AN EVALUATION OF STORMWATER PERMEABLE RAPID INFILTRATION BARRIERS FOR USE IN CLASS V STORMWATER INJECTION WELLS

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AN EVALUATION OF STORMWATER PERMEABLE RAPID INFILTRATION BARRIERS FOR USE IN CLASS V STORMWATER INJECTION WELLS

by

David Yonge and Piper Roelen
Department of Civil and Environmental Engineering
Washington State University
Pullman, Washington 99163

Washington State Transportation Center (TRAC)
Department of Civil and Environmental Engineering
Washington State University
Pullman, WA 99164-2910

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Technical Monitor
Edward Molash

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16. ABSTRACT

Stormwater injection wells are widely used as stormwater management systems. These wells may act as a low resistance conduit for contaminants transported by stormwater to enter groundwater. This paper summarizes the testing of a natural filtration medium, referred to as a Stormwater Permeable Rapid Infiltration Barrier (SPRIB), that has been proposed as a potential retrofit option for stormwater injection wells in Spokane, Washington because of its theoretical contaminant attenuation capabilities and its good hydraulic properties. This medium was tested in the laboratory and at a field site using near field-scale columns to determine its useful life span in terms of metal (Cu, Pb, and Zn) removal capacity and maintenance of acceptable infiltration rates. After a series of simulated storm events, the SPRIB demonstrated contaminant concentration reduction rates of total metals greater than 99% and soluble metals from 91 to 98%. Surface clogging of the columns by stormwater particulate matter was shown to be the limiting factor in the useful life span of an unmaintained SPRIB. Based on the observed linear decline in infiltration rates due to sediment loading, the predicted life span of SPRIB is 20 to 22 storms (roughly 6 months in the Spokane area) before infiltration falls below acceptable rates (8 to 12 in/hr). A significantly longer life span is expected if pretreatment for suspended solids or periodic SPRIB maintenance is performed.

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EXECUTIVE SUMMARY

The Washington State Department of Transportation (WSDOT) has constructed hundreds of dry wells for the disposal of highway storm water runoff, many of which now lie within sole source aquifer and wellhead protection areas. Dry wells are deep slotted concrete sumps designed to facilitate the rapid infiltration of stormwater, and are classified as Class V underground injection wells under federal regulations in the Code of Federal Regulations (CFR) part 144. Dry wells have historically been important stormwater disposal options in eastern Washington and the glacial outwash plains in western Washington. Although current design standards mandate pre-treatment of storm water disposal to dry wells for a 6 month / 24 hour storm event, many older facilities are without this added level of protection for ground water resources. The US Environmental Protection Agency (EPA) has indicated that transportation improvement projects will have to address methods to retrofit dry wells in the future so that groundwater will not be impacted by stormwater runoff or toxic spills on state highways. A cost effective dry well retrofit strategy is needed to assist in project delivery in those areas where dry wells are present. This report presents the findings of a laboratory and field study of a potential retrofit strategy; the use of a stormwater permeable reactive infiltration barrier (SPRIB).

Near full-scale columns were constructed from three-foot sections of 30-inch diameter double-walled ABS culvert material. Three laboratory columns and one field columns were used in the study. The laboratory columns were filled with sand, sand and clay (95%:5% W/W) and sand, clay, mulch (compost) (95%:5%:5% W/W), referred to as the SPRIB mixture. The field column was identical to the laboratory column that contained SPRIB. Simulated stormwater was fed to the laboratory columns and influent and effluent solids, copper, lead, and zinc concentrations were monitored during "storm events". Infiltration rates were checked periodically throughout the experimental period. The field column was installed at the outfall of a culvert system that drains an estimated 3.68 acres of Interstate 90 (I-90) near Sprague Avenue in southern Spokane. Average daily traffic (ADT) along this stretch of I-90 is 100,000 vehicles. Influent and effluent data was collected by automated data loggers and samples for solids and metal analysis were collected by automated samplers.

The results indicate that in the laboratory, the SPRIB mixture reduced dissolved metals concentrations (Cu, Pb, and Zn) at a level greater than 91%, total metals concentrations at a level greater than 99%, and total suspended solids concentrations at a level greater than 85%. These laboratory results were confirmed with the field column that also demonstrated attenuation of

metals in stormwater runoff to negligible concentrations. Based on metal and TSS concentration reduction, use of SPRIB as a stormwater treatment method in injection wells appears to be a promising concept. However, two key factors were observed during this study that could limit or preclude the use of SPRIB in stormwater injection wells:

1) Based on required infiltration rates for stormwater management facilities, the useful life of SPRIB is limited by the quantity of TSS allowed to enter the treatment unit; therefore, SPRIB should not be used as a primary treatment process unless periodic replacement or removal of the clogged media surface can be routinely performed.

2) SPRIB should not be used in locations where the normal infiltration rates of the media are required during winter months as freezing can cause partial to complete loss of infiltration capabilities and excess sediment from road sanding operations can cause rapid surface clogging of the filter. However, placement of the media at greater depths below ground surface (i.e. inside injection wells) and pre-settling of solids could potentially mitigate the adverse effects of freezing conditions and high sediment concentrations respectively.

Although there may be limitations to the operating conditions, the results of this study have shown that if adequate maintenance and/or pretreatment is provided, SPRIB technology can provide significant mitigation of contaminated stormwater.

INTRODUCTION

Under the authority of the Safe Drinking Water Act (SDWA), the United States Environmental Protection Agency (USEPA) established the Underground Injection Control (UIC) program in 1984 for the purpose of ensuring the protection of underground sources of drinking water (USDW). Under the UIC program, injection wells are divided into five classes, primarily based on the types of fluids that are injected into the wells. Stormwater injection wells are categorized as Class V, Subclass 5D2 injection wells, or "shallow injection wells designed for the disposal of rain water and melted snow" (40 CFR 146). Although storm sewer systems are used more frequently in urban settings, the USEPA estimates there are nearly 250,000 stormwater injection wells utilized throughout the U.S. (USEPA, 1999b). There are inherent problems and risks with the use of stormwater injection wells, the foremost being that standard injection wells may provide a relatively low resistance conduit for contaminant migration to groundwater. The potential for groundwater contamination is a significant concern since it is well documented that stormwater runoff can carry a wide range of contaminants, which often exceed federal maximum contaminant levels (MCLs) (USEPA, 1999). Additional information on the regulatory framework of the UIC program and federal MCLs can be found in Appendices A and B respectively.

It is estimated the State of Washington utilizes nearly 23,000 stormwater injection wells; and in the City of Spokane, Washington, stormwater injection into such wells accounts for nearly 100 percent of groundwater recharge into the Spokane Aquifer (USEPA, 1999b). Figure 1 illustrates the design of a typical stormwater injection well used in the Spokane area. Stormwater Permeable Rapid Infiltration Barrier (SPRIB) is composed of several natural filtration media, the combination of which was developed as a single medium in cooperation with the United States Geological Survey (USGS) for its theoretical contaminant retention properties.

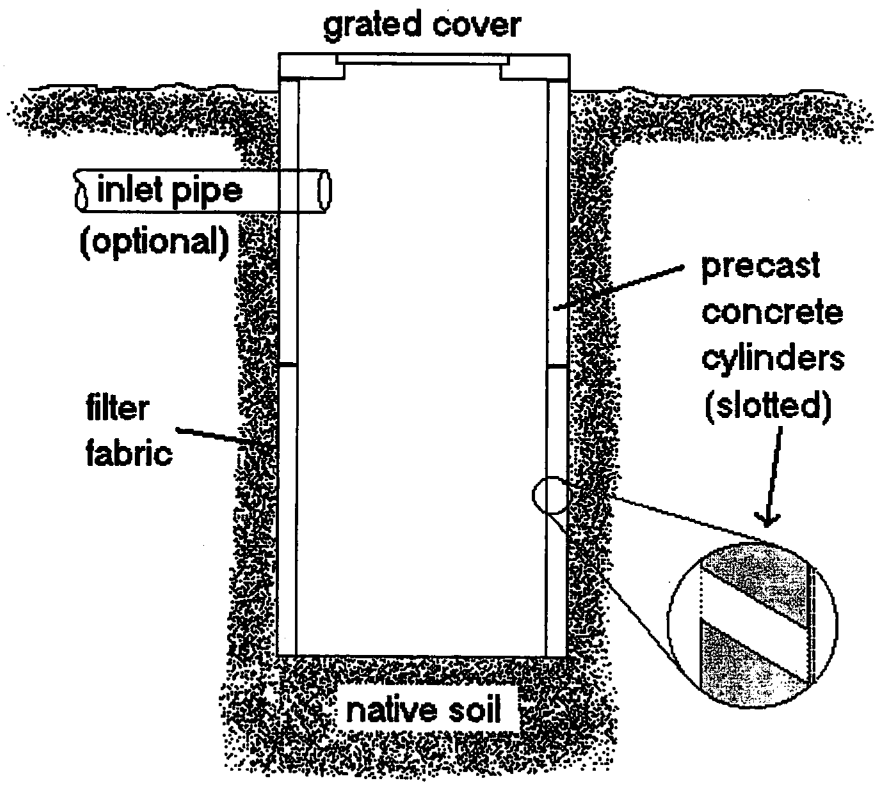

Figure 1. Typical Class V stormwater injection well.

Additional information regarding the State of Washington's and City & County of Spokane's role in the UIC and aquifer protection program can be found in Appendix A. General information pertaining to the Spokane Aquifer and background groundwater quality in the Spokane area can be found in Appendix C.

OBJECTIVES

The SPRIB medium, which consists of a mixture of sand, clay, and mulch (90:5:5 by weight) was tested by the USGS to assure sufficient hydraulic conductivity; however, prior to the research described in this paper, only preliminary testing of SPRIB contaminant removal capabilities had been conducted. The primary objective of this research was to determine the useful lifespan of a near field-scale SPRIB column, under laboratory controlled conditions, in terms of providing 1) acceptable metals (Cu, Pb, and Zn) removal capacity over an extended time frame, and 2) adequate infiltration rates, during simulated storm/runoff events. The results of these laboratory experiments were compared with results from two other identical columns, one containing only sand and one containing a sand and clay mixture (95:5 by weight). Additionally, a fourth column containing the complete SPRIB mixture was placed in the field at the outlet of a freeway runoff culvert in Spokane, Washington in order to verify that laboratory experiment results were representative of actual field conditions.

BACKGROUND AND PREVIOUS STUDIES

The concept of the rapid infiltration barrier for stormwater mitigation is based on using readily available, easily replaceable, natural materials to provide contaminant attenuation while at the same time allowing rapid infiltration rates so as to minimize the potential for flooding. The following sections provide an overview of previous studies and known technologies upon which the SPRIB concept is based.

Rapid Infiltration Systems

The desired rate of infiltration for the SPRIB medium was designated by the WSDOT to be 8 to 12 inches per hour (WSDOT, email communications, 2000) to provide adequate drainage in stormwater management facilities. Studies by the USGS indicated that two separate 90:5:5

mixes had infiltration rates between 9 and 50 inches per hour (Ames, 2001). The requirement for such fast infiltration rates indicates the need for the application of a "rapid infiltration" technology. Table 1 identifies typical percent removals in rapid infiltration systems (such as rapid sand filters) used in wastewater treatment systems, the performances of which can reasonably be expected to be similar to that of a rapid infiltration barriers in stormwater injection wells.

Table 1. Typical percent removals in rapid sand filters (USEPA, 1999c)

Pollutant	Typical Removals (%)
Sediment	90
Metals (total recoverable)	90
Organics	90
Bacteria	90
Total Phosphorous	60
Total Nitrogen	60
Biochemical Oxygen Demand	70 - 80

Natural Soil Filtration

Several mechanisms have been shown to exist naturally in soils that can remove contaminants commonly found in stormwater runoff, prior to contact with groundwater. It logically follows that in the development of SPRIB technology, some or all of these mechanisms could be utilized, simulated, or enhanced. The following is a brief summary of some of these mechanisms (Pitt, 1996):

- *Suspended Solids* – Studies have indicated that fine to medium grained soils remove nearly all suspended solids through straining and adsorption, while larger grained soils allow deeper penetration that may reach groundwater.

- *Metals* – Metals are removed from soils through several mechanisms including 1) adsorption to surface soils; 2) cation exchange with clays and organic matter and chelation with organic molecules that, after decomposition of the organic molecule, lead to immobilization in the soil through reactions with iron and aluminum hydroxides, calcium, and other compounds; and 3) precipitation through bacterial processes. Most of these mechanisms are pH and solubility dependent. It is important to note that the form of metal can have significant impact on removal. Total metal concentrations consist of particulate-bound and soluble fractions. The soluble fraction is typically defined based upon the filtration procedure employed, often a 0.45 or 0.2 µm. obviously, the filter size used can impact the ultimate concentration.
- *Nutrients* – During infiltration through soils, some nutrients, such as phosphorous, can be removed through direct precipitation or chemical adsorption onto soil surfaces through reactions with exposed iron, aluminum, or calcium on solid soil surfaces. Nitrates can also be removed through a biologic denitrification process.
- *Bacterial Pathogens* - Straining, sedimentation, sorption, and inactivation by the soil are the primary mechanisms of bacterial removal.
- *Organic Compounds* – Removal of organics in soil can occur through volatilization, sorption, and/or degradation. Volatilization is controlled by physical and chemical properties of the compound, the sorptive characteristics of the soils, moisture content in the soil, air concentration and movement, temperature, and the potential for diffusion in the soil. There are multiple sorption mechanisms, each of which are functions of the sorbate shape and configuration; chemical characteristics; and sorbent nature, with the clay and particulate organic matter content controlling the sorption. Degradation can be either chemical (including hydrolysis and photodegradation) or biological. Biological degradation is the

primary removal mechanism of trace organics and can be limited by factors such as temperature, air availability, pH, and moisture.

- *Pesticides* – Due to the mobility of some pesticides, soil removal is limited; however, some volatilization can occur if residence time in the soil (controlled by water applied and chemical adsorption to stationary solid sources) is long enough.
- *Salts* – Studies have indicated that neither soil nor groundwater systems have an effective removal mechanism for most salts.

Organic Amended Filtration Media

Several studies have indicated that modifying infiltration systems by adding a layer of sand, with peat, loam, or other organic material will enhance removal of many contaminants. The USEPA states that this addition "appears to enhance the removal of metals and nutrients through adsorption" (USEPA, 1999c). The following examples demonstrate this result.

Clark and Pitt conducted a laboratory and field study of several filter media to determine pollutant removal capabilities. Media tested included sand, and sand mixed with each of: activated carbon, peat moss, compost, zeolite, enretech, forest products agrofiber, and Gunderboom and EMCON filter fabrics. Column testing indicated that an activated carbon-sand filter was best at removing a wide range of pollutants commonly found in normal stormwater that has not been pre-settled or pretreated (Clark & Pitt, 1999).

In a similar study, Koob and Barber conducted column tests with fifteen types of filter media including aquarium rocks, cedar bedding, charcoal, a compost mixture, corn cobs, garden bark, glass beads, kitty litter, iron oxide coated sand, sand/steel wool, peat moss, persolite, sand, and zeolite; analyzing for Cd, Cu, Pb, Zn, nitrate, phosphate, pH, total suspended solids (TSS), and total petroleum hydrocarbons (TPH). The study concluded that garden bark, peat moss, sand, and compost were the best filter media for treating stormwater runoff in vaults because of a combination of good hydraulic properties and pollutant removal abilities (Koob & Barber, 1999).

Hathorn and Yonge concluded from column testing that high concentrations of natural organic matter dissolved in solution in stormwater improve soil retention of several heavy metals (Cd, Cu, Pb, Zn) through sorption (Hathorn & Yonge, 1996).

Using computer models, researchers at the University of Arizona demonstrated that layers of sediment with a high organic content in wells and in the vadose zone retard the movement of most organic compounds, except those with exceptionally high mobility (USEPA, 1999b).

Limitations

There are several limitations and/or disadvantages to the use of infiltration type stormwater management systems (USEPA, 1999c). For example, if located above ground in cold weather areas, the surface of the system may freeze and either reduce or prevent infiltration into the soils and groundwater. Untreated stormwater may then run into nearby surface waters. In addition, site features may preclude the use of stormwater injection wells or other similar stormwater infiltration systems. Such features include excessive slope of the drainage area; proximity to the groundwater table and/or bedrock; high content of relatively impermeable soils such as clay, silt, or other fine-particles; and fill material. The proximity to sites that use, store, or dispose of chemicals or hazardous materials should also be considered as a possible preclusion.

Infiltration systems have often demonstrated fairly limited life spans. The USEPA states that 50 percent of checked stormwater infiltration trenches, which have a similar design to stormwater injection wells, have had partial or complete failure after 5 years (USEPA, 1999c).

Siltation has been widely documented as a key cause of failure in infiltration systems. It has been found that infiltration rates in stormwater infiltration systems are impacted by a number of variables, many of which cannot be controlled. These variables can include soil type, depth to the groundwater table, sediment or other types of clogging, groundwater mounding during storm events, antecedent moisture content in surrounding soils, and available surface areas of soils within the system which are exposed to and capable of accepting stormwater (Duchene, 1994).

Stormwater Runoff Quality in Washington

Several studies have been conducted on stormwater runoff that have included test sites in the Spokane area. Table 2 is a summary of data from some of these studies. Note that for each location and contaminant, a range of measured values (if available) precedes an average value; single values indicate that only one value was given in the reference.

Table 2. Contaminant concentrations in runoff at various sites in Spokane, WA.

Analyte	Contaminant Concentration (mg/L unless otherwise noted)			
	Industrial Site [1]	**Commercial Site** [1]	**Residential Site** [1]	**Interstate-90** [2]
Total Dissolved Solids (TDS)	62 - 378 208	66 – 305 217	20 – 192 80	-
Total Suspended Solids (TSS)	139 - 929 605	291 – 1310 853	107 – 660 394	9.60 – 1850.00 356.25
Cu (Total)	-	-	-	0.007 – 0.209 0.059
Cu (Dissolved)	0.04 – 0.1 0.07	<0.01 - 0.05 0.025	<0.01 – 0.02 0.01	0.007 – 0.027 .013
Pb (Total)	-	-	-	0.007 – 0.194 0.058
Pb (Dissolved)	0.10 – 0.85 0.48	0.20 – 0.73 0.47	0.01 – 0.09 0.32	.001 – 0.008 0.006
Zn (Total)	-	-	-	0.108 – 1.267 0.489
Zn (Dissolved)	0.14 – 0.25 0.27	0.24 – 0.39 0.31	0.02 – 0.11 0.07	0.022 – 0.113 0.050
Cl (Dissolved)	3.4 – 40.3 16.2	2.2 – 62.5 37.9	1.0 – 12.2 2.0 1.9	-
Ca (Dissolved)	13.9 – 42.5 28.2	10.0 – 51.0 27.2	3.0 – 18.5 4.0 11.1	-
Cr (Dissolved)	<0.01 – 0.02 0.01	<0.01 – 0.03 0.015	<0.01	-
Fe (Dissolved)	3.3 – 9.3 6.3	6.8	0.9 – 1.5 1.17	-
Hg (Dissolved)	<0.0002 – 13.4 4.47	0.62	<0.0002 – 6.2 3.10	-
K (Dissolved)	1.86 – 9.00 6.59	2.1 – 6.47 4.69	0.80 – 3.43 1.86	-
Na (Dissolved)	2.1 – 25.0 11.2	1.6 – 35.0 11.6	0.9 – 3.1 1.9	-
TOC	20.2 – 121.0 128.25	16.5 – 240.0 64.2	7.8 – 33.5 20.2	-
NO_3, N	0.3 – 0.8 0.5	0.4 – 0.9 0.6	0.4 – 0.9 0.7	-
TKN	1.33 – 6.16 3.82	0.84 – 11.20 4.36	1.23 – 2.80 1.78	0.80 – 11.46 4.53
T-PO_4	0.23 – 1.02 0.67	0.44 – 1.35 0.80	0.26 – 0.71 0.42	0.11 – 1.01 0.46
SO_4	6.1 – 32.0 21.1	5.3 – 62.5 24.0	1.0 – 12.2 2.0 5.1	-
oil & gas	0.9 – 15.9 6.5	3.4 – 8.6 6.0	0.0	-
pH	7.0 – 7.2 7.1	6.9 – 7.3 7.1	6.9 – 7.1 7.0	-

1) Campbell, 1985
2) Yonge and Hossain, 2002
"-" = not reported in reference

EXPERIMENTAL METHODS

Experimental Columns

Four experimental columns were constructed from three-foot sections of 30-inch diameter, commercial grade, double-walled, acrylonitrile-butadiene-styrene (ABS) culvert with an end cap for the base (Figure 2). The base was tapped with a 1-inch bulkhead fitting, covered with a stainless steel screen to prevent gravel migration, and plumbed downstream with 1-inch Schedule-40 PVC pipe and fittings. The sampling port was fitted with ½-inch non-reactive Tygon tubing to aid in sample collection. Six inches of 1½-inch minus road gravel was placed in the bottom of each column followed by one inch of 3/8-inch pea gravel. Three columns were used for laboratory experiments and the fourth for field testing. The gravel in the three laboratory columns was washed to remove fine particles prior to adding the SPRIB.

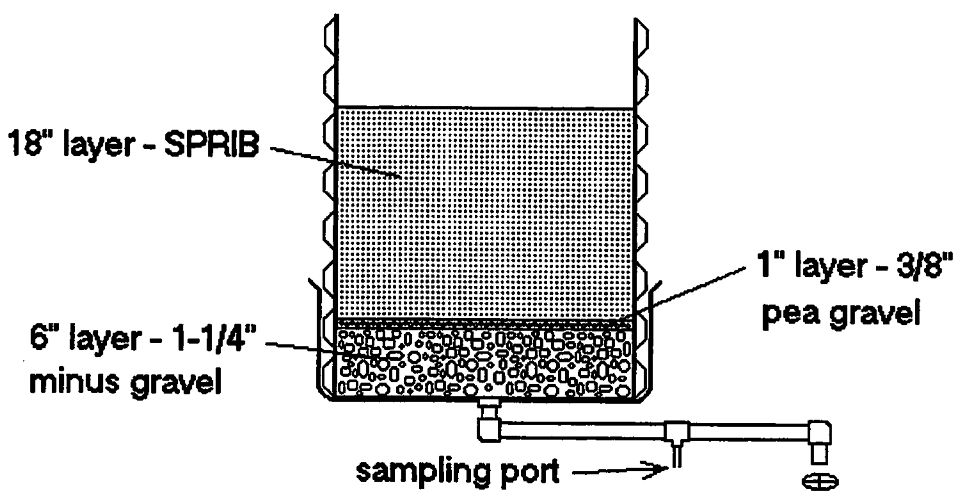

Figure 2. Simplified schematic diagram of the experimental column.

The SPRIB medium was composed of 70-grit silica sand obtained from Lane Mountain Sand, in Spokane, Washington, ground red clay from Mutual Materials Inc., in Auburn, Washington, and alderwood mulch from H&B Fuel in Puyallup, Washington. The SPRIB medium was mixed in a sand:clay:mulch ratio of 90:5:5 by dry weight (materials were weighed, dried at 110 °C until constant mass was achieved, reweighed, and the difference taken to determine moisture content). Large batches for the columns were mixed in a portable cement mixer, maintaining the same weight ratio (corrected for moisture content), and poured to a depth of 18 inches above the pea gravel. The sand/clay column was similarly prepared with a sand:clay ratio of 95:5 by dry weight.

The minimum and maximum index densities of the sand, clay, and mulch were determined by ASTM Methods D 4252-91 Test Method C and D 4253-93 (reapproved 1996) respectively. The test for determining the minimum index density (the density of a soil in the loosest state of compactness at which it can be placed) of each medium was accomplished by placing a known weight of the medium into a capped 2000-mL graduated cylinder, rapidly tipping the cylinder upside down and back to vertical, and measuring the volume the medium occupies. The minimum index density was then calculated as follows:

$$\rho_{dmin} = M_s/V \qquad (1)$$

where ρ_{dmin} = dry minimum index density of the specimen (g/cm^3)

M_s = mass of dry specimen (g)

V = volume of specimen (cm^3)

The test for determining the maximum index density (the density of a soil in the densest state of compactness that can be attained without breakdown) of each medium was accomplished by placing a known weight of the medium into a graduated mold, placing a surcharge weight (equivalent to a surcharge pressure of 2.00 ± 0.02 lb/in^2 for the mold being used) onto the surface of the medium, vibrating the mold on a vibrating table and thereby compacting the sample, and measuring the volume the medium occupies. The maximum index density was then calculated as follows:

$$\rho_{dmax} = M_s/V \qquad (2)$$

where ρ_{dmax} = dry maximum index density of the specimen (g/cm^3)

M_s = mass of dry specimen (g)

V = volume of specimen (cm^3)

The porosity of the sand and clay (mulch was considered too heterogeneous to accurately quantify) were then determined as follows:

$$n = 1 - \rho_{dmin}/\rho_{solids} \qquad (3)$$

where n = porosity of the specimen

ρ_{dmin} = dry minimum index density of the specimen (g/cm^3)

ρ_{solids} = dry density of the specimen (= 2.65 g/cm^3)

The particle size distribution of the sand was determined by ASTM Method C 136-96a for sieve analysis of fine and coarse aggregates. This method involves separating a known weight of a material by passing the material through a series of standard size sieves with progressively smaller openings mounted on a mechanical sieve shaker and weighing the quantity of material left in each sieve to determine a distribution of particle sizes. The particle size distributions of the clay and Hanford silt (used in the simulated stormwater) were analyzed by centrifuge by the University of Idaho (UI) Department of Agriculture Soils Laboratory.

The three different media (sand, clay, and mulch), the complete SPRIB mix (sand/clay/mulch), and the Hanford silt were also analyzed for cation-exchange capacities by the UI laboratory. The three column mixtures (sand, sand/clay, and SPRIB) were analyzed for the contaminants of concern (Cu, Pb, Zn) by the EPA Method 200.7 protocol for total recoverable metals (USEPA, 1994), which is an acid extraction procedure. Additionally, the clay was analyzed for iron and manganese content by the UI laboratory through CBD extraction. The BET (Brunauer, Emmett, and Teller) specific surface areas of the three media were analyzed at the Washington State University Chemical Engineering Laboratory by a Coulter SA 3100 Series Surface Area Analyzer. The results of all these analyses are shown in Table 3.

Table 3. Experimental column media characteristics.

