as determined by lead acetate paper, or if sulfide is known or suspected to be present, immediately conduct one of the volatilization treatments or the precipitation treatment as follows: Volatilization—Headspace expelling. In a fume hood or well-ventilated area, transfer 0.75 liter of sample to a 4.4 L collapsible container (e.g., Cubitainer™). Acidify with concentrated hydrochloric acid to pH < 2. Cap the container and shake vigorously for 30 seconds. Remove the cap and expel the headspace into the fume hood or open area by collapsing the container without expelling the sample. Refill the headspace by expanding the container. Repeat expelling a total of five headspace volumes. Adjust the pH to > 12, refrigerate, and ship or transport to the laboratory. Scaling to a smaller or larger sample volume must maintain the air to sample volume ratio. A larger volume of air will result in too great a loss of cyanide (> 10%). Dynamic stripping: In a fume hood or well-ventilated area, transfer 0.75 liter of sample to a container of the material specified and acidify with concentrated hydrochloric acid to pH < 2. Using a calibrated air sampling pump or flowmeter, purge the acidified sample into the fume hood or open area through a fritted glass aerator at a flow rate of 2.25 L/min for 4 minutes. Adjust the pH to > 12, refrigerate, and ship or transport to the laboratory. Scaling to a smaller or larger sample volume must maintain the air to sample volume ratio. A larger volume of air will result in too great a loss of cyanide (> 10%). Precipitation: If the sample contains particulate matter that would be removed by filtration, filter the sample prior to treatment to assure that cyanide associated with the particulate matter is included in the measurement. Ship or transport the filter to the laboratory. In the laboratory, extract the filter with 100 mL of 5% NaOH solution for a minimum of 2 hours. Filter the extract and discard the solids. Combine the 5% NaOH-extracted filtrate with the initial filtrate, lower the pH to approximately 12 with concentrated hydrochloric or sulfuric acid, and analyze the combined filtrate. Because the detection limit for cyanide will be increased by dilution by the filtrate from the solids, test the sample with and without the solids procedure if a low detection limit for cyanide is necessary. Do not use the solids procedure if a higher cyanide concentration is obtained without it. Alternatively, analyze the filtrates from the sample and the solids separately, add the amounts determined (in µg or mg), and divide by the original sample volume to obtain the cyanide concentration. For removal of sulfide by precipitation, raise the pH of the sample to > 12 with NaOH solution, then add approximately 1 mg of powdered cadmium chloride for each mL of sample. For example, add approximately 500 mg to a 500-mL sample. Cap and shake the container to mix. Allow the precipitate to settle and test the sample with lead acetate paper. If necessary, add cadmium chloride but avoid adding an excess. Finally, filter through 0.45 micron filter. Cool the sample as specified and ship or transport the filtrate and filter to the laboratory. In the laboratory, extract the filter with 100 mL of 5% NaOH solution for a minimum of 2 hours. Filter the extract and discard the solids. Combine the 5% NaOH-extracted filtrate with the initial filtrate, lower the pH to approximately 12 with concentrated hydrochloric or sulfuric acid, and analyze the combined filtrate. Because the detection limit for cyanide will be increased by dilution by the filtrate from the solids, test the sample with and without the solids procedure if a low detection limit for cyanide is necessary. Do not use the solids procedure if a higher cyanide concentration is obtained without it. Alternatively, analyze the filtrates from the sample and the solids separately, add the amounts determined (in µg or mg), and divide by the original sample volume to obtain the cyanide concentration. If a ligand-exchange method is used (e.g., ASTM D6888), it may be necessary to increase the ligand-exchange reagent to offset any excess of cadmium chloride.

(3) Sulfite, thiosulfate, or thiocyanate: If sulfite, thiosulfate, or thiocyanate is known or suspected to be present, use UV digestion with a glass coil (Method Kelada-01) or ligand exchange (Method OIA-1677) to preclude cyanide loss or positive interference.

(4) Aldehyde: If formaldehyde, acetaldehyde, or another water-soluble aldehyde is known or suspected to be present, treat the sample with 20 mL of 3.5% ethylenediamine solution per liter of sample.

(5) Carbonate: Carbonate interference is evidenced by noticeable effervescence upon acidification in the distillation flask, a reduction in the pH of the absorber solution, and incomplete cyanide spike recovery. When significant carbonate is present, adjust the pH to ≥ 12 using calcium hydroxide instead of sodium hydroxide. Allow the precipitate to settle and decant or filter the sample prior to analysis (also see Standard Method 4500-CN.B.3.d).

(6) Chlorine, hypochlorite, or other oxidant: Treat a sample known or suspected to contain chlorine, hypochlorite, or other oxidant as directed in footnote 5.

⁷For dissolved metals, filter grab samples within 15 minutes of collection and before adding preservatives. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), filter the sample within 15 minutes after completion of collection and before adding preservatives. If it is known or suspected that dissolved sample integrity will be compromised during collection of a composite sample collected automatically over time (e.g., by interchange of a metal between dissolved and suspended forms), collect and filter grab samples to be composited (footnote 2) in place of a composite sample collected automatically.

⁸Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

⁹If the sample is not adjusted to pH 2, then the sample must be analyzed within seven days of sampling.

¹⁰The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

¹¹When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity (i.e., use all necessary preservatives and hold for the shortest time listed). When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to ≤ 6°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (regarding the requirement for thiosulfate reduction), and footnotes 12, 13 (regarding the analysis of benzidine).

¹²If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0 ± 0.2 to prevent rearrangement to benzidine.

¹³Extracts may be stored up to 30 days at < 0 °C.

¹⁴For the analysis of diphenylnitrosamine, add 0.008% Na₂S₂O₃ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

¹⁵The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% Na₂S₂O₃.