Media	Particle Size Distribution	Mineral/Media Characteristics	Cation Exchange Capacity	BET Specific Surface Area
Sand	total retained in US Standard Testing Sieve: #30: .03% #50: 13.87% #70: 38.34% #80: 13.38% #100: 10.24% #140: 15.83% passing #140: 8.02%	Cu: 0.01 mg/kg Pb: nd Zn: 0.75 mg/kg index densities: $\rho_{dmax} = 1.47$ g/cm^3 $\rho_{dmin} = 1.33$ g/cm^3 porosity: 0.50	0.20 cmol(+)/kg	<0.10 m^2/g [1)]
Clay	very coarse sand: 0.18% coarse sand: 0.27% medium sand: 0.30% fine sand: 1.77% very fine sand: 11.76% silt: 47.64% clay: 38.07%	Fe: 37698 mg/kg [2)] Mn: 168 mg/kg [2)] index density: $\rho_{dmin} = 1.19$ g/cm^3 porosity: 0.45	7.22 cmol(+)/kg	26.92 m^2/g
Mulch	na	index density: $\rho_{dmin} = 0.72$ g/cm^3	29.77 cmol(+)/kg	2.71 m^2/g
Sand/Clay Mix (95:5)	na	Cu: 0.65 mg/kg Pb: 0.56 mg/kg Zn: 1.76 mg/kg	na	na
SPRIB Mix (90:5:5)	na	Cu: 2.0 mg/kg Pb: 1.19 mg/kg Zn: 5.57 mg/kg	1.65 cmol(+)/kg	na

Media	Particle Size Distribution	Mineral/Media Characteristics	Cation Exchange Capacity	BET Specific Surface Area
Hanford Silt	very coarse sand: 0.02% coarse sand: 0.03% medium sand: 0.01% find sand: 5.46% very fine sand: 37.24% silt: 49.86% clay: 7.38%	na	17.50 cmol(+)/kg	na

1) value below method detection limit = <0.1 m^2/g
2) determined by CBD extraction
"na" = not analyzed
"nd" = not detected above method detection limit

Preliminary Column Experiments

Prior to performing water quality and performance experiments on the columns, several background information tests were performed on them including background effluent quality, and initial infiltration rates and hydraulic residence times (HRT). To determine the background quality of effluent passing from each of the columns, each one was flooded with "clean" tap water. Samples of the tap water influent and the column effluent (at "first flush" and 20 minute run time) were collected and analyzed for TSS, and total and dissolved copper, lead, and zinc. Protocols for sample preparation and analyses are described in a later section. To determine background infiltration rates, each column was flooded with tap water so that one foot of head was observed above the media and the flow rate adjusted until a static water level was observed for a minimum of five minutes. The flow rate was then measured with a graduated container and stopwatch and converted to an infiltration rate. Background HRTs were measured by flooding each column with tap water to a static water level of 1 inch above the media surface, allowing the column to flow steadily until a relatively constant conductivity in the effluent was observed, adding a 100 mL "pulse" of lithium chloride solution (4170 mg Cl^- to obtain theoretic overall column concentration of 50 mg/L Cl^-) to the influent, and measuring conductivity at the effluent. By integrating the conductivity versus time curve created, mean HRTs were calculated for each column.

Multi-Component Isotherm Studies

In addition to the tests described above, batch competitive equilibrium isotherm studies were conducted on each of the three filtration media to identify preferential order of sorption for the three metals of concern and relative affinity of the metals to each medium. Isotherms were prepared by measuring a range of weights of each sorbent into 125 mL polyethylene jars, adding 100 mL aliquots of metal solution, sealing the jars, and agitating with a wrist-shaker for 48 hours to allow equilibrium to be established. The contents of each container were then filtered through a 0.45-μm membrane filter and the residual soluble metal concentrations in solution were analyzed. Protocols for sample preparation and analyses are described in a later section. The metal solution used for the studies was prepared by adding stock metal solutions to filtered tap water. Target constituent concentrations were 2 mg/L for Cu & Pb and 3.5 mg/L for Zn. The metals solution was also analyzed for soluble metals to determine precise concentrations for isotherm calculations.

Simulated Stormwater

Thirty-gallon batches of simulated stormwater were prepared in 55-gallon Nalgene® tanks. Simulated stormwater was composed of tap water (pH ~7.45), silt, and stock solutions of dissolved copper, lead, and zinc. Silt was collected from a site near Hanford, Washington, and only that portion that passed through a #80 US Standard Sieve was used in the stormwater mix. Stock solutions of dissolved copper, lead, and zinc were prepared according to EPA Method 200.7 for use with inductively coupled plasma/mass spectrometers (ICP/MS) (USEPA, 1994).

The simulated stormwater (mean pH ~8.4) was mixed for a minimum of 18 hours to allow partitioning of metals to reach equilibrium. Simulated stormwater was transferred through non-reactive Masterflex® tubing from the tanks to the columns by a peristaltic pump. Contaminant constituents for simulated stormwater batches were mixed in two sets of concentrations for three types of simulated storm events (described in the following section). Approximate target concentrations for each type of event are detailed in Table 4.

Table 4. Target concentrations for simulated stormwater batches.

Constituent	Concentration (mg/L)	
	Average & Double Flow Events	Overload Events
Total Copper	1.0	4.0
Total Lead	1.0	4.0
Total Zinc	1.5	6.0
Total Suspended Solids	350	700

Simulated Storm Events

To achieve the objectives of this research simulated events were broken into two types with regard to the applied flow rate and constituent concentrations.

1) *Average flow events* - Eleven simulated storm events were run through each of the columns (time constraints allowed only 6 runs through the sand/clay column). These events were conducted to simulate actual peak runoff duration, average sediment loading, and exaggerated upper limits of total metal concentrations in Spokane area highway and roadway runoffs (see Table 2). Duration of simulated storm events were based on analysis of hydrograph data from the Spokane area. This data indicated that peak runoff during typical storms lasted approximately 30 minutes, based on observations of 43 storm events between

September 1997 and August 1998 (Yonge and Hossain, 2002). Therefore, simulated runoff duration in each event lasted 30 minutes. In each "average" event, flow rates into the columns were maintained at 1 gallon per minute (gpm), which corresponded to the approximate infiltration rate of the column that exhibited the lowest initial infiltration rate (SPRIB). This flow rate yielded a total volume of 30 gallons of simulated stormwater being introduced during each event.

2) *Double flow events* - Every fifth event, "runoff" flow rates were doubled to 2 gpm to simulate a larger storm, but with the same duration as "average" events. The duration and flow rates for these events yielded a total volume of 60 gallons of simulated stormwater introduced per event. Concentrations of TSS and total copper, lead, and zinc also remained consistent with the "average" events.

3) *Overload events* – After sufficient data was collected from the other simulated storm events, 4 overload events were conducted on the SPRIB column only. The purpose of the overload events was to push the contaminant retention capacity of the SPRIB column to saturation breakthrough (if possible) and decrease the infiltration rates, through siltation, to below acceptable values. This allowed for a more rapid determination of the overall useful lifespan of the SPRIB. In the overload events, TSS concentrations were doubled and metal concentrations were quadrupled (Table 4). Flow rates into the column were maintained at 1 gpm, but total liquid volumes (and thus duration) were doubled for each event.

Sample Collection, Preparation, and Analysis

At the beginning of each simulated storm event, samples were collected from the influent to confirm contaminant concentrations in the simulated stormwater. Samples were collected from the effluent of the column as soon as outflow was observed; then at a predetermined frequency throughout the event until flow rates from the effluent dropped to a level prohibitive to practical sample collection. This drop in effluent flow typically corresponded to shortly after influent flow ended or after hydraulic head dropped below the medium surface (when ponding occurred). During each sampling event, samples were collected into three 500-mL acid-washed glass Erlenmeyer flasks and then preserved or filtered as required for subsequent analysis. During periods of passive sample preparation, beakers were sealed with a parafilm wax to prevent contamination from the outside environment.

All water samples, stock solutions, and calibration standards were handled, preserved, and prepared following EPA Method 200.7 for analysis of total and dissolved metals by ICP/MS (USEPA, 1994). Preparation of samples for metals analyses consisted of an acid digestions procedure for total metals, and filtration of samples through a 0.45-μm membrane filter followed by acidification for soluble metals. Analyses were performed at the WSU Geoanalytical Laboratory on a Hewlett-Packard Model 4500 ICP/MS. TSS analyses were performed gravimetrically by filtering samples through pre-washed glass fiber filters as specified in procedures established in Standard Methods 2450 D (Standard Methods, 1995). All glassware used in laboratory procedures was acid washed prior to use, and stored and handled so as to prevent contamination from the environment. All acids used in sample preparation (HNO_3 and HCl) were omnipure ("metal-free") acids.

Solid Phase Metal Concentration Profiles

After completion of testing of the SPRIB and sand columns, three 19-inch deep core samples (spaced horizontally 10 inches apart across a transect of the column) were collected from each of the two columns in order to get an estimate of the vertical metal concentration profile. Core samples were collected from the top inch (the deposited silt layer) and from each

3-inch interval of the 18 inches of filter bed below. Below the silt layer, cores were taken in 3-inch "lifts" with an ¾-inch (i.d.) acid-washed glass tube, taking care to minimize sloughing between lifts. The tube was rinsed in Millipore® double-deionized (DDI) water between lifts. All core samples were oven-dried to constant mass, and one-gram composite samples from each lift were prepared for total recoverable metals analyses by acid extraction as specified in EPA Method 200.7 (USEPA, 1994).

Field Column Setup, Measurements, and Sample Collection

The field column was installed at the outfall of a culvert system that drains an estimated 3.68 acres of Interstate 90 (I-90) near Sprague Avenue in southern Spokane. Average daily traffic (ADT) along this stretch of I-90 is 100,000 vehicles. Runoff in the culvert for a 0.9-inch 6-month quality storm yields approximately 2.4 cubic feet per second (cfs). A plan view of the drainage area is provided in Figure 3.

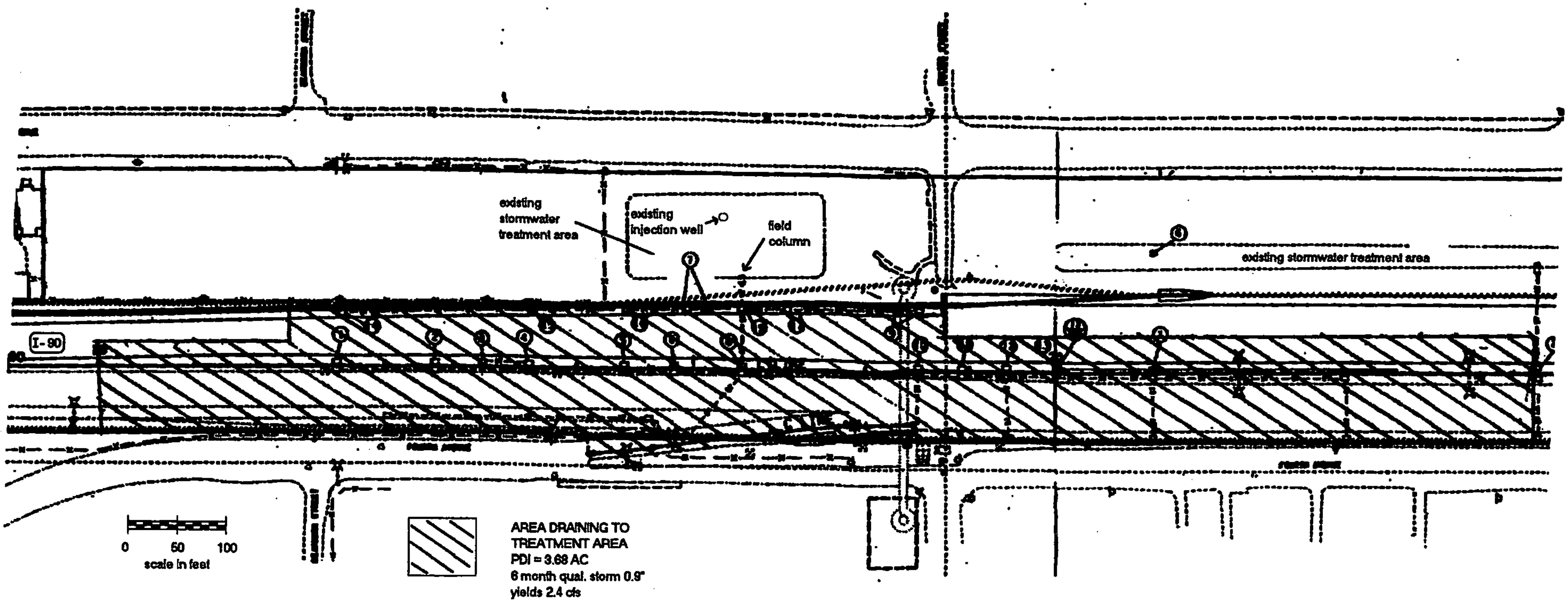

Figure 3. Site Plan of Field Column Location and Drainage Area.

The column placed in the field was equipped with additional features and instrumentation to the laboratory columns in order to accurately record field conditions and collect field samples. A schematic representation of the field setup is presented in Figure 4. Field measurements and samples were collected by two American Sigma Company model 980 data loggers and associated model 900 auto samplers.

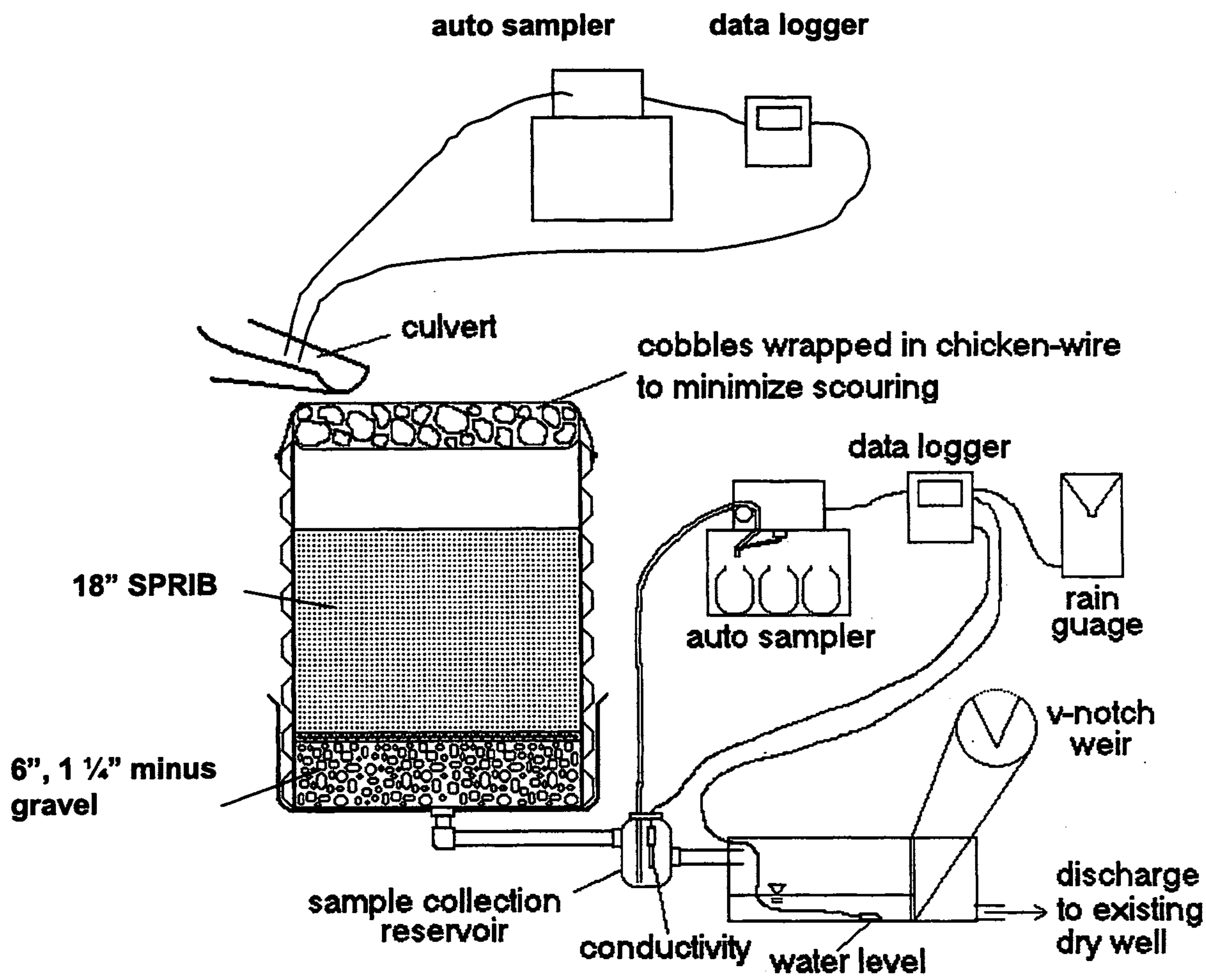

Figure 4. Simplified schematic diagram of experimental field column setup.

The data loggers recorded flow, conductivity, and water level in the influent culvert; conductivity and flow in the column effluent; and rainfall at the site. Flow rates in the culvert were calculated automatically by the data logger, which was supplied with appropriate inputs (pipe type, roughness, diameter, and slope). Flow in the effluent was calculated by collecting water level readings with a pressure transducer at a calibrated 45° V-notch weir (Figure 5) attached downstream of the column outflow. The auto samplers were programmed, via environmental triggers, to collect samples during storm events of both the influent from the culvert and effluent from the column. Samples were collected into 1.9-liter acid-washed glass containers. Additionally, field conditions and equipment functionality were routinely monitored remotely via internal data logger modems hooked to Motorola analog cellular telephones.

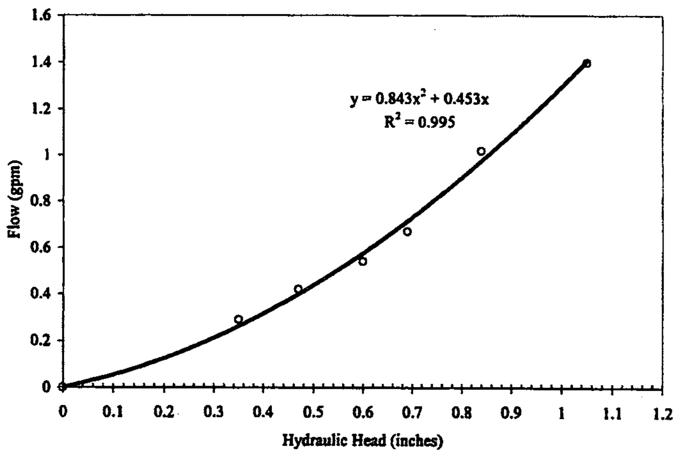

Figure 5. Calibration curve for 45° V-notch weir.

RESULTS AND DISCUSSION

Results from Preliminary Column Tests

Results from the preliminary column tests and background experiments are presented in Table 5.

Table 5. Experimental column background analyses.

Column	Infiltration Rate (in/hr)	Hydraulic Residence Time (min)	Contaminant Concentration		
			Cu (µg/L)	Pb (µg/L)	Zn (µg/L)
Sand Column	37.03	13.99	1st flush: [1] T[2]: 6.88 D[3]: 4.71 20 min: T: 4.59 D: 3.61	1st flush: T: 7.95 D: 5.81 20 min: T: 7.54 D: 5.54	1st flush: T: 6.38 D: nd 20 min: T: 3.97 D: nd
Sand/Clay Column	20.72	24.79	1st flush: T: 12.25 D: 6.34 20 min: T: 5.09 D: 5.89	1st flush: T: 9.61 D: 6.65 20 min: T: 9.46 D: 5.60	1st flush: T: 19.38 D: 0.88 20 min: T: 2.80 D: nd
SPRIB Column	19.42	30.69	1st flush: T: 19.81 D: 6.34 20 min: T: 17.60 D: 5.89	1st flush: T: 9.31 D: 7.41 20 min: T: 10.90 D: 7.99	1st flush: T: 25.20 D: nd 20 min: T: 16.44 D: nd
Tap Water	n/a	n/a	T: 9.89 D: 5.00	T: 16.12 D: 7.54	T: 660.0 D: 458.0

1) 1st flush refers to the initial outflow of effluent which typically carries the highest quantities of sediment and contaminants
2) T = total metals
3) D = dissolved metals
"n/a" = not applicable

Results of Multi-Component Isotherm Studies

Figure 6 – Figure 8 illustrate the sorption isotherms for each of the three experimental media with respect to copper, lead, and zinc.

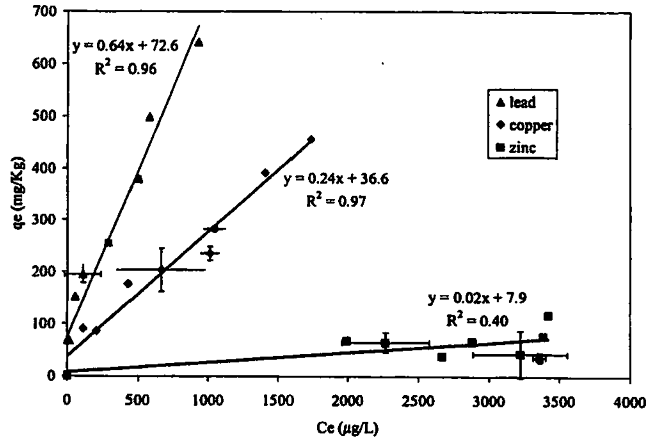

Figure 6. SPRIB multi-component isotherm data.

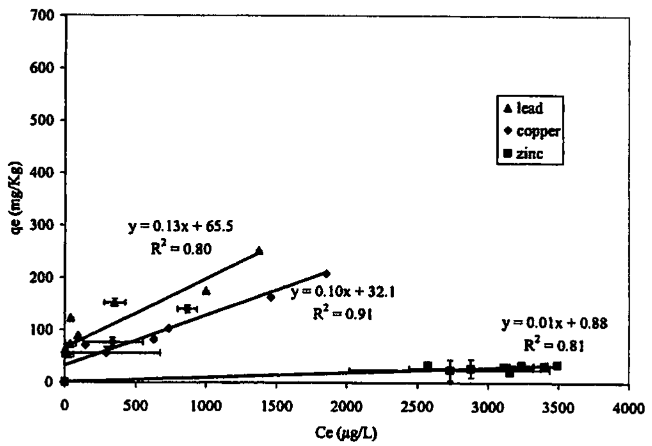

Figure 7. Sand/Clay multi-component isotherm data.

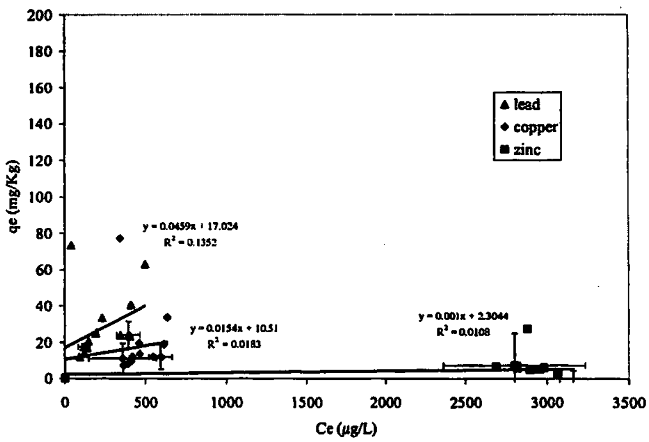

Figure 8. Sand multi-component isotherm data.

The slope of each individual metal isotherm, compared with the others in that batch, indicates the lyotrophic series (hierarchy of exchange or relative preference of sorption) for that medium. As evidenced in each of these three figures, the comparative slope for each metal (Table 6) indicates that lead is preferentially sorbed over copper, which in turn is preferentially sorbed over zinc. These results are not unexpected based on other well-documented lyotrophic series and sorbent selectivities for divalent metal ions (Watts, 1998). Additionally, based on the slope of each individual metal isotherm between media, it is also evident that, relative to one another, each of the metals has a greater affinity to the SPRIB mixture than to the sand/clay mixture, than to the sand filter. The relative affinity to each medium is also not unexpected based on the cation exchange capacity (CEC) of the mulch, clay, and sand (Table 3). Comparatively, the mulch has a much higher CEC than the other two media, and the clay has a significantly higher CEC than the sand.

Table 6. Isotherm slopes for each constituent with each medium.

Filtration Media	Slope of Constituent Isotherm		
	Pb	Cu	Zn
SPRIB	0.64	0.24	0.02
Sand & Clay	0.13	0.10	0.01
Sand	0.02	0.01	0.001

Results From Simulated Storm Events

Figure 9 - Figure 11 illustrate the concentrations of total and dissolved copper in the column effluents over the duration of all the simulated storm events. Here copper is used to represent lead and zinc, as the trends between metals were essentially the same (figures with results for lead and zinc can be found in Appendix D). Note that the time axis is the approximate overall run time, placing each event back to back (actual events were separated by time periods ranging from 2 days to several months).

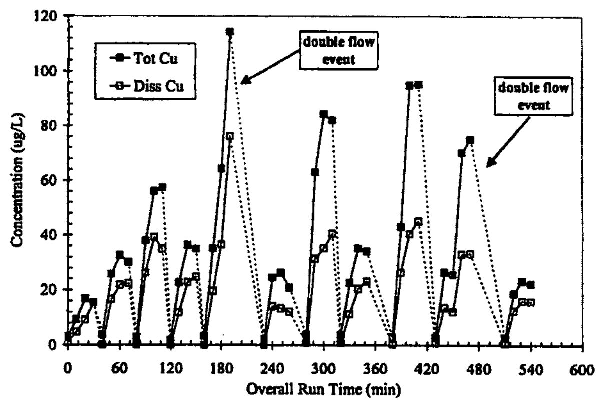

Figure 9. Sand Column - Total & Dissolved Cu.

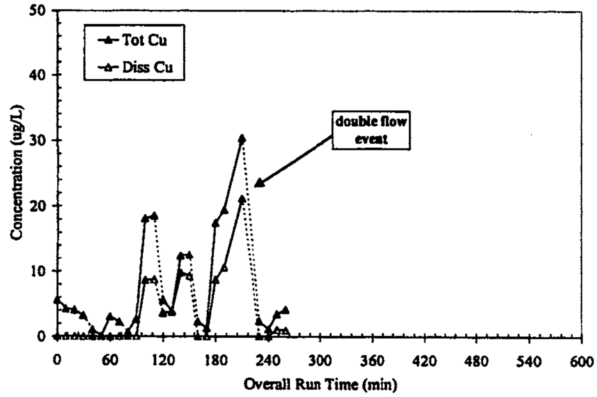

Figure 10. Sand/Clay Column – Total & Dissolved Cu.

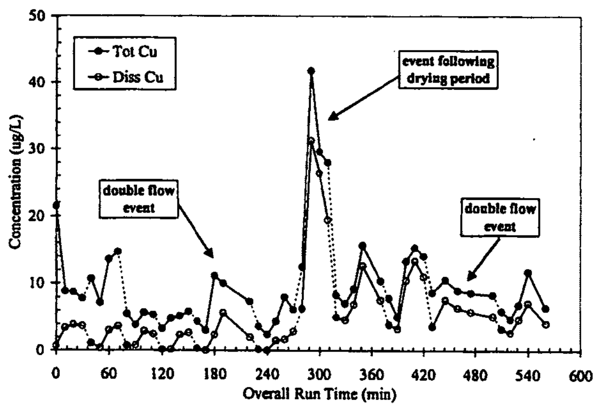

Figure 11. SPRIB Column - Total & Dissolved Cu.

These figures indicate that, for all three columns, peak effluent concentrations do not generally increase from event to event as might be expected. Rather, effluent concentrations reach a pseudo steady state condition after the first few events. This phenomena is due to the various filtration media removing the large majority of the influent metals (as discussed later) from the stormwater and releasing only residual concentrations in the effluent. This is most probably due to the quantity of metal sorbed by the various filtration media not coming near to reaching their respective sorption capacities. Notable exceptions to this trend include a higher than average peak for the sand column at approximately 180 minutes, which corresponds to the first "double" flow event for that column, and a sharp spike in effluent concentrations in the

SPRIB column at approximately 300 minutes, which corresponds to the first event after a drying period (discussed in greater detail below).

A typical effluent concentration profile for an individual simulated storm event is shown in Figure 12. For an individual storm event, metal concentrations in the effluent are usually negligible at the initiation of a run. The concentrations then increase throughout the event, but typically taper off at the end of the run when stormwater is no longer supplied to the column (and a corresponding decrease in hydraulic head is observed above the surface of the medium). Negligible concentrations are again observed at the initiation of the next run. Note that the curve between the end of one run and start of the next is illustrated with a dashed line to indicate there was insufficient flow in the effluent to collect samples during this period and that initiation of the next event did not actually occur until at least 2 days later.

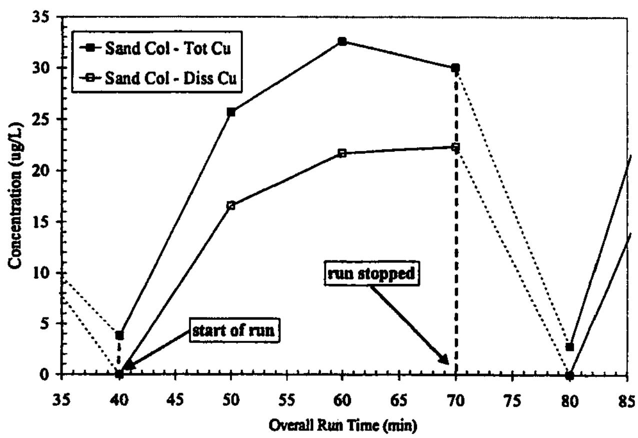

Figure 12. Results from an individual "storm."

Figure 13 through Figure 15 illustrate other identifiable trends that are unique for each column.

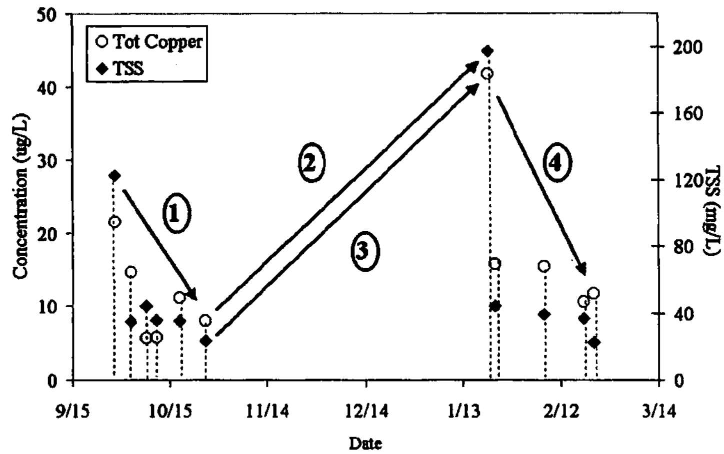

Figure 13. SPRIB column – peak Cu & TSS measured during simulated events.

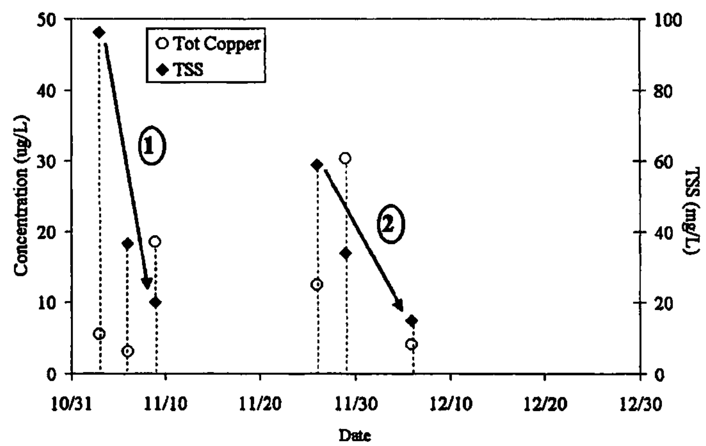

Figure 14. Sand & clay column - peak Cu & TSS measured during simulated events.

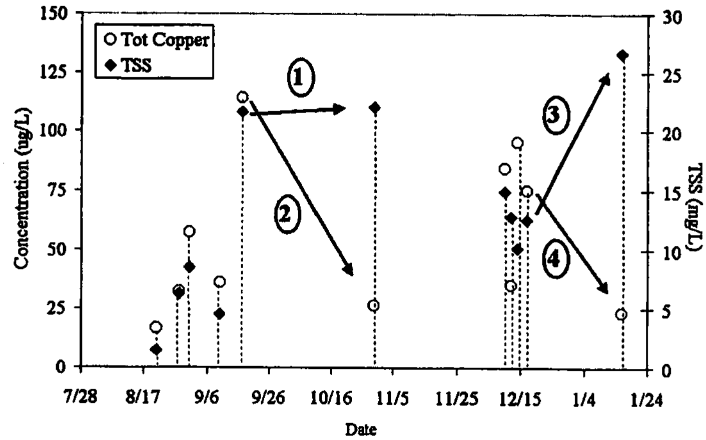

Figure 15. Sand column - peak Cu & TSS measured during simulated events.

These figures illustrate peak concentrations of metals (represented by total copper) and total suspended solids on the actual dates on which simulated events were conducted (between August 2001 and February 2002). Upon inspection of these results, several trends can be identified.

In the SPRIB column, an overall decrease in metals and suspended solids concentrations can be observed (Figure 13, Arrows 1 & 4) when events are closer together and thus saturated to semi-saturated conditions are maintained within the medium. This trend can also be noted in the sand/clay column for metal concentrations (Figure 14, Arrows 1 & 2). This may be a result of buildup of the simulated stormwater sediment on the surface of the column media, which enhances solids removal and results in lower effluent solids and total metal concentrations during frequently spaced storm events. This phenomenon of enhanced solids removal over the early stage of a filter run, sometimes termed "aging," has been observed in water and wastewater filtration unit operations. What is interesting in the data for the SPRIB column is that after an extended period of drying (late October 2001 through mid January 2002), the effluent metal and TSS concentrations are shown to increase significantly compared to the last simulated storm event prior to the drying period (Figure 13, Arrows 2 & 3). In fact, the observed solids and total metal concentrations for the first run following the drying period were greater than those observed at the initiation of experimentation (September 2001). This observation could be a result of partial cracking of the SPRIB media during drying which, at the initiation of a simulated storm event, causes preferential flow paths with higher velocities that "erode" some of the clay/organic material in the SPRIB. The clays and organic materials carry with them relatively high metal concentrations due to their high metal partition coefficient.

The results of sand column experiments showed none of the trends in effluent metal concentrations following a drying event, at least in part supporting the hypothesis stated above. In the sand column, an overall increase in effluent metals and suspended solids concentrations was observed in the initial events, but then stayed relatively constant afterward at concentrations below 100 μg/L. After a drying period (mid September to early November 2001) suspended solids in the effluent increased from the previous events, but metals in the effluent decreased significantly (Figure 15, Arrows 1 & 2 respectively), contrary to the results observed in the SPRIB column. These results were shown to be repeatable, after a second grouping of events, when another drying period was allowed to occur (mid December 2001 to mid January 2002) and similar results were recorded (Figure 15, Arrows 3 & 4). These results indicate that under saturated to semi-saturated conditions, the amount of metals passing through the column is proportional to the amount of sediment being flushed through the column. However, unlike the SPRIB column, after a drying period, fine sand sediments are flushed out that do not carry the metal loads that the clays and organics in the SPRIB column carry, thus the resulting metals concentrations actually decrease. This effect is most likely explained by the fact that fine silica particles have far less sorptive capacity than clays and organics (as indicated by their respective CECs - Table 3).

Explanations of these trends could not be proven by the tests performed in this study. Events (or the relative magnitudes of the results thereof) that appear irregular, or do not correspond with predicted results or trends are likely attributable to a combination of several conditions, including:

- altered liquid flow paths through the media between events due to siltation or clogging of preferential pathways, changes in influent flow rates, or cracking caused by drying which creates new flow paths;
- altered contact time with the media caused by degree of saturation of inter- and intra-particle pore spaces; and
- changes in total hydraulic head under steady influent flow conditions caused by siltation, leading to slower infiltration rates and increased ponding of influent water above the media.

Overall Metal and Suspended Solids Concentration Reduction

By direct comparison of total metal concentrations in the effluents of each column (represented by total copper in Figure 16), it is evident that the highest removal rates were from the SPRIB column, followed by the sand/clay mix, with the lowest removal rates by the sand column.

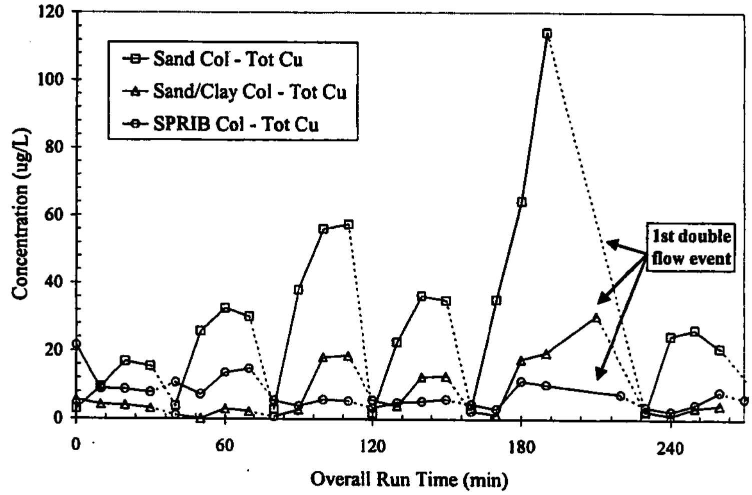

Figure 16. Relative metal concentrations in effluent of each column.

Table 7 indicates the average metals and TSS concentration reduction rates of all the laboratory columns after completion of eleven simulated storm events (6 for the sand/clay column). Concentration reduction rates are represented as an average of all events based on a comparison between mean influent and effluent concentrations for each individual event. As expected, on average the SPRIB reduced concentrations of both dissolved and total metals at greater rates than the other two columns (with the exception of copper, which was reduced by a slightly higher amount in the sand/clay column). Reductions of total metal concentrations were above 96% for all three columns; however, the addition of the clay and mulch obviously have a significant impact on the removal of dissolved constituents, the concentrations of which were reduced at rates between 61% and 80% by the sand and between 91% and 99.5% by the columns containing mulch and/or clay.

Table 7. Average concentration reductions of suspended solids and metals.

Column	Total Solids Reduction	Metal Concentration Reduction					
		Copper		Lead		Zinc	
		Dissolved	Total	Dissolved	Total	Dissolved	Total
Sand Column	98.8%	61.3%	96.5%	78.9%	96.8%	75.9%	96.6%
Sand/Clay Column	95.5%	93.4%	99.3%	95.0%	99.2%	96.1%	99.1%
SPRIB Column	94.7%	91.3%	99.2%	97.6%	99.5%	98.2%	99.4%

While TSS reduction appears to decrease from the sand, sand/clay, and SPRIB columns respectively, the majority of solids filtered out of the effluents of the sand/clay and SPRIB columns during suspended solids analysis were observed to be red clay. This indicated that a fraction of clay already in the columns was being flushed out during storm events, rather than actual passage of stormwater solids through the columns. The flushed out solids from the SPRIB column also appeared to contain dark particles of mulch, which also added to the effluent TSS concentration.

Effects of Simulated and Overload Events on Observed Infiltration Rates

Based on the combination of siltation from simulated storm events and overload events, data from the laboratory columns identified an approximate linear relationship between increased TSS surface loading and decreased flow velocity. Simulated storm and overload events were conducted on the SPRIB column until this linear decline in flow velocity was observed to drop below the prescribed acceptable infiltration rate of 8 in/hr (Figure 17); this occurred after 15 simulated events (11 storm, 4 overload).

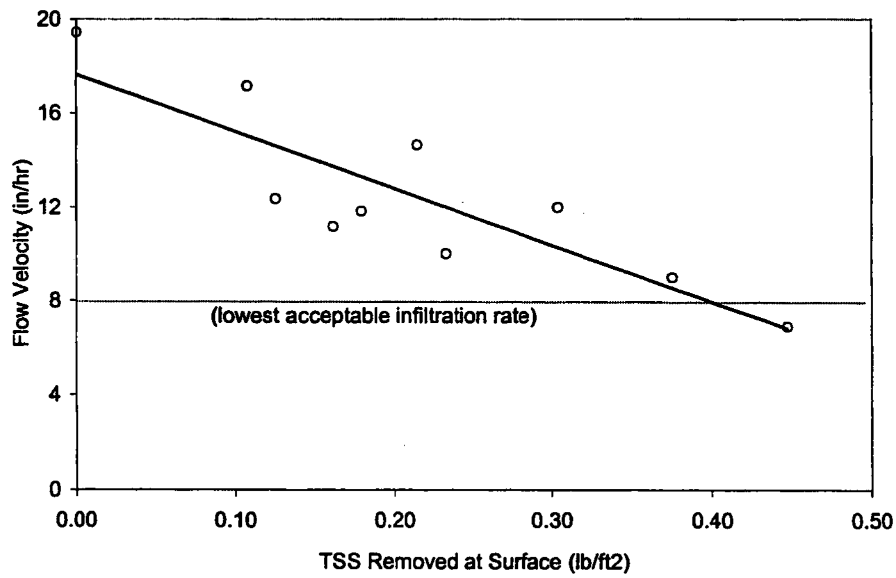

Figure 17. Surface removal of suspended solids vs. flow velocity in SPRIB column.

"Maintenance" was performed on the SPRIB column upon completion of testing, which consisted of scraping approximately one inch of material, which included the entire deposited silt layer, from the top of the column. By flooding the column with tap water to a static level of one foot, a test was then conducted to determine the post-maintenance infiltration rate of the column. This test showed that after maintenance was performed, the column infiltration rate rebounded to 17.65 in/hr (approximately 90% of its original infiltration rate of 19.42 in/hr).

Solid Phase Metal Concentration Profiles

After 4 overload events, the columns were still removing approximately the same fraction of metals as were being removed during the simulated storm events, providing evidence that their capacities were not reached during testing. The findings of these tests agree with the USEPA's findings (USEPA, 1999e) regarding filtration media, in that clogging of the media was observed well before the sorptive capacity of the media was reached.

After testing completion on the SPRIB and sand columns, core samples were collected from the two columns and total recoverable metals analyses were performed in order to obtain an estimate of the vertical metal concentration profile of the columns.

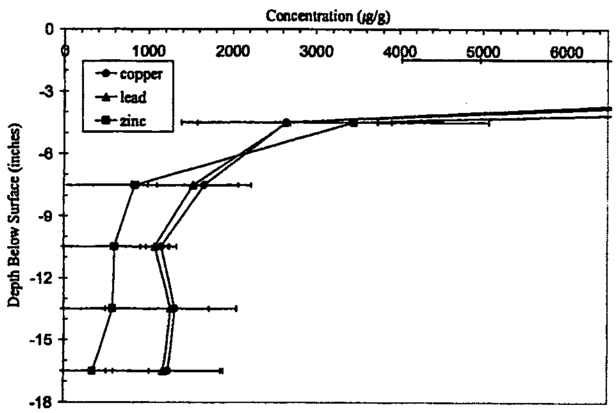

Figure 18. Sand column core results.

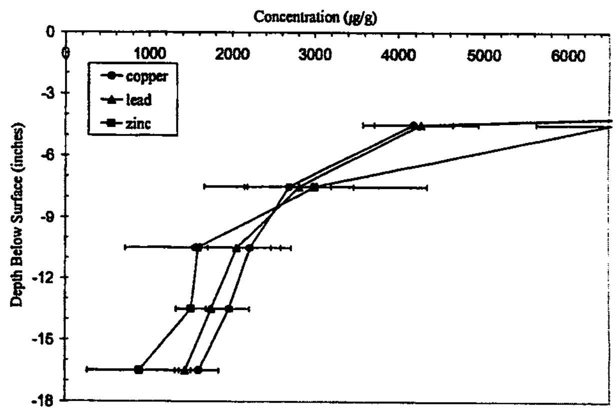

Figure 19. SPRIB column core results.

Results from these tests (Figure 18 and Figure 19) indicate that in both columns, sediment with high concentrations of bound metals may have penetrated approximately 4 to 5 inches into the filter bed. This is implied by extremely high metal concentrations at the surface followed by a very rapid decline in the metal concentrations to the aforementioned depth. Below this, metal concentrations in the columns decline much more slowly. In the sand column the declines in concentrations go nearly to zero, reaching steady concentrations of approximately 500 µg/g for zinc and 1250 µg/g for copper and lead. This even distribution of metals below 6 inches most likely indicates that so little sorption occurs on the sand that nearly equal concentrations of soluble metal are reaching all of the sand in the filter bed. In the SPRIB column below 6 inches, a roughly linear decline is observed in metal concentrations down to approximately 1000 µg/g for zinc and 1500 µg/g for copper and lead. This most likely indicates that soluble metals are being strongly sorbed to the SPRIB material all the way through the depth of the filter bed. Note that the lowest concentrations observed in each profile were at least two orders of magnitude greater than measured background concentrations for each medium (Table 3).

Estimated Column Lifespan

Estimates have been established for the useful life spans of the columns. These estimates (Table 8) are based on 1) a runoff duration of 30 minutes; 2) stormwater containing ~350 mg/L TSS; and 3) a mean of 46 runoff-producing storms per year (as indicated in a study by Urbonas (Urbonas, 1999) for the Spokane vicinity).

Table 8. Estimated life spans of filtration media.

Filtration Media	**Life Span Based on Acceptable Infiltration Rates***	
	Storms	**Years**
Sand	50 - 55	1.2
Sand/Clay	22 - 25	0.6
SPRIB Mix	20 - 22	0.5

* based on the linear decline in infiltration rates related to surface loading of TSS, siltation is considered the limiting variable for the column life spans.

Results From Field Column Experiments

The field column was initially installed in December 2001. During the period of operation from December to February 2002, roughly 20 runoff-producing storms were recorded at the field site. During field tests over this period, several SPRIB deficiencies were observed. Periodic freezing of the top several inches of the SPRIB medium was observed which caused partial to complete arrest of infiltration through the medium. However, this phenomenon could potentially be mitigated with placement of the SPRIB at greater depths below ground surface in injection wells. Additionally, winter road sanding operations on the freeway caused premature clogging of the column due to greater than average quantities of silt and sediment entering the column. Due to freezing and other operational considerations, no quality samples were collected during this period of operation.

In mid April 2002, after the spring thaw, the SPRIB medium was replaced and field testing was resumed. During the operational period from April to early June, approximately 10 runoff-producing events were recorded at the site. Hydrographs for this period are provided in Appendix E. Of these storms, samples were collected during 5 events. Column effluent samples (avg. pH = 7.20) and influent stormwater samples (avg. pH = 7.30) were analyzed in the same manner as the laboratory samples. None of the deficiencies noted during winter months were observed over this period. Results from the sample TSS and total metals analyses identified similar results to the laboratory column results.

Table 9. Average concentration reduction rates of suspended solids and metals in field SPRIB column.

Total Solids Reduction	Metal Concentration Reduction					
	Copper		Lead		Zinc	
	Dissolved	Total	Dissolved	Total	Dissolved	Total
93.7%	40.4	74.9%	56.6%	86.1%	74.2%	93.5%

Similar to the laboratory results, concentration reduction rates (Table 9) were based on mean influent concentrations compared with mean effluent concentrations. These results indicate that on average, TSS reduction was approximately 85%, and total metals concentration reductions ranged from 75% for copper to 94% for zinc. Although dissolved metals analyses indicated concentration reduction rates approximately 25 – 50% lower than those from laboratory experiments, it should be noted that this was primarily due to influent concentrations being up to an order of magnitude lower than those introduced into the laboratory SPRIB column. Measured peak effluent dissolved metal concentrations were very similar to those observed in the laboratory, and at no time exceeded 10 μg/L for lead or 20 μg/L for copper or zinc. These results indicate a good correlation with laboratory results, and show that metals in stormwater runoff are being mitigated to negligible concentrations.

Observations of freezing and premature clogging in the winter months indicate that there is a need for pretreatment of runoff for suspended solids prior to discharge into SPRIB columns, especially in regions where frequent snow and ice can be expected. If pretreatment is not provided, the columns may become overly maintenance intensive. Maintenance protocols for sand filters are described in the WDOE Stormwater Management Manual for Western Washington (WDOE, 2001).

CONCLUSIONS

In this study it was shown that in the laboratory the SPRIB mixture composed of sand, clay, and mulch, reduced dissolved metals concentrations (Cu, Pb, and Zn) at a level greater than 91%, total metals concentrations at a level greater than 99%, and total suspended solids concentrations at a level greater than 85%. These laboratory results were confirmed with a pilot field column that also demonstrated attenuation of metals in stormwater runoff to negligible concentrations. Based on metal and TSS concentration reduction, use of SPRIB as a stormwater treatment method in injection wells appears to be a promising concept. However, two key factors were observed during this study that could limit or preclude the use of SPRIB in stormwater injection wells:

1) Based on required infiltration rates for stormwater management facilities, the useful life of SPRIB is limited by the quantity of TSS allowed to enter the treatment unit; therefore, SPRIB should not be used as a primary treatment process unless periodic replacement or removal of the clogged media surface can be routinely performed.
2) SPRIB should not be used in locations where the normal infiltration rates of the media are required during winter months as freezing can cause partial to complete loss of infiltration capabilities and excess sediment from road sanding operations can cause rapid surface clogging of the filter. However, placement of the media at greater depths below ground surface (i.e. inside injection wells) and pre-settling of solids could potentially mitigate the adverse effects of freezing conditions and high sediment concentrations respectively.

Although there may be limitations to the operating conditions, the results of this study have shown that if adequate maintenance and/or pretreatment is provided, SPRIB technology can provide significant mitigation of contaminated stormwater.

REFERENCES/LITERATURE CITED

40 CFR 141 and 143. National Revised Primary Drinking Water Regulations; Maximum Contaminant Levels; National Secondary Drinking Water Regulations.

40 CFR 144, 145, and 146. Class V Injection Wells Underground Injection Control Regulations, Revisions; Proposed Rule.

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APPENDICES

APPENDIX A - REGULATORY FRAMEWORK

Federal

Part C of the Safe Drinking Water Act (SDWA) mandates the regulation of wells used for underground injection of fluids. Under the authority of the SDWA, the USEPA established the Underground Injection Control (UIC) program in 1984 for the purpose of ensuring the protection of underground sources of drinking water (USDW). Under the UIC program, injection wells are divided into five classes, primarily based on the types of fluids that are injected into the wells. The following is a brief description of the five injection well classes (40 CFR 146):

- Class I – receives non-hazardous waste beneath the lowermost formation containing a USDW within ¼ mile of the well.
- Class II – receives fluids generated by oil or natural gas exploration, recovery or production; or for storage of hydrocarbons.
- Class III – used for injection extraction of minerals or unconventional in-situ mining.
- Class IV – receive hazardous or radioactive wastes into or above a formation containing a USDW within ¼ mile of the well.
- Class V – any well not included in Classes I through IV, including (but not limited to) wells for air conditioning return flows, cesspools, cooling water return flows, stormwater drainage, dry wells, salt water intrusion barriers, backfill, septic systems, and subsidence control. To be considered a Class V well, the fluid injected into the well must not be a hazardous waste as defined by the Resource Conservation and Recovery Act (RCRA).

As indicated above, Class V wells are divided into multiple subcategories. Stormwater injection wells are categorized as Class V, Subclass 5D2 injection wells, or "shallow injection wells designed for the disposal of rain water and melted snow" (40 CFR 146).

Under the SDWA, individual states may be granted status as "Primacy States" and have primary responsibility for running the UIC program. States must apply to the USEPA for primacy status. USEPA must administer the UIC program in states that do not meet USEPA requirements (or that do not apply for primacy). Whether the program is administered by the USEPA or a Primacy State, three basic requirements must be met by well owners or operators under the UIC program (USEPA, 1999a):

1) a performance standard that prohibits the injection of any contaminated fluid into USDW;
2) supply of well inventory information by well owners; and
3) compliance with general program requirements set forth by the UIC program director, which may include permitting of wells.

Many states have implemented additional requirements which ban or restrict installation of new wells, or require permit or registration of certain types or depths of wells. Federal programs and guidances, such as the Sole Source Aquifer Program, Federal Highway Administration highway runoff water quality standards, Coastal Zone Management Act, and Coastal Nonpoint Pollution Control Program, are being used to augment some states' regulatory programs (USEPA, 1999a).

State of Washington/City & County of Spokane

The 1972 Federal Water Pollution Control Act (FWPCA) set a goal of attaining water quality that is fishable and swimable, wherever possible, by 1983. Under Section 208 of the FWPCA, each state was required to develop a water quality management program. Spokane County was designated responsibility for developing a water quality management program for the Spokane-Rathdrum Aquifer. Based on cause and effect studies of the aquifer, a "no further degradation of the aquifer" policy was recommended and goals were set for this to be accomplished (WDOE, 1983).

Under the authority of the SDWA, the State of Washington was delegated authority as an UIC Primacy State in 1984 by the USEPA. The program is administered by the Washington Department of Ecology (WDOE), the policy of whom is "to maintain the highest possible standards to prevent the injection of fluids that may endanger ground waters which are available for beneficial uses or which may contain fewer than 10,000 mg/L TDS" (USEPA, 1999a). Based on this "anti-degradation" policy, all Class I, III, and IV wells are prohibited in Washington, and any well that injects fluid into a USDW that may cause a violation of primary drinking water standards or adversely affect the beneficial use thereof is prohibited. The UIC program in Washington is rule authorized, meaning that all existing and new Class V wells must apply to and be registered by the UIC program (USEPA, 1999a; WDOE, 2000).

The document "Storm Water Management for Western Washington" (2002) (which recently replaced the "Storm Water Management for the Puget Sound Basin: The Technical Manual" (1992)), although not specifically addressing stormwater injection wells, provides guidance on siting, construction, and other technical specifications for new stormwater infiltration and filtration systems. In the manual infiltration is identified as "the preferred stormwater management practice due to its ability to both effectively treat runoff and control stream bank erosion."