¹⁶Sufficient ice should be placed with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the preservation temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature cannot be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature.

¹⁷Samples collected for the determination of trace level mercury (<100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. A sample collected for dissolved trace level mercury should be filtered in the laboratory within 24 hours of the time of collection. However, if circumstances preclude overnight shipment, the sample should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. If sample integrity will not be maintained by shipment to and filtration in the laboratory, the sample must be filtered in a designated clean area in the field within the time period necessary to maintain sample integrity. A sample that has been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

¹⁸Aqueous samples must be preserved at ≤ 6°C, and should not be frozen unless data demonstrating that sample freezing does not adversely impact sample integrity is maintained on file and accepted as valid by the regulatory authority. Also, for purposes of NPDES monitoring, the specification of "≤ 6°C" is used in place of the "4 °C" and "< 4 °C" sample temperature requirements listed in some methods. It is not necessary to measure the sample temperature to three significant figures (1/100th of 1 degree); rather, three significant figures are specified so that rounding down to 6 °C may not be used to meet the ≤ 6°C requirement. The preservation temperature does not apply to samples that are analyzed immediately (less than 15 minutes).

¹⁹An aqueous sample may be collected and shipped without acid preservation. However, acid must be added at least 24 hours before analysis to dissolve any metals that adsorb to the container walls. If the sample must be analyzed within 24 hours of collection, add the acid immediately (see footnote 2). Soil and sediment samples do not need to be preserved with acid. The allowances in this footnote supersede the preservation and holding time requirements in the approved metals methods.

²⁰To achieve the 28-day holding time, use the ammonium sulfate buffer solution specified in EPA Method 218.6. The allowance in this footnote supersedes preservation and holding time requirements in the approved hexavalent chromium methods, unless this supersession would compromise the measurement, in which case requirements in the method must be followed.

²¹Holding time is calculated from time of sample collection to elution for samples shipped to the laboratory in bulk and calculated from the time of sample filtration to elution for samples filtered in the field.

²²Samples analysis should begin immediately, preferably within 2 hours of collection. The maximum transport time to the laboratory is 6 hours, and samples should be processed within 2 hours of receipt at the laboratory.

²³For fecal coliform samples for sewage sludge (biosolids) only, the holding time is extended to 24 hours for the following sample types using either EPA Method 1680 (LTB-EC) or 1681 (A-1): Class A composted, Class B aerobically digested, and Class B anaerobically digested.

[38 FR 28758, Oct. 16, 1973]

EDITORIAL NOTE: For FEDERAL REGISTER citations affecting § 136.3, see the List of CFR Sections Affected, which appears in the Finding Aids section of the printed volume and on GPO Access.

§ 136.4 Application for alternate test procedures.

(a) Any person may apply to the Regional Administrator in the Region where the discharge occurs for approval of an alternative test procedure.

(b) When the discharge for which an alternative test procedure is proposed occurs within a State having a permit program approved pursuant to section 402 of the Act, the applicant shall submit his application to the Regional Administrator through the Director of the State agency having responsibility for issuance of NPDES permits within such State.

(c) Unless and until printed application forms are made available, an application for an alternate test procedure may be made by letter in triplicate. Any application for an alternate test procedure under this paragraph (c) shall:

(1) Provide the name and address of the responsible person or firm making the discharge (if not the applicant) and the applicable ID number of the existing or pending permit, issuing agency, and type of permit for which the alternate test procedure is requested, and the discharge serial number.

(2) Identify the pollutant or parameter for which approval of an alternate testing procedure is being requested.

(3) Provide justification for using testing procedures other than those specified in Table I.

(4) Provide a detailed description of the proposed alternate test procedure, together with references to published studies of the applicability of the alter-

nate test procedure to the effluents in question.

(d) An application for approval of an alternate test procedure for nationwide use may be made by letter in triplicate to the Alternate Test Procedure Program Coordinator, Office of Science and Technology (4303), Office of Water, U.S. Environmental Protection Agency, 1200 Pennsylvania Ave., NW., Washington, DC 20460. Any application for an alternate test procedure under this paragraph (d) shall:

(1) Provide the name and address of the responsible person or firm making the application.

(2) Identify the pollutant(s) or parameter(s) for which nationwide approval of an alternate testing procedure is being requested.

(3) Provide a detailed description of the proposed alternate procedure, together with references to published or other studies confirming the general applicability of the alternate test procedure to the pollutant(s) or parameter(s) in waste water discharges from representative and specified industrial or other categories.

(4) Provide comparability data for the performance of the proposed alternate test procedure compared to the performance of the approved test procedures.

[38 FR 28760, Oct. 16, 1973, as amended at 41 FR 52785, Dec. 1, 1976; 62 FR 30763, June 5, 1997; 72 FR 11239, Mar. 12, 2007]

§ 136.5 Approval of alternate test procedures.

(a) The Regional Administrator of the region in which the discharge will

EXPERIMENTAL PHOTOS



Image 1. Experimental Setup (side view)



Image 2. Stormwater Delivery System



Image 3. Experimental Setup (top view)



Image 4. Stormwater Mixing Tank



Image 5. Influent Delivery T-Spreader



Image 6. Column Plant (Carex Flacca)



Image 7. BSM Media



Image 8. HDPE Barrel Mixer



Image 9. Top of Type-26 Drainage Layer



Image 10. Soil Compactor



Image 11. Vegetation Preparation



Image 12. Flow Control Valve System



Image 13. Loading of Barren Mesocosm



Image 14. Effluent – No Saturation Zone



Image 15. Effluent Mixing Regime



Image 16. Flow-Weighted Sampling



Image 17. Effluent Collection on Ice