APPENDIX B - FEDERAL PRIMARY AND SECONDARY MCLS

Primary and Secondary MCLs for Inorganic Constituents Commonly Found in Storm Water Runoff (40 CFR 141/143)

Constituents	MCL (mg/L unless noted otherwise)
Solids	
Total dissolved solids (TDS)*	500 (s)
Metals/Inorganics	
Aluminum, total recoverable*	0.05 - 0.2
Antimony (Sb)*	0.006
Arsenic (As)*	0.05
Barium (Ba)	2
Beryllium (Be)*	0.004
Cadmium (Cd)*	0.005
Chloride*	250 (s)
Chromium (Cr)*	0.1
Copper (Cu)*	1.0 (s)
Cyanides*	0.2
Fluoride	2 (s) - 4
Iron (Fe)*	0.3 (s)
Lead (Pb)*	0.015 (action level)
Manganese (Mn)*	0.05 (s)
Mercury (Hg)*	0.002
Nickel*	0.1
Selenium (Se)*	0.05
Silver (Ag)	0.1 (s)
Thallium (Tl)	0.002
Zinc (Zn)	5 (s)
Nutrients	
Nitrate*	10
Nitrate & Nitrite	10
Pathogens	
Total Coliform (colonies/100mL)*	5% positive samples (>40 samples/month) or 1 positive sample (<40 samples/month)
Fecal Coliform (colonies/100mL)*	1 positive sample
Polycyclic Aromatic Hydrocarbons (PAHs)	
Benzo (a) pyrene*	0.0002
Pesticides/Herbicides	
Chlordane*	0.002
Endrin	0.002
Heptachlor	0.0004
Heptachlor epoxide	0.0002

Constituents	MCL (mg/L unless noted otherwise)
Lindane	0.0002
Pentachlorophenol*	0.001
Toxaphene	0.003
Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs)	
Benzene*	0.005
Carbon tetrachloride	0.005
1,1-Dichloroethene	0.007
Dichloromethane*	0.005
1,2-Dichloropropane	0.005
Ethylbenzene	0.7
Tetrachloroethylene*	0.005
Toluene	1.0
1,1,1-Trichloroethane	0.2
1,1,2-Trichloroethane	0.005
Trichloroethylene*	0.005
General Water Chemistry/Miscellaneous	
pH (units)*	6.5 - 8.5 (s)
Turbidity (nephelometric units)*	0.5 – 1.0 NTU
Color (platinum-cobalt units)*	15 Pt/Co Units (s)
Sulfate	250 (s)

Notes:

(s) denotes secondary MCL

* constituent has been detected in stormwater runoff at concentrations exceeding federal MCL (USEPA, 1999a)

APPENDIX C - SPOKANE AQUIFER AND GROUNDWATER QUALITY

Spokane Aquifer

The Spokane Aquifer is located beneath approximately 283 square-miles of the Rathdrum Prairie in Idaho and in Washington below the City of Spokane. The aquifer is an unconfined aquifer formed in and estimated 700 feet of fluvioglacial deposits of coarse sand, gravel, cobbles, and boulders, with little to no silts or clays below the upper 3 to 6 feet of soil. The aquifer is the primary source of drinking water for the greater Spokane area and as such, the Spokane Aquifer was designated a "Sole Source Aquifer" in 1978 by the USEPA (Hale, 1990; Molenaar, 1988).

According to a local groundwater map, depth to ground water in the greater Spokane area ranges from just below ground surface in areas adjacent to the Spokane River, to 200 – 250 feet below ground surface in northwest Spokane, to greater than 250 feet below ground surface in the Fivemile Prairie area northwest of the Spokane city limits (Berenbrock, 1995). The saturate thickness of the aquifer ranges from less than 50 feet in the northwest Spokane/Fivemile Prairie area up to 500 feet east of Spokane in the Opportunity/Greenacres area (Molenaar, 1988).

In general, water flow within the aquifer follows the path of the Spokane River except in northwest Spokane where flow divides around Fivemile Prairie. A 1977-78 study indicated that transmissivity of the aquifer ranges from less than 0.05 ft^2/min in the Fivemile Prairie area up to 70 ft^2/min in the Greenacres area (Molenaar, 1988). However, much higher transmissivities (from 188 to 7,639 ft^2/min indicating water movement averaging 60 ft/day) have been estimated for the Spokane/Rathdrum Prairie Aquifer (Hale, 1990).

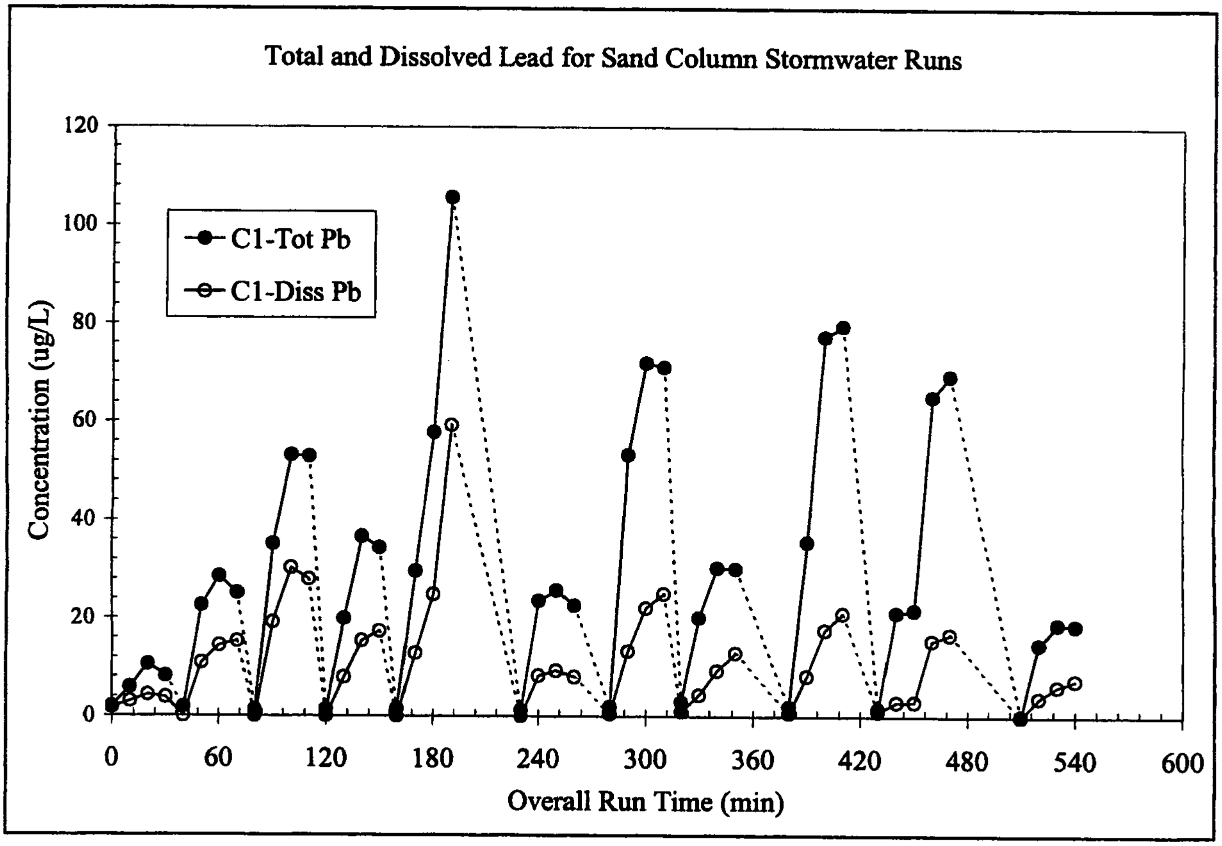
Baseline Groundwater Quality in the Spokane Area

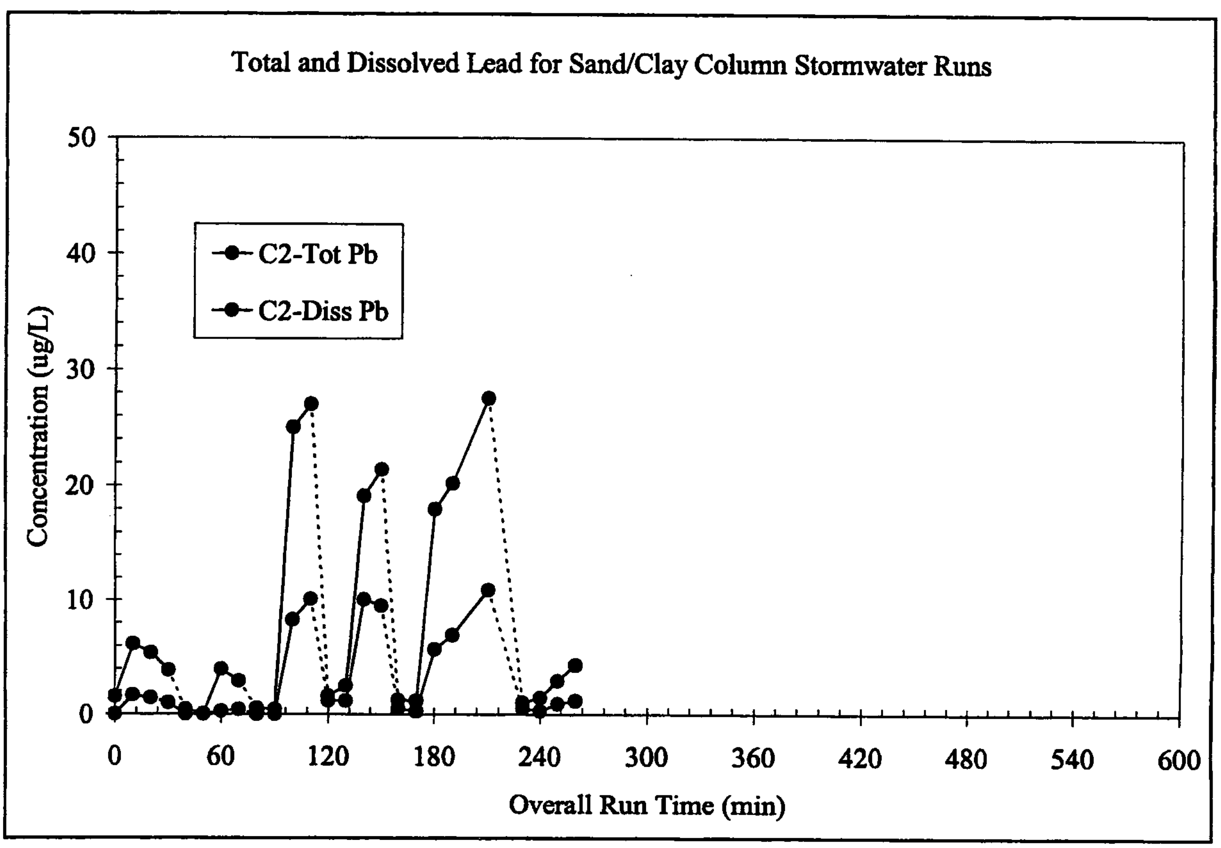
A 1996 study of general groundwater quality in northern Spokane County (from roughly two miles north of Chattaroy to the confluence of the Spokane and Little Spokane Rivers), 44 wells were sampled and analyzed for nitrogen (as nitrate + nitrite), iron, pH, chloride, calcium hardness, and specific conductance. Analysis of these groundwater samples indicated the following (Boese, 1996):

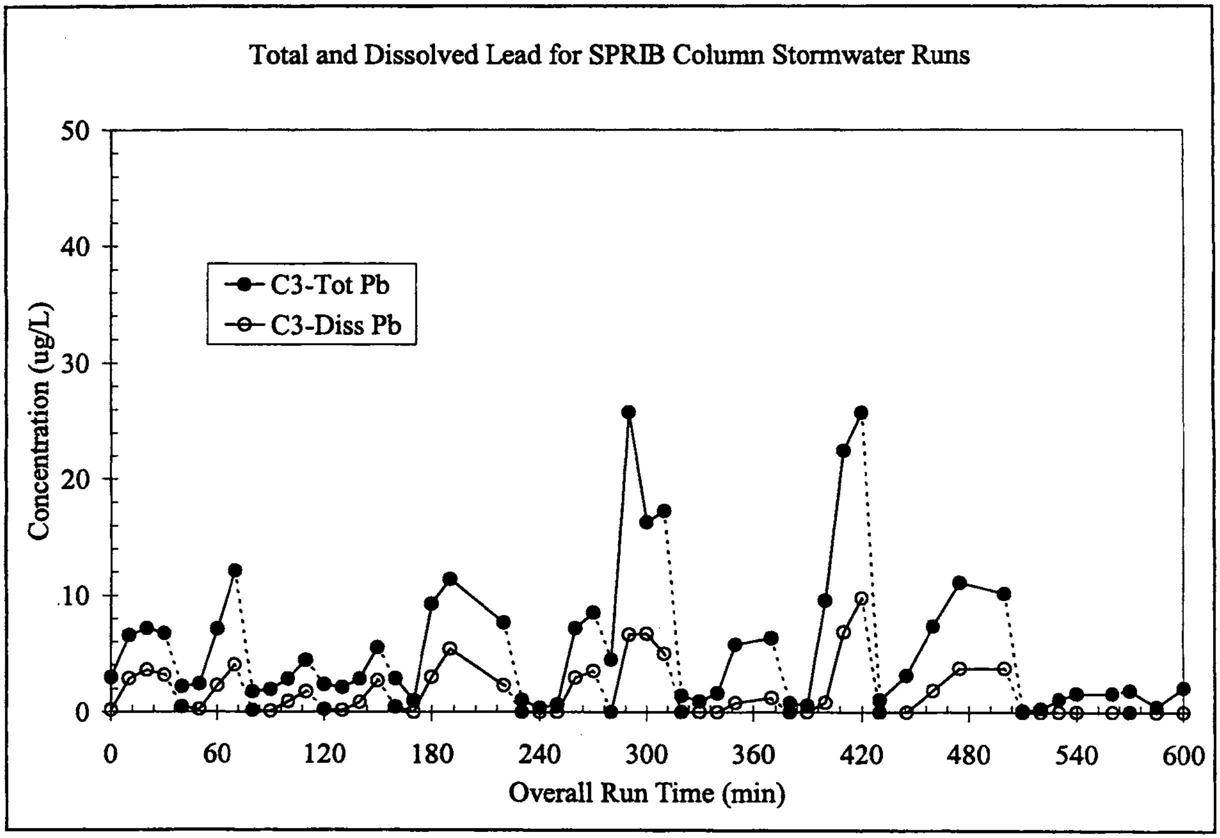
- Iron concentrations ranged from <0.010 to 14.9 mg/L (2.37 mg/L mean). Water from 23 of the wells had iron concentrations greater than the secondary MCL (0.30 mg/L).
- Nitrogen (as nitrate + nitrite) concentrations ranged from <0.01 to 9.86 mg/L (1.20 mg/L mean); all below the primary MCL (10 mg/L).
- PH values ranged from 6.51 to 8.18 (7.35 mean); within the secondary MCL range (6.5 – 8.5).
- Total hardness (as $CaCO_3$) concentrations ranged from <1 – 497 mg/L (189 mg/L mean); no MCL currently exists for $CaCO_3$.
- Chloride concentrations ranged from 1.06 to 235 mg/L (9.50 mg/L mean); all below the secondary MCL (250 mg/L).
- Specific conductance ranged from 196 to 1163 μmhos/cm (373 μmhos/cm mean); no MCL currently exists for specific conductance.

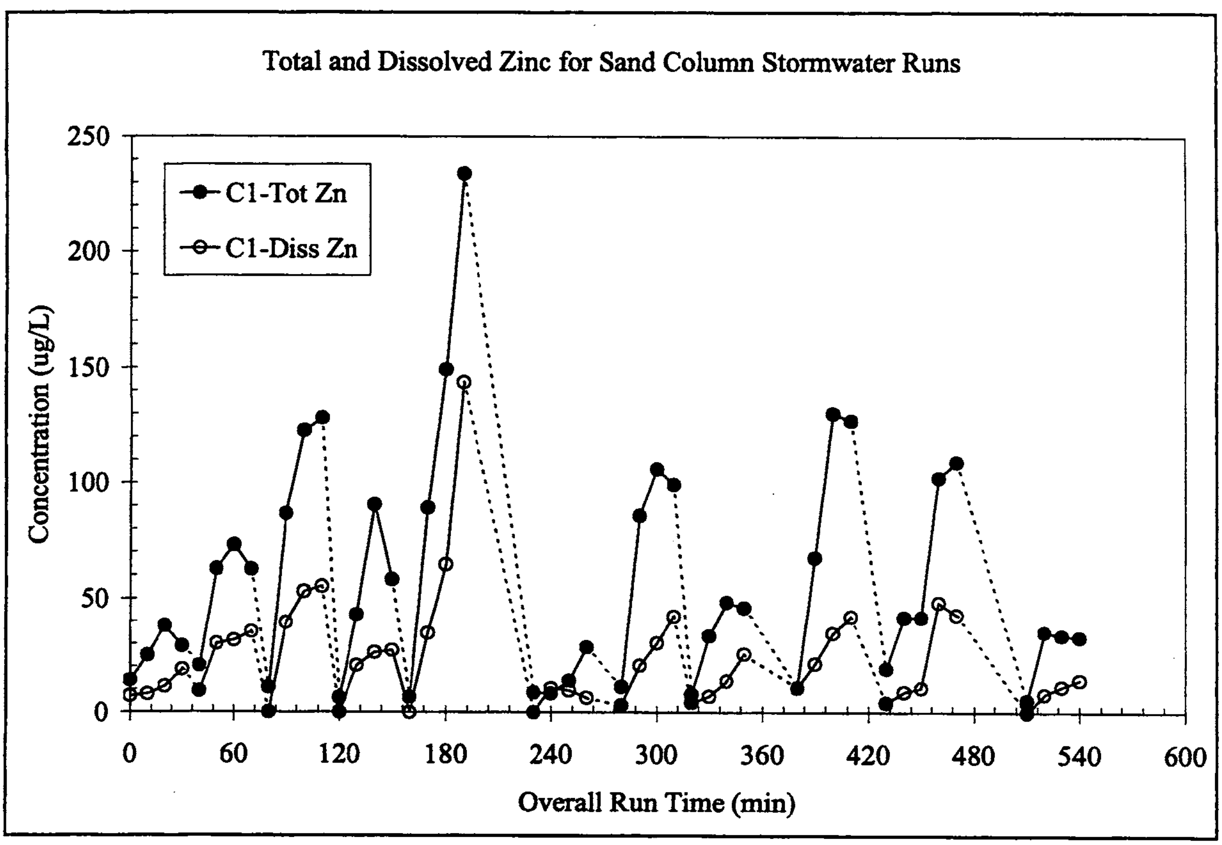
In a 1977-78 study of the Spokane Aquifer (Molenaar, 1988) from Post Falls to the confluence of the Spokane and Little Spokane Rivers, similar average values were found for nitrate, chloride, and specific conductance. In a 1995 study of the Wanapum and Grande Ronde Aquifers (Deobald, 1995) west of Spokane, similar average values were found for nitrogen, pH, hardness, chloride, and specific conductance; however, average iron concentrations were somewhat lower.

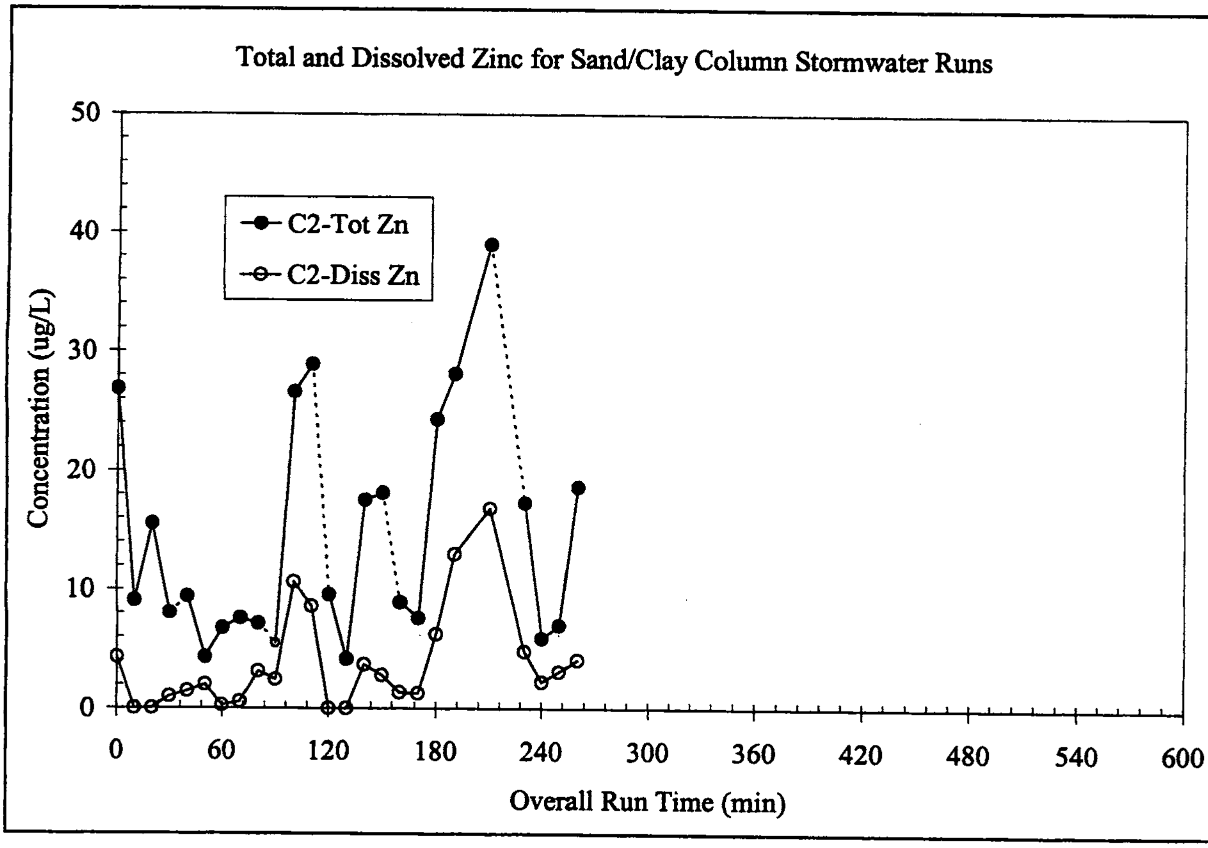
APPENDIX D - SUPPLEMENTARY FIGURES

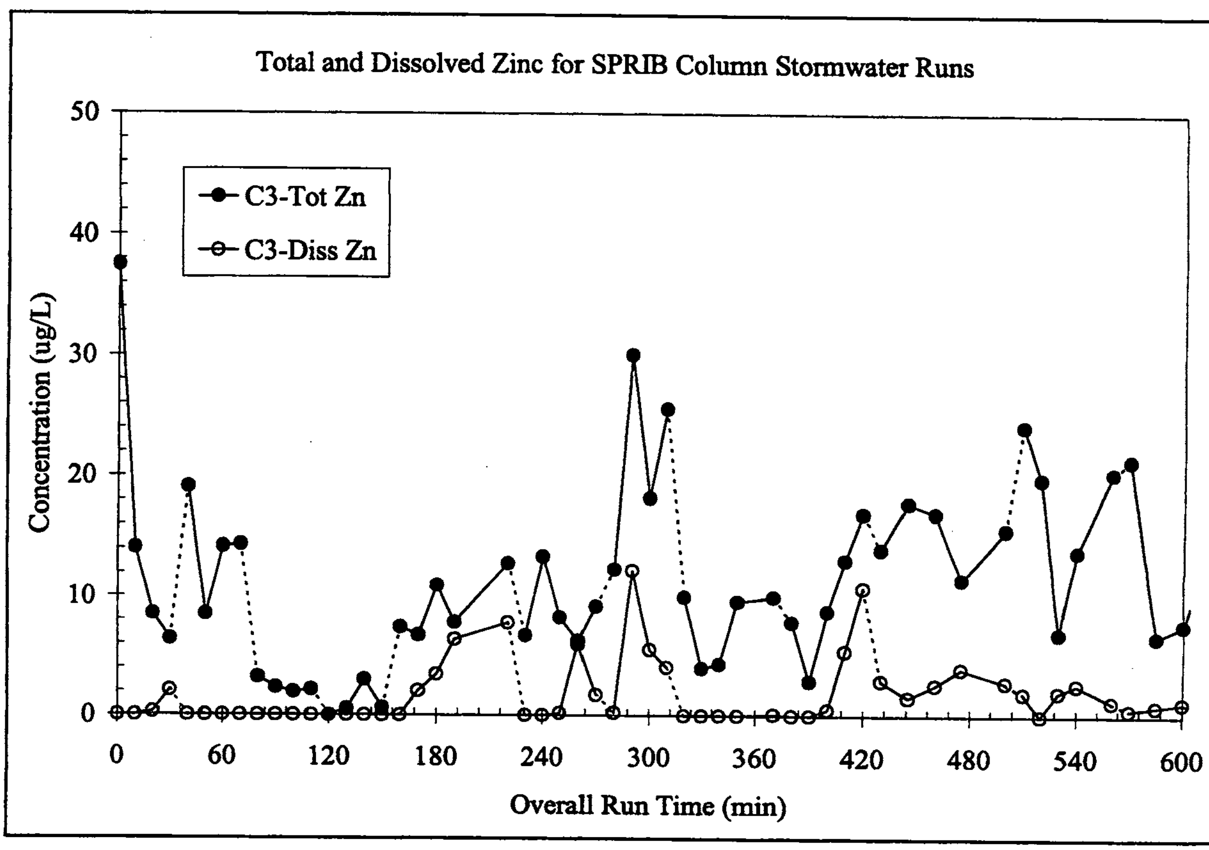

Total and Dissolved Lead for Sand Column Stormwater Runs
C1-Tot Pb
C1-Diss Pb
Concentration (ug/L)
Overall Run Time (min)
0
20
40
60
80
100
120
0
60
120
180
240
300
360
420
480
540
600

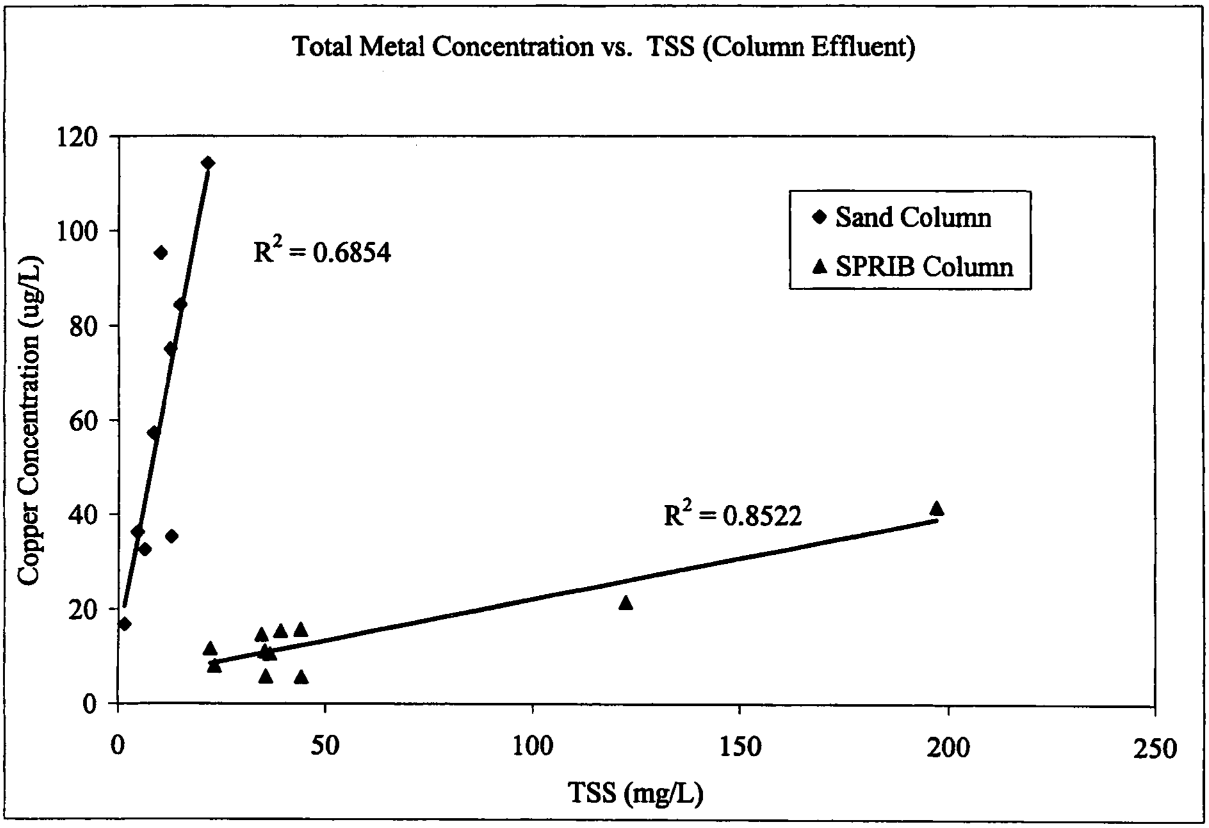

Total and Dissolved Lead for Sand/Clay Column Stormwater Runs
C2-Tot Pb
C2-Diss Pb
Concentration (ug/L)
Overall Run Time (min)
0
10
20
30
40
50
0
60
120
180
240
300
360
420
480
540
600


Total and Dissolved Lead for SPRIB Column Stormwater Runs
C3-Tot Pb
C3-Diss Pb
Concentration (ug/L)
0
10
20
30
40
50
0
60
120
180
240
300
360
420
480
540
600
Overall Run Time (min)

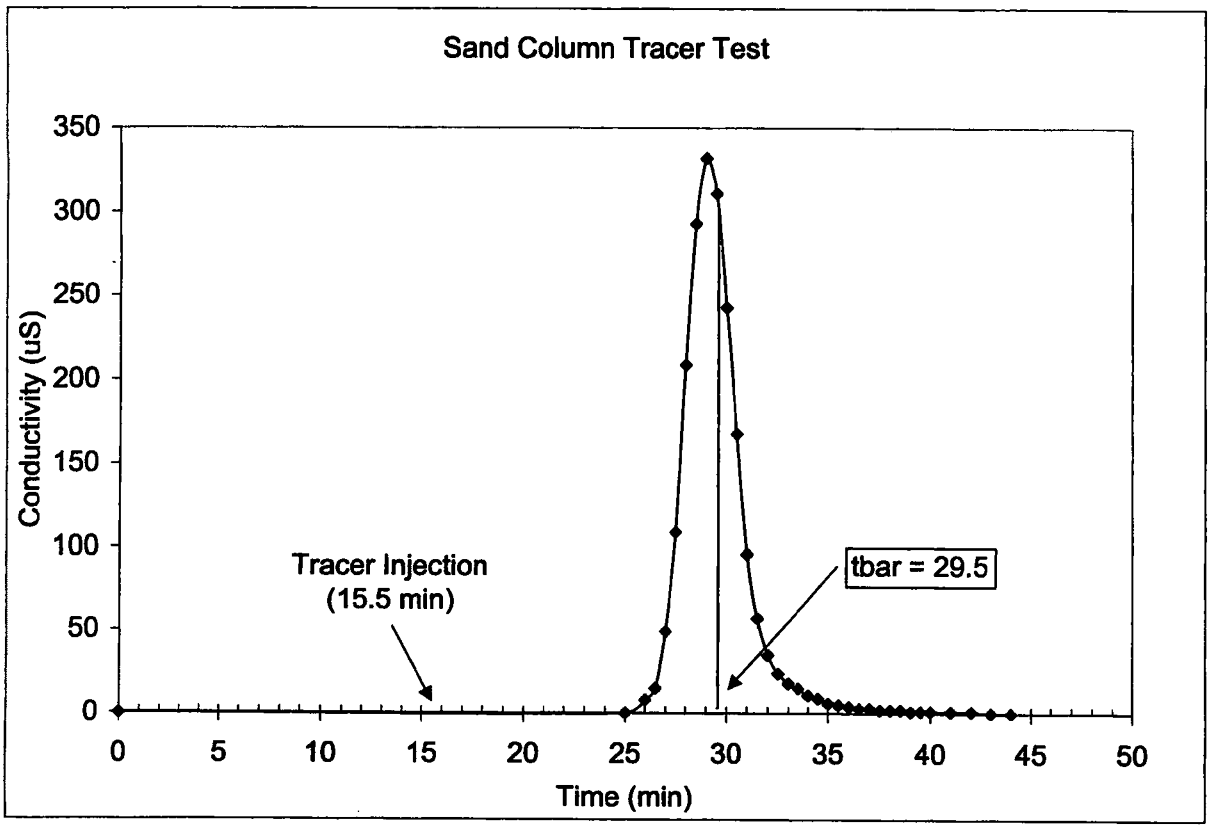

Total and Dissolved Zinc for Sand Column Stormwater Runs
C1-Tot Zn
C1-Diss Zn
Concentration (ug/L)
0
50
100
150
200
250
0
60
120
180
240
300
360
420
480
540
600
Overall Run Time (min)


Total and Dissolved Zinc for Sand/Clay Column Stormwater Runs
C2-Tot Zn
C2-Diss Zn
Concentration (ug/L)
50
40
30
20
10
0
0
60
120
180
240
300
360
420
480
540
600
Overall Run Time (min)

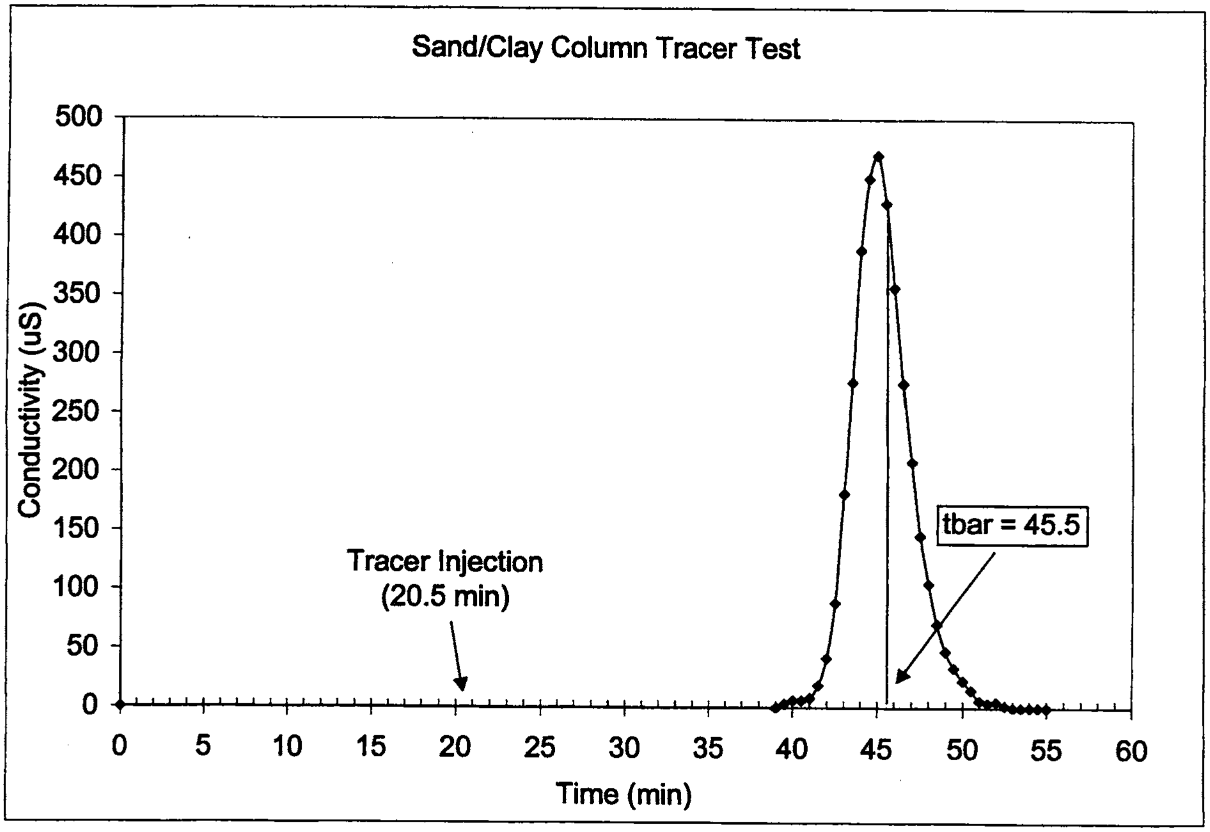

Total and Dissolved Zinc for SPRIB Column Stormwater Runs
C3-Tot Zn
C3-Diss Zn
Concentration (ug/L)
50
40
30
20
10
0
0
60
120
180
240
300
360
420
480
540
600
Overall Run Time (min)

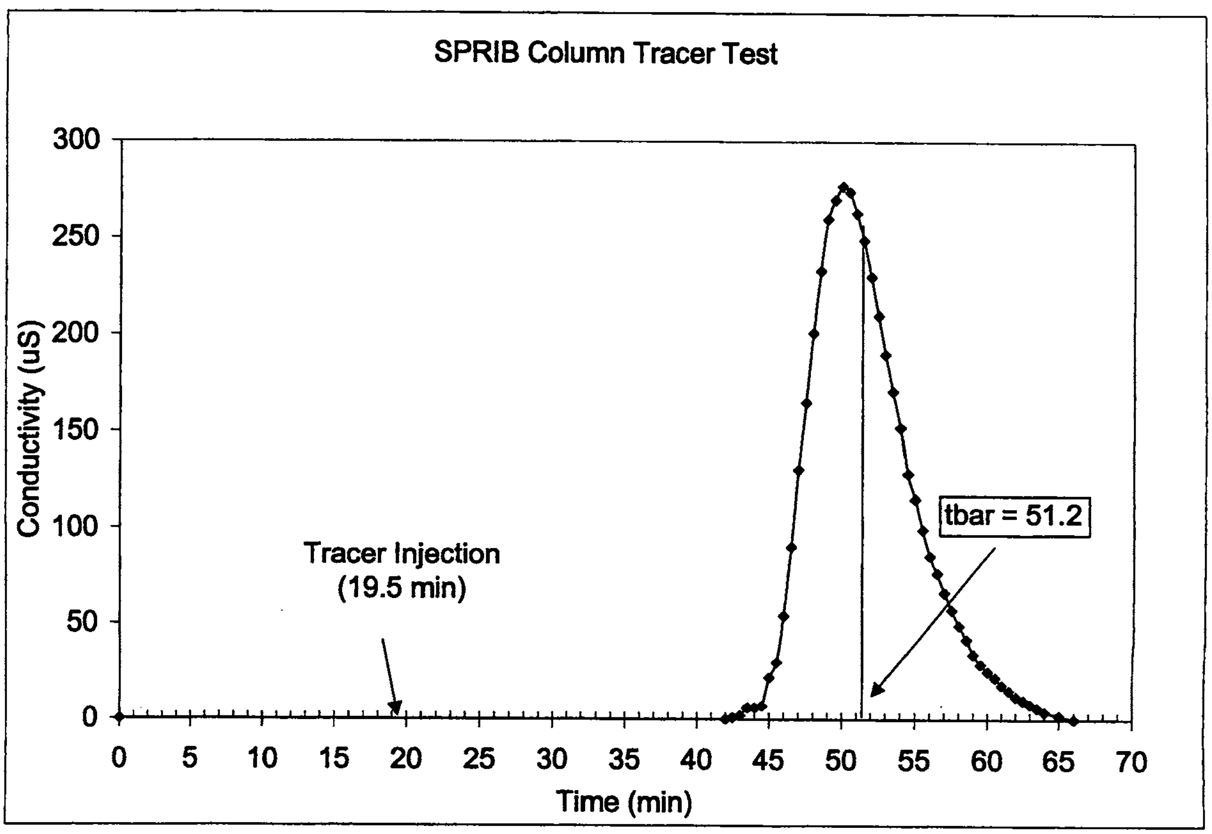


Total Metal Concentration vs. TSS (Column Effluent)
Copper Concentration (ug/L)
TSS (mg/L)
Sand Column
SPRIB Column
R² = 0.6854
R² = 0.8522

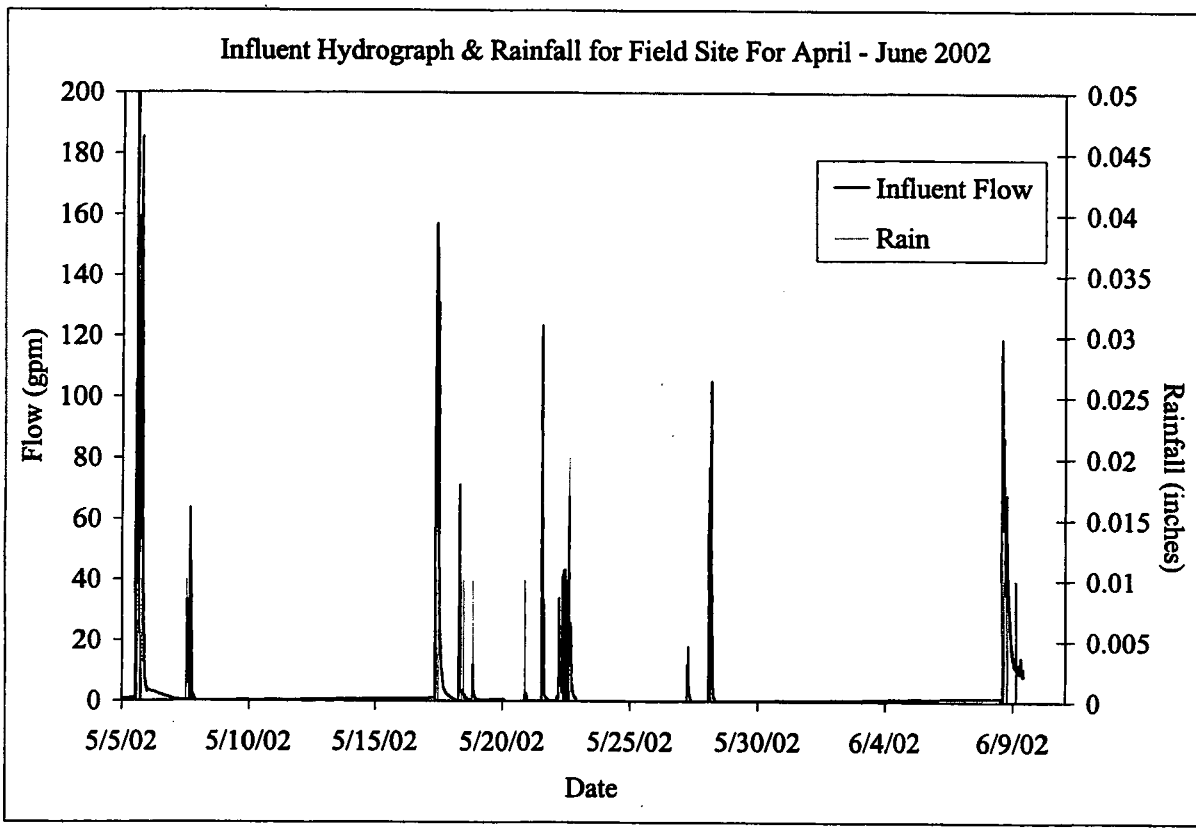


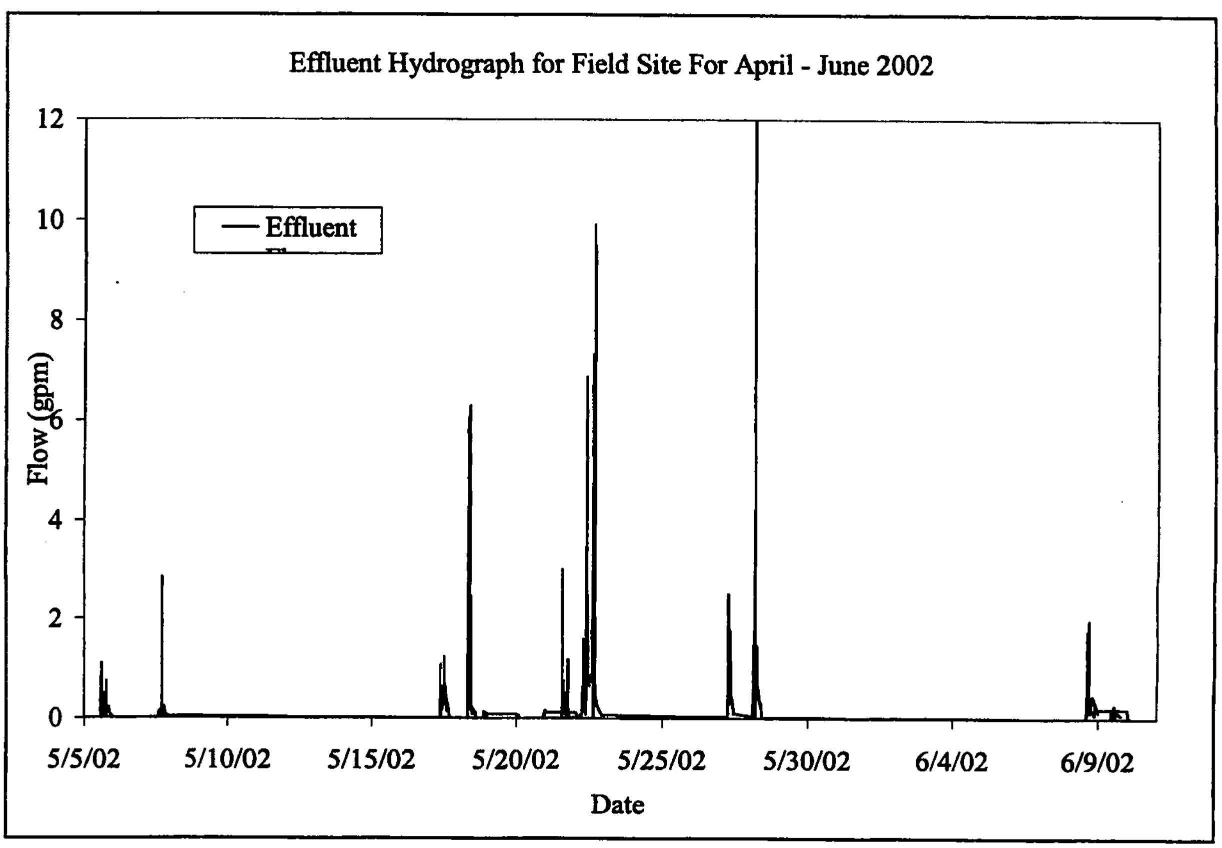
Sand Column Tracer Test
Conductivity (uS)
Time (min)
Tracer Injection
(15.5 min)
tbar = 29.5


Sand/Clay Column Tracer Test
Conductivity (uS)
500
450
400
350
300
250
200
150
100
50
0
Tracer Injection
(20.5 min)
tbar = 45.5
0
5
10
15
20
25
30
35
40
45
50
55
60
Time (min)


SPRIB Column Tracer Test
Conductivity (uS)
300
250
200
150
100
50
0
Tracer Injection
(19.5 min)
tbar = 51.2
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Time (min)

APPENDIX E - INFLUENT AND EFFLUENT HYDROGRAPHS FOR FIELD SITE


Influent Hydrograph & Rainfall for Field Site For April - June 2002
Flow (gpm)
200
180
160
140
120
100
80
60
40
20
0
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Rainfall (inches)
Influent Flow
Rain
5/5/02
5/10/02
5/15/02
5/20/02
5/25/02
5/30/02
6/4/02
6/9/02
Date


Effluent Hydrograph for Field Site For April - June 2002
Flow (gpm)
12
10
8
6
4
2
0
Effluent
5/5/02
5/10/02
5/15/02
5/20/02
5/25/02
5/30/02
6/4/02
6/9/02
Date

APPENDIX F - SUPPLEMENTARY DATA

Legend:

diss – dissolved metal concentration
tot – total metal concentration
ns – no sample
nd – constituent not detected above method detection limit
C# - column number (1 through 4)
    C1 – sand
    C2 – sand/clay mix
    C3 – sand/clay/compost mix (SPRIB)
    C4 – field column containing SPRIB
R# - experimental run number

Field column samples are labeled as **C4S#-xx.** C4 refers to column 4, S# refers to the particular storm event number sampled, and –xx refers to the time from the initiation of sampling within a given storm event. For example, sample label C4S3-70 refers to a sample collected 70 minutes into a the third storm event. Overall run time reported refers to the cumulative time that samples were collected from the field column.

Laboratory Columns – Influent Concentrations

Column 1 - Sand Column

Dissolved Copper

Overall Run Time (min)	Sample ID	Concentration (µg/L) sample a	sample b	sample c	average
20	C1R1-IN:diss	70.18	49.78	ns	59.98
60	C1R2-IN:diss	49.05	49.27	48.37	48.90
100	C1R3-IN:diss	41.12	38.39	40.05	39.85
140	C1R4-IN:diss	49.95	48.86	49.21	49.34
200	C1R5-IN:diss	42.46	40.50	40.80	41.25
250	C1R6-IN:diss	47.98	47.23	46.56	47.26
300	C1R7-IN:diss	53.63	54.00	52.88	53.50
340	C1R8-IN:diss	50.12	50.21	48.71	49.68
400	C1R9-IN:diss	51.51	50.19	52.74	51.48
450	C1R10-IN:diss	57.67	57.65	58.58	57.97
530	C1R11-IN:diss	48.66	48.88	48.83	48.79

Total Copper

Sample ID	Concentration (µg/L) sample a	sample b	sample c	average
C1R1-IN:tot	1117.50	984.00	ns	1050.75
C1R2-IN:tot	968.50	995.00	985.50	983.00
C1R3-IN:tot	997.50	1026.00	1044.50	1022.67
C1R4-IN:tot	979.00	865.00	870.50	904.83
C1R5-IN:tot	982.00	979.50	962.50	974.67
C1R6-IN:tot	933.00	895.00	914.50	914.17
C1R7-IN:tot	887.00	906.50	896.50	896.67
C1R8-IN:tot	917.00	902.50	895.50	905.00
C1R9-IN:tot	969.50	935.50	1037.00	980.67
C1R10-IN:tot	964.00	934.50	980.50	959.67
C1R11-IN:tot	921.00	886.00	888.00	898.33

Dissolved Zinc

Overall Run Time (min)	Sample ID	Concentration (µg/L) sample a	sample b	sample c	average
20	C1R1-IN:diss	105.70	86.86	ns	96.28
60	C1R2-IN:diss	115.60	118.20	116.60	116.80
100	C1R3-IN:diss	132.20	121.30	128.70	127.40
140	C1R4-IN:diss	98.53	95.40	96.37	96.77
200	C1R5-IN:diss	117.70	110.60	111.30	113.20
250	C1R6-IN:diss	79.63	75.61	75.75	77.00
300	C1R7-IN:diss	80.59	79.85	80.03	80.16
340	C1R8-IN:diss	115.00	115.20	110.10	113.43
400	C1R9-IN:diss	84.23	84.07	89.76	86.02
450	C1R10-IN:diss	57.67	57.65	58.58	57.97
530	C1R11-IN:diss	103.4	102.8	104.1	103.43

Total Zinc

Sample ID	Concentration (µg/L) sample a	sample b	sample c	average
C1R1-IN:tot	1851.00	1772.00	ns	1811.50
C1R2-IN:tot	2090.00	2148.00	2134.50	2124.17
C1R3-IN:tot	2291.50	2325.00	2337.00	2317.83
C1R4-IN:tot	1461.00	1357.50	1372.00	1396.83
C1R5-IN:tot	1930.50	1925.00	1920.00	1925.17
C1R6-IN:tot	1497.50	1444.50	1460.50	1467.50
C1R7-IN:tot	1372.00	1414.50	1376.50	1387.67
C1R8-IN:tot	1533.50	1510.50	1481.00	1508.33
C1R9-IN:tot	1514.00	1480.00	1452.00	1482.00
C1R10-IN:tot	1648.00	1608.50	1654.00	1636.83
C1R11-IN:tot	1632.00	1576.00	1589.50	1599.17

Dissolved Lead

Overall Run		Concentration (µg/L)

Total Lead

	Concentration (µg/L)

Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
20	C1R1-IN:diss	58.54	56.69	ns	57.62		C1R1-IN:tot	920.00	898.50	ns	909.25
60	C1R2-IN:diss	45.47	45.33	44.86	45.22		C1R2-IN:tot	894.00	912.50	909.50	905.33
100	C1R3-IN:diss	51.69	49.71	50.73	50.71		C1R3-IN:tot	951.50	974.00	980.50	968.67
140	C1R4-IN:diss	63.56	61.78	61.82	62.39		C1R4-IN:tot	915.00	817.50	822.00	851.50
200	C1R5-IN:diss	51.31	50.26	50.19	50.59		C1R5-IN:tot	904.50	906.00	901.00	903.83
250	C1R6-IN:diss	49.48	48.67	48.79	48.98		C1R6-IN:tot	916.00	918.50	903.50	912.67
300	C1R7-IN:diss	57.09	55.90	55.42	56.14		C1R7-IN:tot	817.50	841.00	833.50	830.67
340	C1R8-IN:diss	53.18	52.09	50.73	52.00		C1R8-IN:tot	892.00	904.00	885.00	893.67
400	C1R9-IN:diss	54.99	53.62	54.52	54.38		C1R9-IN:tot	890.50	876.00	1047.00	937.83
450	C1R10-IN:diss	43.87	42.43	42.22	42.84		C1R10-IN:tot	908.50	909.50	924.50	914.17
530	C1R11-IN:diss	56.67	56.66	57.17	56.83		C1R11-IN:tot	906.00	882.50	888.00	892.17
Column 2 - Sand/Clay Column											
	Dissolved Copper						**Total Copper**				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
20	C2R1-IN:diss	84.31	84.26	86.19	84.92		C2R1-IN:tot	962.00	929.00	919.50	936.83
60	C2R2-IN:diss	48.92	47.85	48.13	48.30		C2R2-IN:tot	918.00	892.00	899.50	903.17
100	C2R3-IN:diss	74.84	75.43	77.20	75.82		C2R3-IN:tot	935.00	958.50	952.00	948.50
140	C2R4-IN:diss	43.81	42.47	41.74	42.67		C2R4-IN:tot	994.00	953.50	978.00	975.17
200	C2R5-IN:diss	46.08	47.14	45.86	46.36		C2R5-IN:tot	911.00	950.50	924.50	928.67
250	C2R6-IN:diss	45.58	44.54	45.67	45.26		C2R6-IN:tot	911.50	954.50	901.50	922.50
	Dissolved Zinc						**Total Zinc**				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
20	C2R1-IN:diss	160.40	160.00	162.60	161.00		C2R1-IN:tot	1669.50	1638.50	1625.50	1644.50
60	C2R2-IN:diss	92.06	88.98	89.86	90.30		C2R2-IN:tot	1482.50	1436.00	1443.50	1454.00
100	C2R3-IN:diss	129.80	130.00	132.00	130.60		C2R3-IN:tot	1504.50	1549.50	1551.00	1535.00
140	C2R4-IN:diss	78.32	71.67	70.82	73.60		C2R4-IN:tot	1748.00	1696.50	1725.00	1723.17
200	C2R5-IN:diss	72.88	75.17	70.49	72.85		C2R5-IN:tot	1483.00	1551.00	1472.00	1502.00
250	C2R6-IN:diss	96.36	96.70	97.99	97.02		C2R6-IN:tot	1472.00	1583.00	1448.50	1501.17

	Dissolved Lead				
Overall Run		Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average
20	C2R1-IN:diss	97.90	96.40	96.33	96.88
60	C2R2-IN:diss	49.70	48.23	48.55	48.83
100	C2R3-IN:diss	75.83	74.79	74.35	74.99
140	C2R4-IN:diss	47.67	45.09	44.95	45.90
200	C2R5-IN:diss	54.87	55.63	54.59	55.03
250	C2R6-IN:diss	46.34	44.85	44.97	45.39

Total Lead				
	Concentration (µg/L)			
Sample ID	sample a	sample b	sample c	average
C2R1-IN:tot	901.00	904.50	913.00	906.17
C2R2-IN:tot	919.50	903.50	907.00	910.00
C2R3-IN:tot	896.50	914.50	917.50	909.50
C2R4-IN:tot	1021.50	1018.50	1029.00	1023.00
C2R5-IN:tot	880.00	909.00	908.00	899.00
C2R6-IN:tot	876.50	882.00	860.00	872.83

Column 3 - Sand/Clay/Compost

	Dissolved Copper				
Overall Run		Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average
20	C3R1-IN:diss	40.11	41.81	43.18	41.70
60	C3R2-IN:diss	47.71	43.74	45.16	45.54
100	C3R3-IN:diss	40.92	39.45	40.70	40.36
140	C3R4-IN:diss	125.00	126.90	127.20	126.37
200	C3R5-IN:diss	45.87	46.53	47.21	46.54
250	C3R6-IN:diss	49.18	49.79	48.46	49.14
300	C3R7-IN:diss	90.01	88.06	90.29	89.45
340	C3R8-IN:diss	46.71	46.63	46.22	46.52
400	C3R9-IN:diss	61.42	60.02	59.42	60.29
450	C3R10-IN:diss	50.64	51.71	52.56	51.64
530	C3R11-IN:diss	43.82	42.06	41.63	42.50
600	C3R12-IN:diss	60.10	57.98	58.49	58.86
710	C3R13-IN:diss	59.24	57.77	56.80	57.94
800	C3R14-IN:diss	61.51	61.61	61.92	61.68
920	C3R15-IN:diss	48.23	48.73	47.38	48.11

Total Copper				
	Concentration (µg/L)			
Sample ID	sample a	sample b	sample c	average
C3R1-IN:tot	873.50	883.00	871.50	876.00
C3R2-IN:tot	984.50	950.50	1207.50	1047.50
C3R3-IN:tot	1210.00	1275.50	1293.50	1259.67
C3R4-IN:tot	1035.00	1060.50	1043.50	1046.33
C3R5-IN:tot	989.50	967.50	957.50	971.50
C3R6-IN:tot	976.00	973.50	947.50	965.67
C3R7-IN:tot	915.00	903.50	890.00	902.83
C3R8-IN:tot	908.00	902.00	920.50	910.17
C3R9-IN:tot	927.00	885.50	932.00	914.83
C3R10-IN:tot	1021.50	991.50	976.50	996.50
C3R11-IN:tot	872.00	857.50	855.00	861.50
C3R12-IN:tot	3765.00	3720.00	3780.00	3755.00
C3R13-IN:tot	3850.00	3845.00	3860.00	3851.67
C3R14-IN:tot	3922.50	4067.50	3970.00	3986.67
C3R15-IN:tot	3867.50	3735.00	3810.00	3804.17

	Dissolved Zinc				
Overall Run		Concentration (µg/L)			

Total Zinc				
	Concentration (µg/L)			

Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
20	C3R1-IN:diss	37.71	60.61	60.25	52.86		C3R1-IN:tot	1753.00	1780.50	1767.00	1766.83
60	C3R2-IN:diss	93.05	83.06	86.56	87.56		C3R2-IN:tot	1978.00	1920.50	2415.00	2104.50
100	C3R3-IN:diss	90.99	82.57	85.41	86.32		C3R3-IN:tot	2366.00	2488.50	2522.00	2458.83
140	C3R4-IN:diss	77.20	79.38	79.55	78.71		C3R4-IN:tot	2228.50	2324.00	2258.50	2270.33
200	C3R5-IN:diss	100.70	102.60	100.30	101.20		C3R5-IN:tot	1902.00	1875.50	1870.00	1882.50
250	C3R6-IN:diss	91.96	92.91	89.11	91.33		C3R6-IN:tot	1715.00	1711.50	1679.50	1702.00
300	C3R7-IN:diss	150.60	140.90	144.60	145.37		C3R7-IN:tot	1466.00	1453.50	1426.50	1448.67
340	C3R8-IN:diss	92.54	94.23	98.24	95.00		C3R8-IN:tot	1493.50	1469.50	1504.50	1489.17
400	C3R9-IN:diss	97.56	94.93	93.84	95.44		C3R9-IN:tot	1553.50	1487.00	1553.00	1531.17
450	C3R10-IN:diss	75.52	71.69	68.71	71.97		C3R10-IN:tot	1643.50	1596.50	1586.00	1608.67
530	C3R11-IN:diss	53.55	40.78	36.23	43.52		C3R11-IN:tot	1409.50	1366.00	1359.50	1378.33
600	C3R12-IN:diss	47.94	42.77	44.59	45.10		C3R12-IN:tot	5665.00	5595.00	5657.50	5639.17
710	C3R13-IN:diss	67.51	64.68	63.82	65.34		C3R13-IN:tot	5757.50	5767.50	5732.50	5752.50
800	C3R14-IN:diss	80.47	81.10	81.24	80.94		C3R14-IN:tot	5957.50	6192.50	6055.00	6068.33
920	C3R15-IN:diss	66.06	66.35	92.72	75.04		C3R15-IN:tot	5882.50	5712.50	5782.50	5792.50

	Dissolved Lead						**Total Lead**				
Overall Run		Concentration (μg/L)						Concentration (μg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
20	C3R1-IN:diss	32.78	37.25	39.51	36.51		C3R1-IN:tot	864.00	866.00	864.50	864.83
60	C3R2-IN:diss	47.82	45.41	44.82	46.02		C3R2-IN:tot	922.50	906.00	1033.50	954.00
100	C3R3-IN:diss	41.17	39.41	39.66	40.08		C3R3-IN:tot	1152.00	1205.50	1203.50	1187.00
140	C3R4-IN:diss	73.51	71.87	71.59	72.32		C3R4-IN:tot	933.00	950.50	949.50	944.33
200	C3R5-IN:diss	38.39	37.90	37.81	38.03		C3R5-IN:tot	666.00	663.00	666.00	665.00
250	C3R6-IN:diss	54.15	53.24	52.18	53.19		C3R6-IN:tot	950.00	950.50	952.50	951.00
300	C3R7-IN:diss	94.89	93.27	94.02	94.06		C3R7-IN:tot	872.00	869.00	857.50	866.17
340	C3R8-IN:diss	60.03	60.06	59.55	59.88		C3R8-IN:tot	911.00	899.00	920.50	910.17
400	C3R9-IN:diss	72.68	71.14	70.45	71.42		C3R9-IN:tot	911.50	886.50	901.50	899.83
450	C3R10-IN:diss	51.83	52.66	52.76	52.42		C3R10-IN:tot	999.50	981.50	971.00	984.00
530	C3R11-IN:diss	53.19	51.20	50.87	51.75		C3R11-IN:tot	852.50	849.50	861.00	854.33
600	C3R12-IN:diss	184.00	181.00	180.70	181.90		C3R12-IN:tot	3645.00	3630.00	3675.00	3650.00
710	C3R13-IN:diss	135.40	134.40	133.80	134.53		C3R13-IN:tot	3432.50	3422.50	3457.50	3437.50
800	C3R14-IN:diss	66.86	67.18	66.35	66.80		C3R14-IN:tot	3777.50	3880.00	3762.50	3806.67
920	C3R15-IN:diss	92.43	93.57	92.72	92.91		C3R15-IN:tot	3757.50	3650.00	3692.50	3700.00

Laboratory Columns – Effluent Concentrations

Column 1 - Sand											
	Dissolved Copper						**Total Copper**				
Overall Run Time (min)		Concentration (µg/L)						Concentration (µg/L)			
	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C1R1-00:diss	1.66	nd	ns	0.83		C1R1-00:tot	3.21	2.62	ns	2.91
10	C1R1-10:diss	7.21	2.22	ns	4.72		C1R1-10:tot	9.51	9.11	ns	9.31
20	C1R1-20:diss	12.38	5.79	ns	9.09		C1R1-20:tot	16.78	16.87	ns	16.82
30	C1R1-30:diss	24.97	5.88	ns	15.43		C1R1-30:tot	16.11	14.76	ns	15.44
40	C1R2-00:diss	nd	nd	nd	0.00		C1R2-00:tot	2.72	1.83	6.84	3.79
50	C1R2-10:diss	16.43	16.74	16.55	16.57		C1R2-10:tot	25.48	25.95	25.59	25.67
60	C1R2-20:diss	21.58	21.92	21.64	21.71		C1R2-20:tot	32.52	32.71	32.44	32.56
70	C1R2-30:diss	22.19	22.43	22.47	22.36		C1R2-30:tot	31.57	29.00	29.53	30.03
80	C1R3-00:diss	nd	nd	nd	0.00		C1R3-00:tot	2.90	2.57	2.94	2.80
90	C1R3-10:diss	26.25	25.80	26.45	26.17		C1R3-10:tot	37.92	37.38	38.62	37.97
100	C1R3-20:diss	39.07	39.31	39.07	39.15		C1R3-20:tot	55.65	55.40	56.80	55.95
110	C1R3-30:diss	35.52	34.48	34.46	34.82		C1R3-30:tot	55.45	58.25	58.20	57.30
120	C1R4-00:diss	nd	nd	nd	0.00		C1R4-00:tot	1.74	1.79	1.52	1.68
130	C1R4-10:diss	11.86	12.07	11.58	11.84		C1R4-10:tot	23.20	22.06	ns	22.63
140	C1R4-20:diss	22.65	23.68	21.93	22.75		C1R4-20:tot	36.33	36.18	ns	36.26
150	C1R4-30:diss	25.10	24.20	24.79	24.70		C1R4-30:tot	35.40	34.39	ns	34.89
160	C1R5-00:diss	nd	nd	nd	0.00		C1R5-00:tot	2.80	3.38	3.24	3.14
170	C1R5-10:diss	19.17	19.59	20.13	19.63		C1R5-10:tot	35.01	35.52	35.01	35.18
180	C1R5-20:diss	37.36	37.05	34.98	36.46		C1R5-20:tot	64.60	63.25	64.95	64.27
190	C1R5-30:diss	76.42	75.71	76.15	76.09		C1R5-30:tot	112.45	113.85	116.40	114.23
230	C1R6-00:diss	nd	ns	ns	0.00		C1R6-00:tot	2.20	ns	ns	2.20
240	C1R6-10:diss	14.16	ns	ns	14.16		C1R6-10:tot	24.53	ns	ns	24.53
250	C1R6-20:diss	13.39	ns	ns	13.39		C1R6-20:tot	26.36	ns	ns	26.36
260	C1R6-30:diss	12.49	12.02	11.85	12.12		C1R6-30:tot	20.89	20.59	20.98	20.82
280	C1R7-00:diss	0.68	ns	ns	0.68		C1R7-00:tot	3.82	ns	ns	3.82
290	C1R7-10:diss	31.41	ns	ns	31.41		C1R7-10:tot	63.00	ns	ns	63.00

300	C1R7-20:diss	35.26	ns	ns	35.26		C1R7-20:tot	84.30	ns	ns	84.30
310	C1R7-30:diss	40.19	40.95	40.68	40.61		C1R7-30:tot	82.25	81.70	82.50	82.15
320	C1R8-00:diss	0.79	ns	ns	0.79		C1R8-00:tot	3.63	ns	ns	3.63
330	C1R8-10:diss	11.39	ns	ns	11.39		C1R8-10:tot	22.62	ns	ns	22.62
340	C1R8-20:diss	20.40	ns	ns	20.40		C1R8-20:tot	35.26	ns	ns	35.26
350	C1R8-30:diss	23.15	23.07	23.08	23.10		C1R8-30:tot	32.95	34.94	34.53	34.14
380	C1R9-00:diss	0.25	ns	ns	0.25		C1R9-00:tot	2.85	ns	ns	2.85
390	C1R9-10:diss	26.39	ns	ns	26.39		C1R9-10:tot	43.20	ns	ns	43.20
400	C1R9-20:diss	40.59	ns	ns	40.59		C1R9-20:tot	94.85	ns	ns	94.85
410	C1R9-30:diss	45.94	45.51	44.11	45.19		C1R9-30:tot	97.45	93.75	94.60	95.27
430	C1R10-00:diss	0.67	ns	ns	0.67		C1R10-00:tot	2.88	ns	ns	2.88
440	C1R10-10:diss	13.67	ns	ns	13.67		C1R10-10:tot	26.60	ns	ns	26.60
450	C1R10-20:diss	12.24	ns	ns	12.24		C1R10-20:tot	25.66	ns	ns	25.66
460	C1R10-30:diss	33.04	ns	ns	33.04		C1R10-30:tot	70.25	nd	nd	70.25
470	C1R10-40:diss	33.30	32.80	33.91	33.34		C1R10-40:tot	73.80	73.90	77.55	75.08
510	C1R11-00:diss	0.47	ns	ns	0.47		C1R11-00:tot	2.77	ns	ns	2.77
520	C1R11-10:diss	12.60	ns	ns	12.60		C1R11-10:tot	18.79	ns	ns	18.79
530	C1R11-20:diss	16.08	ns	ns	16.08		C1R11-20:tot	23.32	ns	ns	23.32
540	C1R11-30:diss	16.14	15.76	15.92	15.94		C1R11-30:tot	22.17	22.36	22.23	22.25
Column 2 - Sand/Clay											
	Dissolved Copper						**Total Copper**				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C2R1-00:diss	nd	ns	ns	0.00		C2R1-00:tot	5.58	ns	ns	5.58
10	C2R1-10:diss	nd	ns	ns	0.00		C2R1-10:tot	4.25	ns	ns	4.25
20	C2R1-20:diss	nd	ns	ns	0.00		C2R1-20:tot	4.04	ns	ns	4.04
30	C2R1-30:diss	nd	nd	nd	0.00		C2R1-30:tot	4.38	2.79	2.41	3.19
40	C2R2-00:diss	nd	ns	ns	0.00		C2R2-00:tot	1.06	ns	ns	1.06
50	C2R2-10:diss	nd	ns	ns	0.00		C2R2-10:tot	0.09	ns	ns	0.09
60	C2R2-20:diss	nd	ns	ns	0.00		C2R2-20:tot	3.07	ns	ns	3.07
70	C2R2-30:diss	nd	nd	nd	0.00		C2R2-30:tot	2.31	2.16	2.19	2.22
80	C2R3-00:diss	nd	ns	ns	0.00		C2R3-00:tot	0.68	ns	ns	0.68
90	C2R3-10:diss	nd	ns	ns	0.00		C2R3-10:tot	2.70	ns	ns	2.70
100	C2R3-20:diss	8.63	ns	ns	8.63		C2R3-20:tot	18.13	ns	ns	18.13

110	C2R3-30:diss	8.47	8.71	8.97	8.72		C2R3-30:tot	18.79	18.34	18.53	18.55
120	C2R4-00:diss	3.63	ns	ns	3.63		C2R4-00:tot	5.57	ns	ns	5.57
130	C2R4-10:diss	3.74	ns	ns	3.74		C2R4-10:tot	3.91	ns	ns	3.91
140	C2R4-20:diss	9.77	ns	ns	9.77		C2R4-20:tot	12.41	ns	ns	12.41
150	C2R4-30:diss	9.37	9.12	9.48	9.32		C2R4-30:tot	12.53	12.33	12.80	12.55
160	C2R5-00:diss	nd	ns	ns	0.00		C2R5-00:tot	2.33	ns	ns	2.33
170	C2R5-10:diss	nd	ns	ns	0.00		C2R5-10:tot	1.29	ns	ns	1.29
180	C2R5-20:diss	8.71	ns	ns	8.71		C2R5-20:tot	17.49	ns	ns	17.49
190	C2R5-30:diss	10.60	ns	ns	10.60		C2R5-30:tot	19.50	ns	ns	19.50
210	C2R5-50:diss	20.94	21.09	21.42	21.15		C2R5-50:tot	31.06	30.26	29.87	30.40
230	C2R6-00:diss	nd	ns	ns	0.00		C2R6-00:tot	2.35	ns	ns	2.35
240	C2R6-10:diss	nd	ns	ns	0.00		C2R6-10:tot	1.13	ns	ns	1.13
250	C2R6-20:diss	1.03	ns	ns	1.03		C2R6-20:tot	3.42	ns	ns	3.42
260	C2R6-30:diss	0.93	0.90	0.97	0.93		C2R6-30:tot	3.96	5.16	3.27	4.13
Column 3 - Sand/Clay/Compost											
	Dissolved Copper						**Total Copper**				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C3R1-00:diss	0.61	0.77	0.57	0.65		C3R1-00:tot	20.55	20.36	23.65	21.52
10	C3R1-10:diss	4.17	2.97	2.97	3.37		C3R1-10:tot	8.88	8.75	8.84	8.82
20	C3R1-20:diss	3.94	3.82	3.81	3.86		C3R1-20:tot	8.66	8.85	8.63	8.71
30	C3R1-30:diss	3.57	3.60	3.81	3.66		C3R1-30:tot	7.63	7.89	7.82	7.78
40	C3R2-00:diss	1.07	ns	ns	1.07		C3R2-00:tot	10.63	ns	ns	10.63
50	C3R2-10:diss	0.38	ns	ns	0.38		C3R2-10:tot	7.19	ns	ns	7.19
60	C3R2-20:diss	3.19	2.77	3.10	3.02		C3R2-20:tot	15.48	12.62	12.67	13.59
70	C3R2-30:diss	3.67	ns	ns	3.67		C3R2-30:tot	14.67	ns	ns	14.67
80	C3R3-00:diss	0.68	ns	ns	0.68		C3R3-00:tot	5.46	ns	ns	5.46
90	C3R3-10:diss	0.74	ns	ns	0.74		C3R3-10:tot	3.81	ns	ns	3.81
100	C3R3-20:diss	2.92	ns	ns	2.92		C3R3-20:tot	5.69	ns	ns	5.69
110	C3R3-30:diss	2.55	2.43	2.33	2.44		C3R3-30:tot	5.29	5.30	5.46	5.35
120	C3R4-00:diss	0.14	ns	ns	0.14		C3R4-00:tot	3.29	ns	ns	3.29
130	C3R4-10:diss	0.15	ns	ns	0.15		C3R4-10:tot	4.84	ns	ns	4.84
140	C3R4-20:diss	2.35	ns	ns	2.35		C3R4-20:tot	5.16	ns	ns	5.16
150	C3R4-30:diss	2.61	2.69	2.63	2.64		C3R4-30:tot	5.92	5.70	ns	5.81

160	C3R5-00:diss	0.30	ns	ns	0.30		C3R5-00:tot	4.40	ns	ns	4.40
170	C3R5-10:diss	nd	ns	ns	0.00		C3R5-10:tot	3.03	ns	ns	3.03
180	C3R5-20:diss	7.10	ns	ns	2.37		C3R5-20:tot	11.15	ns	ns	11.15
190	C3R5-30:diss	5.75	5.57	ns	5.66		C3R5-30:tot	9.83	10.28	ns	10.05
220	C3R5-60:diss	1.91	1.93	2.09	1.98		C3R5-60:tot	8.11	6.55	ns	7.33
230	C3R6-00:diss	0.14	ns	ns	0.14		C3R6-00:tot	3.61	ns	ns	3.61
240	C3R6-10:diss	nd	ns	ns	0.00		C3R6-10:tot	2.41	ns	ns	2.41
250	C3R6-20:diss	1.51	ns	ns	1.51		C3R6-20:tot	4.40	ns	ns	4.40
260	C3R6-30:diss	5.06	ns	ns	1.69		C3R6-30:tot	8.03	ns	ns	8.03
270	C3R6-40:diss	3.14	2.82	2.69	2.88		C3R6-40:tot	5.99	5.99	6.50	6.16
280	C3R7-00:diss	6.29	ns	ns	6.29		C3R7-00:tot	12.42	ns	ns	12.42
290	C3R7-10:diss	31.29	ns	ns	31.29		C3R7-10:tot	41.75	ns	ns	41.75
300	C3R7-20:diss	26.42	ns	ns	26.42		C3R7-20:tot	29.66	ns	ns	29.66
310	C3R7-30:diss	19.25	19.39	19.87	19.50		C3R7-30:tot	23.58	25.93	34.53	28.01
320	C3R8-00:diss	5.01	ns	ns	5.01		C3R8-00:tot	8.30	ns	ns	8.30
330	C3R8-10:diss	4.61	ns	ns	4.61		C3R8-10:tot	7.06	ns	ns	7.06
340	C3R8-20:diss	6.91	ns	ns	6.91		C3R8-20:tot	9.25	ns	ns	9.25
350	C3R8-30:diss	12.63	ns	ns	12.63		C3R8-30:tot	15.70	ns	ns	15.70
370	C3R8-50:diss	7.49	7.51	7.60	7.53		C3R8-50:tot	10.26	10.73	10.14	10.38
380	C3R9-00:diss	3.89	ns	ns	3.89		C3R9-00:tot	7.82	ns	ns	7.82
390	C3R9-10:diss	3.30	ns	ns	3.30		C3R9-10:tot	5.06	ns	ns	5.06
400	C3R9-20:diss	10.53	ns	ns	10.53		C3R9-20:tot	13.34	ns	ns	13.34
410	C3R9-30:diss	13.38	ns	ns	13.38		C3R9-30:tot	15.38	ns	ns	15.38
420	C3R9-40:diss	11.16	11.02	11.01	11.06		C3R9-40:tot	13.84	14.09	14.31	14.08
430	C3R10-00:diss	3.59	ns	ns	3.59		C3R10-00:tot	8.69	ns	ns	8.69
445	C3R10-15:diss	7.59	ns	ns	7.59		C3R10-15:tot	10.58	ns	ns	10.58
460	C3R10-30:diss	6.42	ns	ns	6.42		C3R10-30:tot	9.02	ns	ns	9.02
475	C3R10-45:diss	5.85	5.74	5.81	5.80		C3R10-45:tot	8.53	9.06	8.48	8.69
500	C3R10-70:diss	5.14	ns	ns	5.14		C3R10-70:tot	8.33	ns	ns	8.33
510	C3R11-00:diss	3.25	ns	ns	3.25		C3R11-00:tot	5.92	ns	ns	5.92
520	C3R11-10:diss	2.72	ns	ns	2.72		C3R11-10:tot	4.73	ns	ns	4.73
530	C3R11-20:diss	4.72	ns	ns	4.72		C3R11-20:tot	6.84	ns	ns	6.84
540	C3R11-30:diss	7.16	ns	ns	7.16		C3R11-30:tot	11.75	ns	ns	11.75
560	C3R11-50:diss	4.08	4.19	4.12	4.13		C3R11-40:tot	6.16	6.34	6.95	6.48
570	C3R12-00:diss	2.85	ns	ns	2.85		C3R12-00:tot	11.85	ns	ns	11.85

585	C3R12-15:diss	4.08	ns	ns	4.08		C3R12-15:tot	6.03	ns	ns	6.03
600	C3R12-30:diss	7.52	ns	ns	7.52		C3R12-30:tot	9.63	ns	ns	9.63
615	C3R12-45:diss	3.97	ns	ns	3.97		C3R12-45:tot	6.23	ns	ns	6.23
650	C3R12-80:diss	1.27	1.23	1.40	1.30		C3R12-80:tot	3.04	3.13	3.21	3.13
660	C3R12-90:diss	1.07	ns	ns	1.07		C3R12-90:tot	7.87	ns	ns	7.87
670	C3R13-00:diss	1.35	ns	ns	1.35		C3R13-00:tot	4.64	ns	ns	4.64
690	C3R13-20:diss	16.60	ns	ns	16.60		C3R13-20:tot	18.05	ns	ns	18.05
710	C3R13-40:diss	6.27	ns	ns	6.27		C3R13-40:tot	9.02	ns	ns	9.02
730	C3R13-60:diss	3.02	2.82	2.77	2.87		C3R13-60:tot	5.57	10.45	5.24	7.08
750	C3R13-80:diss	2.67	ns	ns	2.67		C3R13-80:tot	10.35	ns	ns	10.35
760	C3R14-00:diss	1.34	ns	ns	1.34		C3R14-00:tot	9.63	ns	ns	9.63
780	C3R14-20:diss	1.80	ns	ns	1.80		C3R14-20:tot	9.45	ns	ns	9.45
800	C3R14-40:diss	5.90	ns	ns	5.90		C3R14-40:tot	12.69	ns	ns	12.69
820	C3R14-60:diss	2.86	2.79	2.81	2.82		C3R14-60:tot	10.35	ns	ns	10.35
840	C3R14-80:diss	1.12	ns	ns	1.12		C3R14-80:tot	8.96	ns	ns	8.96
850	C3R15-00:diss	5.69	ns	ns	5.69		C3R15-00:tot	6.88	ns	ns	6.88
870	C3R15-20:diss	6.31	ns	ns	6.31		C3R15-20:tot	7.11	ns	ns	7.11
890	C3R15-40:diss	8.85	ns	ns	8.85		C3R15-40:tot	9.03	ns	ns	9.03
920	C3R15-70:diss	5.92	ns	ns	5.92		C3R15-70:tot	6.41	ns	ns	6.41
950	C3R15-100:diss	5.09	5.18	5.37	5.21		C3R15-100:tot	6.29	7.24	7.74	7.09
980	C3R15-130:diss	5.53	ns	ns	5.53		C3R15-130:tot	6.95	ns	ns	6.95

Column 1 - Sand											
	Dissolved Zinc						Total Zinc				
Overall Run Time (min)		Concentration (µg/L)						Concentration (µg/L)			
	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C1R1-00:diss	nd	14.33	ns	7.17		C1R1-00:tot	4.01	23.79	ns	13.90
10	C1R1-10:diss	nd	15.56	ns	7.78		C1R1-10:tot	12.90	36.71	ns	24.80
20	C1R1-20:diss	3.97	18.44	ns	11.21		C1R1-20:tot	24.35	51.40	ns	37.88
30	C1R1-30:diss	25.80	11.64	ns	18.72		C1R1-30:tot	16.13	41.79	ns	28.96
40	C1R2-00:diss	9.18	8.81	9.52	9.17		C1R2-00:tot	23.37	17.52	20.13	20.34
50	C1R2-10:diss	29.88	30.29	30.02	30.06		C1R2-10:tot	63.00	63.65	61.10	62.58
60	C1R2-20:diss	31.31	31.39	31.50	31.40		C1R2-20:tot	71.90	72.60	74.00	72.83
70	C1R2-30:diss	35.17	35.24	35.74	35.38		C1R2-30:tot	73.15	58.10	55.65	62.30
80	C1R3-00:diss	nd	nd	nd	0.00		C1R3-00:tot	10.98	10.95	10.49	10.81
90	C1R3-10:diss	40.07	38.57	39.47	39.37		C1R3-10:tot	83.50	87.95	88.10	86.52
100	C1R3-20:diss	54.09	52.76	51.77	52.87		C1R3-20:tot	117.45	130.30	119.85	122.53
110	C1R3-30:diss	56.61	54.29	53.98	54.96		C1R3-30:tot	110.10	120.85	153.30	128.08
120	C1R4-00:diss	nd	nd	nd	0.00		C1R4-00:tot	9.74	3.97	4.83	6.18
130	C1R4-10:diss	20.55	20.82	19.85	20.41		C1R4-10:tot	40.72	44.69	ns	42.71
140	C1R4-20:diss	26.02	28.41	24.16	26.20		C1R4-20:tot	107.10	73.75	ns	90.43
150	C1R4-30:diss	27.09	26.63	27.48	27.07		C1R4-30:tot	60.85	55.15	ns	58.00
160	C1R5-00:diss	nd	nd	nd	0.00		C1R5-00:tot	6.22	5.79	7.55	6.52
170	C1R5-10:diss	34.14	35.18	34.86	34.73		C1R5-10:tot	89.00	88.05	89.90	88.98
180	C1R5-20:diss	66.64	64.83	61.61	64.36		C1R5-20:tot	150.65	143.85	152.85	149.12
190	C1R5-30:diss	144.20	143.70	142.90	143.60		C1R5-30:tot	227.75	233.45	240.05	233.75
230	C1R6-00:diss	nd	ns	ns	0.00		C1R6-00:tot	25.79	ns	ns	8.60
240	C1R6-10:diss	10.43	ns	ns	10.43		C1R6-10:tot	24.53	ns	ns	8.18
250	C1R6-20:diss	9.44	ns	ns	9.44		C1R6-20:tot	41.14	ns	ns	13.71
260	C1R6-30:diss	7.60	5.87	5.87	6.45		C1R6-30:tot	29.64	28.09	28.06	28.60
280	C1R7-00:diss	3.15	ns	ns	3.15		C1R7-00:tot	11.08	ns	ns	11.08
290	C1R7-10:diss	20.45	ns	ns	20.45		C1R7-10:tot	85.50	ns	ns	85.50
300	C1R7-20:diss	30.41	ns	ns	30.41		C1R7-20:tot	105.85	ns	ns	105.85
310	C1R7-30:diss	41.52	42.47	42.18	42.06		C1R7-30:tot	101.00	97.85	98.30	99.05

320	C1R8-00:diss	4.20	ns	ns	4.20		C1R8-00:tot	7.87	ns	ns	7.87
330	C1R8-10:diss	6.99	ns	ns	6.99		C1R8-10:tot	33.48	ns	ns	33.48
340	C1R8-20:diss	13.78	ns	ns	13.78		C1R8-20:tot	48.27	ns	ns	48.27
350	C1R8-30:diss	26.50	24.94	25.63	25.69		C1R8-30:tot	44.31	48.52	45.02	45.95
380	C1R9-00:diss	10.59	ns	ns	10.59		C1R9-00:tot	10.85	ns	ns	10.85
390	C1R9-10:diss	21.22	ns	ns	21.22		C1R9-10:tot	67.30	ns	ns	67.30
400	C1R9-20:diss	34.68	ns	ns	34.68		C1R9-20:tot	130.10	ns	ns	130.10
410	C1R9-30:diss	43.00	42.02	41.01	42.01		C1R9-30:tot	122.70	136.20	121.60	126.83
430	C1R10-00:diss	4.27	ns	ns	4.27		C1R10-00:tot	19.01	ns	ns	19.01
440	C1R10-10:diss	8.94	ns	ns	8.94		C1R10-10:tot	41.62	ns	ns	41.62
450	C1R10-20:diss	10.52	ns	ns	10.52		C1R10-20:tot	41.73	ns	ns	41.73
460	C1R10-30:diss	48.16	ns	ns	48.16		C1R10-30:tot	102.05	nd	nd	102.05
470	C1R10-40:diss	42.72	42.16	43.42	42.77		C1R10-40:tot	92.85	95.85	138.40	109.03
510	C1R11-00:diss	nd	ns	ns	0.00		C1R11-00:tot	5.29	ns	ns	5.29
520	C1R11-10:diss	7.85	ns	ns	7.85		C1R11-10:tot	35.37	ns	ns	35.37
530	C1R11-20:diss	11.21	ns	ns	11.21		C1R11-20:tot	33.60	ns	ns	33.60
540	C1R11-30:diss	14.87	13.84	13.67	14.13		C1R11-30:tot	32.95	32.54	33.40	32.96
Column 2 - Sand/Clay											
	Dissolved Zinc						**Total Zinc**				
Overall Run		Concentration (μg/L)						Concentration (μg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C2R1-00:diss	4.28	ns	ns	4.28		C2R1-00:tot	26.86	ns	ns	26.86
10	C2R1-10:diss	nd	ns	ns	0.00		C2R1-10:tot	9.06	ns	ns	9.06
20	C2R1-20:diss	nd	ns	ns	0.00		C2R1-20:tot	15.49	ns	ns	15.49
30	C2R1-30:diss	2.39	0.37	0.19	0.98		C2R1-30:tot	8.84	7.35	7.85	8.01
40	C2R2-00:diss	1.44	ns	ns	1.44		C2R2-00:tot	9.41	ns	ns	9.41
50	C2R2-10:diss	1.97	ns	ns	1.97		C2R2-10:tot	4.28	ns	ns	4.28
60	C2R2-20:diss	0.24	ns	ns	0.24		C2R2-20:tot	6.73	ns	ns	6.73
70	C2R2-30:diss	1.05	0.20	0.46	0.57		C2R2-30:tot	10.90	6.50	5.38	7.59
80	C2R3-00:diss	3.12	ns	ns	3.12		C2R3-00:tot	7.14	ns	ns	7.14
90	C2R3-10:diss	2.40	ns	ns	2.40		C2R3-10:tot	5.48	ns	ns	5.48
100	C2R3-20:diss	10.59	ns	ns	10.59		C2R3-20:tot	26.60	ns	ns	26.60
110	C2R3-30:diss	9.02	8.42	8.32	8.59		C2R3-30:tot	28.81	29.69	28.19	28.89
120	C2R4-00:diss	nd	ns	ns	0.00		C2R4-00:tot	9.55	nd	nd	9.55

130	C2R4-10:diss	nd	ns	ns	0.00	C2R4-10:tot	4.16	nd	nd	4.16
140	C2R4-20:diss	3.69	ns	ns	3.69	C2R4-20:tot	17.52	nd	nd	17.52
150	C2R4-30:diss	3.22	2.44	2.74	2.80	C2R4-30:tot	21.06	16.90	16.41	18.12
160	C2R5-00:diss	1.35	ns	ns	1.35	C2R5-00:tot	8.92	nd	nd	8.92
170	C2R5-10:diss	1.29	ns	ns	1.29	C2R5-10:tot	7.59	nd	nd	7.59
180	C2R5-20:diss	6.23	ns	ns	6.23	C2R5-20:tot	24.29	nd	nd	24.29
190	C2R5-30:diss	12.93	ns	ns	12.93	C2R5-30:tot	28.11	nd	nd	28.11
210	C2R5-50:diss	16.70	16.37	17.37	16.81	C2R5-50:tot	41.03	38.89	37.04	38.98
230	C2R6-00:diss	4.80	ns	ns	4.80	C2R6-00:tot	17.29	nd	nd	17.29
240	C2R6-10:diss	2.25	ns	ns	2.25	C2R6-10:tot	5.90	nd	nd	5.90
250	C2R6-20:diss	3.07	ns	ns	3.07	C2R6-20:tot	6.99	nd	nd	6.99
260	C2R6-30:diss	4.83	3.34	4.08	4.08	C2R6-30:tot	14.67	12.05	29.14	18.62
Column 3 - Sand/Clay/Compost										
	Dissolved Zinc					**Total Zinc**				
Overall Run		Concentration (µg/L)					Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average	Sample ID	sample a	sample b	sample c	average
0	C3R1-00:diss	nd	nd	nd	0.00	C3R1-00:tot	35.63	36.89	39.97	37.50
10	C3R1-10:diss	nd	nd	nd	0.00	C3R1-10:tot	20.46	10.34	11.40	14.06
20	C3R1-20:diss	nd	0.69	nd	0.23	C3R1-20:tot	9.42	7.87	8.17	8.49
30	C3R1-30:diss	1.89	0.98	3.39	2.09	C3R1-30:tot	5.11	5.15	8.89	6.38
40	C3R2-00:diss	nd	ns	ns	0.00	C3R2-00:tot	19.04	ns	ns	19.04
50	C3R2-10:diss	nd	ns	ns	0.00	C3R2-10:tot	8.45	ns	ns	8.45
60	C3R2-20:diss	nd	nd	nd	0.00	C3R2-20:tot	15.22	16.90	10.31	14.14
70	C3R2-30:diss	nd	ns	ns	0.00	C3R2-30:tot	14.33	ns	ns	14.33
80	C3R3-00:diss	nd	ns	ns	0.00	C3R3-00:tot	3.18	ns	ns	3.18
90	C3R3-10:diss	nd	ns	ns	0.00	C3R3-10:tot	2.32	ns	ns	2.32
100	C3R3-20:diss	nd	ns	ns	0.00	C3R3-20:tot	1.94	ns	ns	1.94
110	C3R3-30:diss	nd	nd	nd	0.00	C3R3-30:tot	2.93	1.05	2.47	2.15
120	C3R4-00:diss	nd	ns	ns	0.00	C3R4-00:tot	nd	ns	ns	0.00
130	C3R4-10:diss	nd	ns	ns	0.00	C3R4-10:tot	0.52	ns	ns	0.52
140	C3R4-20:diss	nd	ns	ns	0.00	C3R4-20:tot	2.97	ns	ns	2.97
150	C3R4-30:diss	nd	nd	nd	0.00	C3R4-30:tot	0.48	0.32	1.08	0.62
160	C3R5-00:diss	nd	ns	ns	0.00	C3R5-00:tot	7.37	ns	ns	7.37
170	C3R5-10:diss	2.04	ns	ns	2.04	C3R5-10:tot	6.70	ns	ns	6.70

180	C3R5-20:diss	3.44	ns	ns	3.44		C3R5-20:tot	10.87	ns	ns	10.87
190	C3R5-30:diss	6.94	5.77	ns	6.36		C3R5-30:tot	7.87	7.72	ns	7.80
220	C3R5-60:diss	7.61	7.47	8.19	7.76		C3R5-60:tot	11.22	14.33	ns	12.77
230	C3R6-00:diss	nd	ns	ns	0.00		C3R6-00:tot	6.68	ns	ns	6.68
240	C3R6-10:diss	nd	ns	ns	0.00		C3R6-10:tot	13.32	ns	ns	13.32
250	C3R6-20:diss	0.20	ns	ns	0.20		C3R6-20:tot	8.23	ns	ns	8.23
260	C3R6-30:diss	5.95	ns	ns	5.95		C3R6-30:tot	6.24	ns	ns	6.24
270	C3R6-40:diss	2.31	1.23	1.57	1.70		C3R6-40:tot	8.23	7.17	12.02	9.14
280	C3R7-00:diss	0.24	ns	ns	0.24		C3R7-00:tot	12.27	ns	ns	12.27
290	C3R7-10:diss	12.16	ns	ns	12.16		C3R7-10:tot	30.07	ns	ns	30.07
300	C3R7-20:diss	5.51	ns	ns	5.51		C3R7-20:tot	18.15	ns	ns	18.15
310	C3R7-30:diss	3.82	3.87	4.39	4.03		C3R7-30:tot	24.73	15.93	36.11	25.59
320	C3R8-00:diss	nd	ns	ns	0.00		C3R8-00:tot	9.92	ns	ns	9.92
330	C3R8-10:diss	nd	ns	ns	0.00		C3R8-10:tot	3.95	ns	ns	3.95
340	C3R8-20:diss	nd	ns	ns	0.00		C3R8-20:tot	4.33	ns	ns	4.33
350	C3R8-30:diss	nd	ns	ns	0.00		C3R8-30:tot	9.55	ns	ns	9.55
370	C3R8-50:diss	0.10	0.23	nd	0.11		C3R8-50:tot	9.56	11.73	8.55	9.95
380	C3R9-00:diss	nd	ns	ns	0.00		C3R9-00:tot	7.82	ns	ns	7.82
390	C3R9-10:diss	nd	ns	ns	0.00		C3R9-10:tot	2.91	ns	ns	2.91
400	C3R9-20:diss	0.51	ns	ns	0.51		C3R9-20:tot	8.72	ns	ns	8.72
410	C3R9-30:diss	5.40	ns	ns	5.40		C3R9-30:tot	13.05	ns	ns	13.05
420	C3R9-40:diss	11.02	10.49	10.56	10.69		C3R9-40:tot	15.62	18.98	16.03	16.88
430	C3R10-00:diss	2.94	ns	ns	2.94		C3R10-00:tot	13.96	ns	ns	13.96
445	C3R10-15:diss	1.56	ns	ns	1.56		C3R10-15:tot	17.77	ns	ns	17.77
460	C3R10-30:diss	2.58	ns	ns	2.58		C3R10-30:tot	16.92	ns	ns	16.92
475	C3R10-45:diss	5.78	2.93	3.05	3.92		C3R10-45:tot	10.84	12.87	10.54	11.42
500	C3R10-70:diss	2.81	ns	ns	2.81		C3R10-70:tot	15.60	ns	ns	15.60
510	C3R11-00:diss	1.91	ns	ns	1.91		C3R11-00:tot	24.15	ns	ns	24.15
520	C3R11-10:diss	nd	ns	ns	0.00		C3R11-10:tot	19.75	ns	ns	19.75
530	C3R11-20:diss	2.01	ns	ns	2.01		C3R11-20:tot	6.89	ns	ns	6.89
540	C3R11-30:diss	2.60	ns	ns	2.60		C3R11-30:tot	13.80	ns	ns	13.80
560	C3R11-50:diss	1.66	0.92	1.00	1.19		C3R11-40:tot	15.72	23.87	21.19	20.26
570	C3R12-00:diss	0.52	ns	ns	0.52		C3R12-00:tot	21.31	ns	ns	21.31
585	C3R12-15:diss	0.79	ns	ns	0.79		C3R12-15:tot	6.58	ns	ns	6.58
600	C3R12-30:diss	1.14	ns	ns	1.14		C3R12-30:tot	7.61	ns	ns	7.61

615	C3R12-45:diss	0.60	ns	ns	0.60		C3R12-45:tot	13.60	ns	ns	13.60
650	C3R12-80:diss	nd	nd	nd	0.00		C3R12-80:tot	6.84	5.20	7.05	6.36
660	C3R12-90:diss	nd	ns	ns	0.00		C3R12-90:tot	7.84	ns	ns	7.84
670	C3R13-00:diss	1.11	ns	ns	1.11		C3R13-00:tot	5.62	ns	ns	5.62
690	C3R13-20:diss	3.18	ns	ns	3.18		C3R13-20:tot	9.96	ns	ns	9.96
710	C3R13-40:diss	nd	ns	ns	0.00		C3R13-40:tot	9.52	ns	ns	9.52
730	C3R13-60:diss	1.16	0.00	0.00	0.39		C3R13-60:tot	6.25	6.57	4.50	5.77
750	C3R13-80:diss	0.00	ns	ns	0.00		C3R13-80:tot	19.37	ns	ns	19.37
760	C3R14-00:diss	0.00	ns	ns	0.00		C3R14-00:tot	13.47	ns	ns	13.47
780	C3R14-20:diss	0.00	ns	ns	0.00		C3R14-20:tot	8.73	ns	ns	8.73
800	C3R14-40:diss	0.00	ns	ns	0.00		C3R14-40:tot	14.13	ns	ns	14.13
820	C3R14-60:diss	0.00	0.00	0.00	0.00		C3R14-60:tot	29.86	ns	ns	29.86
840	C3R14-80:diss	0.00	ns	ns	0.00		C3R14-80:tot	15.52	ns	ns	15.52
850	C3R15-00:diss	1.94	ns	ns	1.94		C3R15-00:tot	7.78	ns	ns	7.78
870	C3R15-20:diss	2.89	ns	ns	2.89		C3R15-20:tot	8.17	ns	ns	8.17
890	C3R15-40:diss	2.71	ns	ns	2.71		C3R15-40:tot	7.36	ns	ns	7.36
920	C3R15-70:diss	2.42	ns	ns	2.42		C3R15-70:tot	6.89	ns	ns	6.89
950	C3R15-100:diss	2.18	2.08	2.14	2.13		C3R15-100:tot	7.37	13.01	14.93	11.77
980	C3R15-130:diss	2.71			2.71		C3R15-130:tot	9.38	ns	ns	9.38

Column 1 - Sand											
	Dissolved Lead						**Total Lead**				
Overall Run Time (min)		Concentration (µg/L)						Concentration (µg/L)			
	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C1R1-00:diss	3.40	nd	ns	1.70		C1R1-00:tot	2.67	1.26	ns	1.97
10	C1R1-10:diss	4.94	1.10	ns	3.02		C1R1-10:tot	4.23	7.54	ns	5.88
20	C1R1-20:diss	6.87	1.72	ns	4.30		C1R1-20:tot	7.07	13.89	ns	10.48
30	C1R1-30:diss	7.00	0.57	ns	3.79		C1R1-30:tot	5.92	10.35	ns	8.13
40	C1R2-00:diss	nd	nd	nd	0.00		C1R2-00:tot	1.19	0.55	3.60	1.78
50	C1R2-10:diss	10.92	10.86	10.89	10.89		C1R2-10:tot	21.46	24.76	21.45	22.56
60	C1R2-20:diss	14.53	14.39	14.30	14.41		C1R2-20:tot	30.30	27.60	27.78	28.56
70	C1R2-30:diss	15.27	15.21	15.40	15.29		C1R2-30:tot	25.84	25.45	23.96	25.08
80	C1R3-00:diss	nd	nd	nd	0.00		C1R3-00:tot	1.92	1.02	0.92	1.28
90	C1R3-10:diss	19.33	18.82	19.33	19.16		C1R3-10:tot	35.27	35.32	34.95	35.18
100	C1R3-20:diss	30.18	30.35	30.19	30.24		C1R3-20:tot	52.80	55.75	50.75	53.10
110	C1R3-30:diss	28.50	27.85	27.44	27.93		C1R3-30:tot	53.15	52.85	52.55	52.85
120	C1R4-00:diss	nd	nd	nd	0.00		C1R4-00:tot	1.06	1.00	2.10	1.38
130	C1R4-10:diss	7.96	7.97	7.92	7.95		C1R4-10:tot	19.52	20.34	ns	19.93
140	C1R4-20:diss	15.18	15.95	15.01	15.38		C1R4-20:tot	36.66	36.55	ns	36.61
150	C1R4-30:diss	17.30	17.05	17.51	17.29		C1R4-30:tot	34.79	34.04	ns	34.41
160	C1R5-00:diss	nd	nd	nd	0.00		C1R5-00:tot	0.86	2.29	1.52	1.56
170	C1R5-10:diss	12.79	12.85	12.87	12.84		C1R5-10:tot	29.40	29.62	29.83	29.62
180	C1R5-20:diss	25.39	25.36	23.71	24.82		C1R5-20:tot	57.40	57.70	58.15	57.75
190	C1R5-30:diss	59.12	59.35	59.17	59.21		C1R5-30:tot	110.05	102.50	104.20	105.58
230	C1R6-00:diss	nd	ns	ns	0.00		C1R6-00:tot	1.21	ns	ns	1.21
240	C1R6-10:diss	8.24	ns	ns	8.24		C1R6-10:tot	23.52	ns	ns	23.52
250	C1R6-20:diss	9.31	ns	ns	9.31		C1R6-20:tot	25.71	ns	ns	25.71
260	C1R6-30:diss	8.12	8.01	7.93	8.02		C1R6-30:tot	22.20	22.07	23.50	22.59
280	C1R7-00:diss	0.48	ns	ns	0.48		C1R7-00:tot	2.02	ns	ns	2.02
290	C1R7-10:diss	13.31	ns	ns	13.31		C1R7-10:tot	53.30	ns	ns	53.30
300	C1R7-20:diss	22.03	ns	ns	22.03		C1R7-20:tot	72.00	ns	ns	72.00
310	C1R7-30:diss	24.92	24.99	25.05	24.99		C1R7-30:tot	71.10	71.10	71.20	71.13

320	C1R8-00:diss	1.00	ns	ns	1.00		C1R8-00:tot	2.89	ns	ns	2.89
330	C1R8-10:diss	4.40	ns	ns	4.40		C1R8-10:tot	20.21	ns	ns	20.21
340	C1R8-20:diss	9.32	ns	ns	9.32		C1R8-20:tot	30.34	ns	ns	30.34
350	C1R8-30:diss	13.07	12.83	12.92	12.94		C1R8-30:tot	30.53	29.60	30.47	30.20
380	C1R9-00:diss	0.71	ns	ns	0.71		C1R9-00:tot	2.03	ns	ns	2.03
390	C1R9-10:diss	8.24	ns	ns	8.24		C1R9-10:tot	35.72	ns	ns	35.72
400	C1R9-20:diss	17.70	ns	ns	17.70		C1R9-20:tot	77.45	ns	ns	77.45
410	C1R9-30:diss	21.06	21.13	20.84	21.01		C1R9-30:tot	80.10	80.40	78.10	79.53
430	C1R10-00:diss	1.00	ns	ns	1.00		C1R10-00:tot	1.61	ns	ns	1.61
440	C1R10-10:diss	3.03	ns	ns	3.03		C1R10-10:tot	21.18	ns	ns	21.18
450	C1R10-20:diss	2.99	ns	ns	2.99		C1R10-20:tot	21.73	ns	ns	21.73
460	C1R10-30:diss	15.55	ns	ns	15.55		C1R10-30:tot	65.20	nd	nd	65.20
470	C1R10-40:diss	16.76	16.90	16.86	16.84		C1R10-40:tot	68.90	67.85	71.50	69.42
510	C1R11-00:diss	nd	ns	ns	0.00		C1R11-00:tot	0.27	ns	ns	0.27
520	C1R11-10:diss	3.85	ns	ns	3.85		C1R11-10:tot	14.81	ns	ns	14.81
530	C1R11-20:diss	6.24	ns	ns	6.24		C1R11-20:tot	18.90	ns	ns	18.90
540	C1R11-30:diss	7.83	7.29	7.30	7.47		C1R11-30:tot	18.37	18.64	18.80	18.60

Column 2 - Sand/Clay

	Dissolved Lead						Total Lead				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C2R1-00:diss	nd	ns	ns	0.00		C2R1-00:tot	1.53	ns	ns	1.53
10	C2R1-10:diss	1.68	ns	ns	1.68		C2R1-10:tot	6.13	ns	ns	6.13
20	C2R1-20:diss	1.42	ns	ns	1.42		C2R1-20:tot	5.37	ns	ns	5.37
30	C2R1-30:diss	1.10	0.96	0.93	1.00		C2R1-30:tot	4.14	3.99	3.39	3.84
40	C2R2-00:diss	nd	ns	ns	0.00		C2R2-00:tot	0.44	ns	ns	0.44
50	C2R2-10:diss	nd	ns	ns	0.00		C2R2-10:tot	0.03	ns	ns	0.03
60	C2R2-20:diss	0.24	ns	ns	0.24		C2R2-20:tot	3.94	ns	ns	3.94
70	C2R2-30:diss	0.44	0.37	0.37	0.39		C2R2-30:tot	2.91	2.99	2.82	2.91
80	C2R3-00:diss	nd	ns	ns	0.00		C2R3-00:tot	0.53	ns	ns	0.53
90	C2R3-10:diss	nd	ns	ns	0.00		C2R3-10:tot	0.45	ns	ns	0.45
100	C2R3-20:diss	8.27	ns	ns	8.27		C2R3-20:tot	25.04	ns	ns	25.04
110	C2R3-30:diss	10.10	10.06	9.99	10.05		C2R3-30:tot	27.17	26.66	27.17	27.00
120	C2R4-00:diss	1.16	ns	ns	1.16		C2R4-00:tot	1.62	ns	ns	1.62

130	C2R4-10:diss	1.16	ns	ns	1.16		C2R4-10:tot	2.50	ns	ns	2.50
140	C2R4-20:diss	10.04	ns	ns	10.04		C2R4-20:tot	19.08	ns	ns	19.08
150	C2R4-30:diss	9.47	9.35	9.55	9.46		C2R4-30:tot	21.89	21.13	21.14	21.39
160	C2R5-00:diss	0.51	ns	ns	0.51		C2R5-00:tot	1.26	ns	ns	1.26
170	C2R5-10:diss	0.26	ns	ns	0.26		C2R5-10:tot	1.19	ns	ns	1.19
180	C2R5-20:diss	5.67	ns	ns	5.67		C2R5-20:tot	17.98	ns	ns	17.98
190	C2R5-30:diss	6.92	ns	ns	6.92		C2R5-30:tot	20.19	ns	ns	20.19
210	C2R5-50:diss	10.79	10.83	10.93	10.85		C2R5-50:tot	28.50	27.35	26.79	27.54
230	C2R6-00:diss	0.52	ns	ns	0.52		C2R6-00:tot	1.03	ns	ns	1.03
240	C2R6-10:diss	0.29	ns	ns	0.29		C2R6-10:tot	1.43	ns	ns	1.43
250	C2R6-20:diss	0.93	ns	ns	0.93		C2R6-20:tot	2.92	ns	ns	2.92
260	C2R6-30:diss	1.21	1.14	1.16	1.17		C2R6-30:tot	3.90	6.19	2.91	4.33
Column 3 - Sand/Clay/Compost											
	Dissolved Lead						**Total Lead**				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C3R1-00:diss	0.19	0.18	0.18	0.18		C3R1-00:tot	3.15	2.63	3.11	2.96
10	C3R1-10:diss	2.98	2.80	2.79	2.86		C3R1-10:tot	6.63	6.48	6.59	6.56
20	C3R1-20:diss	3.65	3.58	3.54	3.59		C3R1-20:tot	7.09	7.23	7.05	7.12
30	C3R1-30:diss	3.08	2.98	3.36	3.14		C3R1-30:tot	6.23	7.50	6.47	6.73
40	C3R2-00:diss	0.42	ns	ns	0.42		C3R2-00:tot	2.18	ns	ns	2.18
50	C3R2-10:diss	0.23	ns	ns	0.23		C3R2-10:tot	2.38	ns	ns	2.38
60	C3R2-20:diss	2.28	2.21	2.20	2.23		C3R2-20:tot	7.58	6.56	7.14	7.09
70	C3R2-30:diss	4.00	ns	ns	4.00		C3R2-30:tot	12.10	ns	ns	12.10
80	C3R3-00:diss	0.13	ns	ns	0.13		C3R3-00:tot	1.74	ns	ns	1.74
90	C3R3-10:diss	0.07	ns	ns	0.07		C3R3-10:tot	1.91	ns	ns	1.91
100	C3R3-20:diss	0.90	ns	ns	0.90		C3R3-20:tot	2.83	ns	ns	2.83
110	C3R3-30:diss	1.81	1.72	1.72	1.75		C3R3-30:tot	4.65	4.27	4.32	4.41
120	C3R4-00:diss	0.22	ns	ns	0.22		C3R4-00:tot	2.35	ns	ns	2.35
130	C3R4-10:diss	0.13	ns	ns	0.13		C3R4-10:tot	2.11	ns	ns	2.11
140	C3R4-20:diss	0.84	ns	ns	0.84		C3R4-20:tot	2.82	ns	ns	2.82
150	C3R4-30:diss	2.70	2.64	2.70	2.68		C3R4-30:tot	5.18	5.80	ns	5.49
160	C3R5-00:diss	0.43	ns	ns	0.43		C3R5-00:tot	2.88	ns	ns	2.88
170	C3R5-10:diss	nd	ns	ns	0.00		C3R5-10:tot	0.97	ns	ns	0.97

180	C3R5-20:diss	2.99	ns	ns	2.99		C3R5-20:tot	9.27	ns	ns	9.27
190	C3R5-30:diss	5.56	5.23	ns	5.40		C3R5-30:tot	11.65	11.10	ns	11.37
220	C3R5-60:diss	2.28	2.27	2.29	2.28		C3R5-60:tot	7.11	8.15	nd	7.63
230	C3R6-00:diss	nd	ns	ns	0.00		C3R6-00:tot	1.01	ns	ns	1.01
240	C3R6-10:diss	nd	ns	ns	0.00		C3R6-10:tot	0.35	ns	ns	0.35
250	C3R6-20:diss	nd	ns	ns	0.00		C3R6-20:tot	0.67	ns	ns	0.67
260	C3R6-30:diss	2.93	ns	ns	2.93		C3R6-30:tot	7.18	ns	ns	7.18
270	C3R6-40:diss	4.10	3.30	3.15	3.52		C3R6-40:tot	7.76	8.28	9.43	8.49
280	C3R7-00:diss	nd	ns	ns	0.00		C3R7-00:tot	4.47	ns	ns	4.47
290	C3R7-10:diss	6.61	ns	ns	6.61		C3R7-10:tot	25.75	ns	ns	25.75
300	C3R7-20:diss	6.71	ns	ns	6.71		C3R7-20:tot	16.29	ns	ns	16.29
310	C3R7-30:diss	5.01	4.90	5.04	4.98		C3R7-30:tot	14.73	14.72	22.36	17.27
320	C3R8-00:diss	nd	ns	ns	0.00		C3R8-00:tot	1.40	ns	ns	1.40
330	C3R8-10:diss	nd	ns	ns	0.00		C3R8-10:tot	0.91	ns	ns	0.91
340	C3R8-20:diss	nd	ns	ns	0.00		C3R8-20:tot	1.64	ns	ns	1.64
350	C3R8-30:diss	0.78	ns	ns	0.78		C3R8-30:tot	5.78	ns	ns	5.78
370	C3R8-50:diss	1.24	1.22	1.21	1.22		C3R8-50:tot	6.37	6.46	6.13	6.32
380	C3R9-00:diss	nd	ns	ns	0.00		C3R9-00:tot	0.81	ns	ns	0.81
390	C3R9-10:diss	nd	ns	ns	0.00		C3R9-10:tot	0.58	ns	ns	0.58
400	C3R9-20:diss	0.84	ns	ns	0.84		C3R9-20:tot	9.57	ns	ns	9.57
410	C3R9-30:diss	6.87	ns	ns	6.87		C3R9-30:tot	22.49	ns	ns	22.49
420	C3R9-40:diss	9.97	9.65	9.68	9.77		C3R9-40:tot	25.82	25.21	26.21	25.74
430	C3R10-00:diss	nd	ns	ns	0.00		C3R10-00:tot	1.07	ns	ns	1.07
445	C3R10-15:diss	nd	ns	ns	0.00		C3R10-15:tot	3.17	ns	ns	3.17
460	C3R10-30:diss	1.85	ns	ns	1.85		C3R10-30:tot	7.34	ns	ns	7.34
475	C3R10-45:diss	3.77	3.75	3.78	3.77		C3R10-45:tot	11.15	11.63	10.55	11.11
500	C3R10-70:diss	3.77	ns	ns	3.77		C3R10-70:tot	10.16	ns	ns	10.16
510	C3R11-00:diss	nd	ns	ns	0.00		C3R11-00:tot	0.14	ns	ns	0.14
520	C3R11-10:diss	nd	ns	ns	0.00		C3R11-10:tot	0.30	ns	ns	0.30
530	C3R11-20:diss	nd	ns	ns	0.00		C3R11-20:tot	1.08	ns	ns	1.08
540	C3R11-30:diss	nd	ns	ns	0.00		C3R11-30:tot	1.58	ns	ns	1.58
560	C3R11-50:diss	nd	nd	nd	0.00		C3R11-40:tot	1.54	1.53	1.68	1.58
570	C3R12-00:diss	0.00	ns	ns	0.00		C3R12-00:tot	1.85	ns	ns	1.85
585	C3R12-15:diss	0.00	ns	ns	0.00		C3R12-15:tot	0.49	ns	ns	0.49
600	C3R12-30:diss	0.00	ns	ns	0.00		C3R12-30:tot	2.11	ns	ns	2.11

615	C3R12-45:diss	0.00	ns	ns	0.00		C3R12-45:tot	1.85	ns	ns	1.85
650	C3R12-80:diss	0.00	nd	nd	0.00		C3R12-80:tot	0.27	0.48	2.43	1.06
660	C3R12-90:diss	0.00	ns	ns	0.00		C3R12-90:tot	0.94	ns	ns	0.94
670	C3R13-00:diss	0.00	ns	ns	0.00		C3R13-00:tot	0.00	ns	ns	0.00
690	C3R13-20:diss	1.62	ns	ns	1.62		C3R13-20:tot	8.59	ns	ns	8.59
710	C3R13-40:diss	0.00	ns	ns	0.00		C3R13-40:tot	3.33	ns	ns	3.33
730	C3R13-60:diss	0.00	0.00	0.00	0.00		C3R13-60:tot	2.02	2.38	1.70	2.03
750	C3R13-80:diss	0.00	ns	ns	0.00		C3R13-80:tot	10.86	ns	ns	10.86
760	C3R14-00:diss	0.00	ns	ns	0.00		C3R14-00:tot	5.04	ns	ns	5.04
780	C3R14-20:diss	0.00	ns	ns	0.00		C3R14-20:tot	4.41	ns	ns	4.41
800	C3R14-40:diss	0.00	ns	ns	0.00		C3R14-40:tot	6.06	ns	ns	6.06
820	C3R14-60:diss	0.00	0.00	0.00	0.00		C3R14-60:tot	6.62	ns	ns	6.62
840	C3R14-80:diss	0.00	ns	ns	0.00		C3R14-80:tot	6.65	ns	ns	6.65
850	C3R15-00:diss	0.00	ns	ns	0.00		C3R15-00:tot	1.07	ns	ns	1.07
870	C3R15-20:diss	0.22	ns	ns	0.22		C3R15-20:tot	0.85	ns	ns	0.85
890	C3R15-40:diss	0.61	ns	ns	0.61		C3R15-40:tot	2.52	ns	ns	2.52
920	C3R15-70:diss	1.09	ns	ns	1.09		C3R15-70:tot	3.65	ns	ns	3.65
950	C3R15-100:diss	1.12	1.10	1.10	1.11		C3R15-100:tot	3.53	3.82	4.63	3.99
980	C3R15-130:diss	0.89	ns	ns	0.89		C3R15-130:tot	4.31	ns	ns	4.31

Laboratory Columns – Influent and Effluent Suspended Solids Concentrations

Column 1 - Sand

Overall Run		Effluent Concentration (mg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average
0	C1R1-00	1.50	1.50	ns	1.50
10	C1R1-10	1.50	1.00	ns	1.25
20	C1R1-20	0.50	0.50	ns	0.50
30	C1R1-30	1.00	1.00	ns	1.00
40	C1R2-00	5.60	6.80	6.40	6.27
50	C1R2-10	2.00	2.80	1.60	2.13
60	C1R2-20	1.60	0.80	0.40	0.93
70	C1R2-30	0.00	0.40	0.00	0.13
80	C1R3-00	7.60	10.80	7.20	8.53
90	C1R3-10	0.40	0.40	1.20	0.67
100	C1R3-20	0.00	0.00	0.00	0.00
110	C1R3-30	0.00	0.00	0.00	0.00
120	C1R4-00	2.40	6.40	4.80	4.53
130	C1R4-10	0.00	0.80	0.80	0.53
140	C1R4-20	1.20	0.80	0.40	0.80
150	C1R4-30	0.00	0.00	0.00	0.00
160	C1R5-00	10.40	15.20	39.20	21.60
170	C1R5-10	2.00	1.60	0.40	1.33
180	C1R5-20	0.40	0.00	0.00	0.13
190	C1R5-30	0.00	0.00	0.00	0.00
230	C1R6-00	20.40	19.20	26.40	22.00
240	C1R6-10	2.00	3.60	2.40	2.67
250	C1R6-20	2.40	2.00	1.60	2.00
260	C1R6-30	0.40	0.40	0.00	0.27
280	C1R7-00	14.80	21.20	8.80	14.93
290	C1R7-10	4.00	7.20	11.60	7.60
300	C1R7-20	2.40	3.20	2.80	2.80
310	C1R7-30	0.40	2.00	1.20	1.20
320	C1R8-00	10.40	12.40	15.60	12.80

Overall Run		Influent Concentration (mg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average
0	C1R1-IN	331.50	366.50	ns	349.00
40	C1R2-IN	347.60	358.40	305.60	337.20
80	C1R3-IN	387.60	434.40	338.40	386.80
120	C1R4-IN	408.80	417.20	322.00	382.67
160	C1R5-IN	373.60	300.00	347.20	340.27
230	C1R6-IN	296.80	335.60	327.70	320.03
280	C1R7-IN	299.20	295.20	312.00	302.13
320	C1R8-IN	372.40	386.80	332.80	364.00
380	C1R9-IN	300.80	358.00	429.20	362.67
430	C1R10-IN	320.00	305.60	365.20	330.27
510	C1R11-IN	281.60	312.80	269.60	288.00
				average =	342.09
	removal =	98.78%			

330	C1R8-10	1.60	0.40	2.40	1.47
340	C1R8-20	2.00	2.40	4.80	3.07
350	C1R8-30	0.00	1.20	2.00	1.07
380	C1R9-00	8.00	12.00	10.40	10.13
390	C1R9-10	3.20	2.00	5.65	3.62
400	C1R9-20	1.60	2.00	3.20	2.27
410	C1R9-30	0.00	0.80	0.80	0.53
430	C1R10-00	11.60	10.80	15.20	12.53
440	C1R10-10	0.80	0.40	1.20	0.80
450	C1R10-20	1.20	0.00	1.20	0.80
460	C1R10-30	2.40	0.00	0.80	1.07
470	C1R10-40	2.00	0.00	0.00	0.67
510	C1R11-00	20.4	22.8	36.8	26.67
520	C1R11-10	2.40	4.40	5.60	4.13
530	C1R11-20	0.00	0.00	1.20	0.40
540	C1R11-30	0.00	0.00	1.20	0.40
				average =	4.17

Column 2 - Sand/Clay

Overall Run		Effluent Concentration (mg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average
0	C2R1-00	83.60	79.20	126.00	96.27
10	C2R1-10	19.20	21.20	36.40	25.60
20	C2R1-20	9.20	8.40	9.20	8.93
30	C2R1-30	4.00	5.20	6.40	5.20
40	C2R2-00	32.00	34.00	44.00	36.67
50	C2R2-10	4.40	4.80	6.40	5.20
60	C2R2-20	6.00	8.40	4.80	6.40
70	C2R2-30	3.20	2.80	4.80	3.60
80	C2R3-00	19.60	20.80	19.60	20.00
90	C2R3-10	4.00	2.40	5.60	4.00
100	C2R3-20	2.80	0.80	0.40	1.33
110	C2R3-30	0.80	0.80	0.80	0.80
120	C2R4-00	53.60	54.00	69.20	58.93

Overall Run		Influent Concentration (mg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average
0	C2R1-IN	308.00	325.20	311.20	314.80
40	C2R2-IN	406.80	402.80	291.60	367.07
80	C2R3-IN	276.40	337.20	349.60	321.07
120	C2R4-IN	294.00	342.80	292.00	309.60
160	C2R5-IN	308.40	338.40	294.00	313.60
230	C2R6-IN	311.60	303.20	316.00	310.27
				average =	322.73
	removal =	95.52%			

130	C2R4-10	6.40	8.40	6.00	6.93
140	C2R4-20	4.80	4.00	4.00	4.27
150	C2R4-30	2.40	2.00	2.24	2.21
160	C2R5-00	28.80	34.00	38.80	33.87
170	C2R5-10	3.60	3.20	2.40	3.07
180	C2R5-20	2.40	3.60	3.20	3.07
190	C2R5-30	6.40	9.60	7.60	7.87
200	C2R5-50	3.20	4.40	3.20	3.60
230	C2R6-00	11.60	12.80	20.80	15.07
240	C2R6-10	3.60	5.60	3.60	4.27
250	C2R6-20	0.80	0.40	3.20	1.47
260	C2R6-30	1.20	0.80	5.60	2.53
				average =	14.45

Column 3 - Sand/Clay/Compost

Overall Run		Effluent Concentration (mg/L)					Overall Run		Influent Concentration (mg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Time (min)	Sample ID	sample a	sample b	sample c	average
0	C3R1-00	63.20	56.80	159.20	93.07		0	C3R1-IN	294.00	344.00	304.40	314.13
10	C3R1-10	128.00	109.60	130.00	122.53		40	C3R2-IN	300.80	292.80	279.20	290.93
20	C3R1-20	46.40	56.80	51.60	51.60		80	C3R3-IN	294.80	290.80	321.60	302.40
30	C3R1-30	26.00	30.40	28.80	28.40		120	C3R4-IN	268.00	281.60	473.20	340.93
40	C3R2-00	30.00	32.80	41.60	34.80		160	C3R5-IN	298.00	292.80	302.80	297.87
50	C3R2-10	4.80	6.80	11.20	7.60		230	C3R6-IN	288.40	303.20	309.60	300.40
60	C3R2-20	6.40	9.20	10.40	8.67		280	C3R7-IN	355.60	294.00	344.00	331.20
70	C3R2-30	4.80	10.00	4.80	6.53		320	C3R8-IN	406.40	400.80	340.80	382.67
80	C3R3-00	83.20	30.80	19.20	44.40		380	C3R9-IN	315.60	324.40	338.80	326.27
90	C3R3-10	8.00	8.80	5.20	7.33		430	C3R10-IN	272.80	329.60	310.00	304.13
100	C3R3-20	5.20	6.40	5.20	5.60		510	C3R11-IN	327.20	261.20	479.60	356.00
110	C3R3-30	5.60	4.40	4.00	4.67		570	C3R12-IN	543.60	753.20	596.00	630.93
120	C3R4-00	41.60	39.60	26.40	35.87		670	C3R13-IN	736.40	842.00	687.20	755.20
130	C3R4-10	6.80	8.00	6.00	6.93		760	C3R14-IN	554.80	843.60	569.20	655.87
140	C3R4-20	3.20	4.80	4.80	4.27		850	C3R15-IN	595.60	698.40	518.80	604.27
150	C3R4-30	2.80	2.00	2.00	2.27						average =	412.88
160	C3R5-00	42.80	32.40	31.60	35.60					avg. for overload =		661.57
170	C3R5-10	7.20	7.60	8.00	7.60							

180	C3R5-20	4.40	3.20	3.20	3.60							
190	C3R5-30	2.40	1.60	2.00	2.00			removal =	94.71%			
220	C3R5-60	2.00	1.60	2.40	2.00							
230	C3R6-00	17.60	18.40	34.40	23.47							
240	C3R6-10	5.60	8.00	10.00	7.87							
250	C3R6-20	5.20	5.60	6.00	5.60							
260	C3R6-30	2.00	4.00	4.00	3.33							
270	C3R6-40	6.80	9.20	6.00	7.33							
280	C3R7-00	129.20	131.20	130.80	130.40							
290	C3R7-10	200.80	189.60	201.20	197.20							
300	C3R7-20	38.00	47.20	44.00	43.07							
310	C3R7-30	42.00	38.40	35.60	38.67							
320	C3R8-00	40.80	50.00	42.00	44.27							
330	C3R8-10	12.40	16.40	26.00	18.27							
340	C3R8-20	8.40	8.80	9.20	8.80							
350	C3R8-30	5.60	7.20	15.20	9.33							
370	C3R8-50	9.20	10.00	12.00	10.40							
380	C3R9-00	40.80	40.40	36.80	39.33							
390	C3R9-10	8.00	9.20	12.80	10.00							
400	C3R9-20	6.80	9.60	16.00	10.80							
410	C3R9-30	6.40	6.00	4.80	5.73							
420	C3R9-40	4.80	8.80	5.20	6.27							
430	C3R10-00	29.20	33.20	48.00	36.80							
445	C3R10-15	8.80	11.60	13.20	11.20							
460	C3R10-30	10.00	11.60	11.20	10.93							
475	C3R10-45	8.80	8.80	8.40	8.67							
500	C3R10-70	10.40	11.60	12.00	11.33							
510	C3R11-00	18.40	20.00	28.80	22.40							
520	C3R11-10	4.40	6.00	6.00	5.47							
530	C3R11-20	4.80	7.20	6.40	6.13							
540	C3R11-30	6.40	10.40	6.80	7.87							
560	C3R11-50	6.80	8.00	7.20	7.33							
570	C3R12-00	19.60	23.20	31.20	24.67							
585	C3R12-15	5.20	10.00	10.00	8.40							
600	C3R12-30	3.60	8.00	8.00	6.53							

615	C3R12-45	7.60	9.20	8.40	8.40							
650	C3R12-80	5.60	4.00	4.80	4.80							
660	C3R12-90	6.40			6.40							
670	C3R13-00	34.00	39.20	65.60	46.27							
690	C3R13-20	7.60	8.80	11.20	9.20							
710	C3R13-40	10.40	18.40	16.40	15.07							
730	C3R13-60	13.60	19.20	15.60	16.13							
750	C3R13-80	14.00	15.60	14.40	14.67							
760	C3R14-00	20.80	21.60	29.20	23.87							
780	C3R14-20	6.80	9.20	6.80	7.60							
800	C3R14-40	8.00	8.00	8.00	8.00							
820	C3R14-60	8.00	9.60	7.60	8.40							
840	C3R14-80	7.60	12.00	9.20	9.60							
850	C3R15-00	28.00	27.20	53.60	36.27							
870	C3R15-20	8.80	12.40	12.00	11.07							
890	C3R15-40	7.60	8.00	10.40	8.67							
920	C3R15-70	9.20	10.00	10.80	10.00							
950	C3R15-100	13.20	13.20		13.20							
980	C3R15-130	9.20	11.60		10.40							
				avg.	21.82							

Field Column Influent (Highway Runoff) and Effluent Suspended Solids Concentrations

Overall Run Time (min)	Sample ID	Effluent Concentration (mg/L)			
		sample a	sample b	sample c	average
0.00	C4S1-00	257.60	ns	ns	257.60
10.00	C4S1-10	83.20	ns	ns	83.20
30.00	C4S1-30	29.60	ns	ns	29.60
50.00	C4S1-50	34.40	ns	ns	34.40
70.00	C4S1-70	28.80	ns	ns	28.80
80.00	C4S2-00	48.40	ns	ns	48.40
90.00	C4S2-10	50.80	ns	ns	50.80
110.00	C4S2-30	36.00	ns	ns	36.00
130.00	C4S2-50	29.60	ns	ns	29.60
150.00	C4S2-70	31.20	ns	ns	31.20
160.00	C4S3-00	18.40	ns	ns	18.40
170.00	C4S3-10	21.60	ns	ns	21.60
190.00	C4S3-30	30.80	ns	ns	30.80
210.00	C4S3-50	22.40	ns	ns	22.40
230.00	C4S3-70	27.60	ns	ns	27.60
240.00	C4S4-00	4.80	ns	ns	4.80
250.00	C4S4-10	11.20	ns	ns	11.20
270.00	C4S4-30	6.80	ns	ns	6.80
290.00	C4S4-50	7.20	ns	ns	7.20
310.00	C4S4-70	9.20	ns	ns	9.20
320.00	C4S5-00		ns	ns	
330.00	C4S5-10		ns	ns	
350.00	C4S5-30		ns	ns	
370.00	C4S5-50		ns	ns	
390.00	C4S5-70		ns	ns	
				average storm 3 and 4=	16.00

Overall Run Time (min)	Sample ID	Influent Concentration (mg/L)			
		sample a	sample b	sample c	average
160.00	C4S3-00	381.00	ns	ns	381.00
170.00	C4S3-10	401.00	ns	ns	401.00
190.00	C4S3-30	126.00	ns	ns	126.00
210.00	C4S3-50	141.00	ns	ns	141.00
230.00	C4S3-70	189.00	ns	ns	189.00
240.00	C4S4-00	363.00	ns	ns	363.00
250.00	C4S4-10	377.00	ns	ns	377.00
270.00	C4S4-30	271.00	ns	ns	271.00
290.00	C4S4-50	173.00	ns	ns	173.00
310.00	C4S4-70	118.80	ns	ns	118.80
320.00	C4S5-00		ns	ns	
330.00	C4S5-10		ns	ns	
350.00	C4S5-30		ns	ns	
370.00	C4S5-50		ns	ns	
390.00	C4S5-70		ns	ns	
				average=	254.1

removal =	93.70%

Field Column Influent (Highway Runoff) Metal Concentrations

	Dissolved Copper							**Total Copper**			
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
160.00	C4S3-00:diss	15.82	ns	ns	15.82		C4S3-00:tot	25.55	ns	ns	25.55
170.00	C4S3-10:diss	15.40	15.32	15.46	15.39		C4S3-10:tot	31.13	30.84	30.55	30.84
190.00	C4S3-30:diss	17.77	ns	ns	17.77		C4S3-30:tot	29.81	ns	ns	29.81
210.00	C4S3-50:diss	16.33	ns	ns	16.33		C4S3-50:tot	29.51	ns	ns	29.51
230.00	C4S3-70:diss	16.29	ns	ns	16.29		C4S3-70:tot	35.18	ns	ns	35.18
240.00	C4S4-00:diss	15.42	ns	ns	15.42		C4S4-00:tot	42.80	ns	ns	42.80
250.00	C4S4-10:diss	15.26	15.26	ns	15.26		C4S4-10:tot	42.94	43.58	44.62	43.71
270.00	C4S4-30:diss	17.58	ns	ns	17.58		C4S4-30:tot	38.14	ns	ns	38.14
290.00	C4S4-50:diss	17.61	ns	ns	17.61		C4S4-50:tot	32.59	ns	ns	32.59
310.00	C4S4-70:diss	17.77	ns	ns	17.77		C4S4-70:tot	28.91	ns	ns	28.91
320.00	C4S5-00:diss		ns	ns			C4S5-00:tot	ns	ns	ns	
330.00	C4S5-10:diss		ns	ns			C4S5-10:tot	ns	ns	ns	
350.00	C4S5-30:diss		ns	ns			C4S5-30:tot	ns	ns	ns	
370.00	C4S5-50:diss		ns	ns			C4S5-50:tot	ns	ns	ns	
390.00	C4S5-70:diss		ns	ns			C4S5-70:tot	ns	ns	ns	
				average =	16.52					average =	33.70
	Dissolved Zinc							**Total Zinc**			
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
160.00	C4S3-00:diss	27.13	ns	ns	27.13		C4S3-00:tot	140.10	ns	ns	140.10
170.00	C4S3-10:diss	25.08	24.48	25.02	24.86		C4S3-10:tot	188.45	187.50	186.55	187.50
190.00	C4S3-30:diss	43.12	ns	ns	43.12		C4S3-30:tot	198.50	ns	ns	198.50
210.00	C4S3-50:diss	35.76	ns	ns	35.76		C4S3-50:tot	182.90	ns	ns	182.90
230.00	C4S3-70:diss	32.62	ns	ns	32.62		C4S3-70:tot	218.65	ns	ns	218.65
240.00	C4S4-00:diss	19.23	ns	ns	19.23		C4S4-00:tot	284.40	ns	ns	284.40
250.00	C4S4-10:diss	21.07	21.34	ns	21.21		C4S4-10:tot	274.90	279.20	289.20	281.10
270.00	C4S4-30:diss	13.28	ns	ns	13.28		C4S4-30:tot	246.20	ns	ns	246.20
290.00	C4S4-50:diss	34.88	ns	ns	34.88		C4S4-50:tot	227.50	ns	ns	227.50

310.00	C4S4-70:diss	25.98	ns	ns	25.98		C4S4-70:tot	160.70	ns	ns	160.70
320.00	C4S5-00:diss		ns	ns			C4S5-00:tot	ns	ns	ns	
330.00	C4S5-10:diss		ns	ns			C4S5-10:tot	ns	ns	ns	
350.00	C4S5-30:diss		ns	ns			C4S5-30:tot	ns	ns	ns	
370.00	C4S5-50:diss		ns	ns			C4S5-50:tot	ns	ns	ns	
390.00	C4S5-70:diss		ns	ns			C4S5-70:tot	ns	ns	ns	
				average =	27.81					average =	212.76
	Dissolved Lead							**Total Lead**			
Overall Run		Concentration (μg/L)						Concentration (μg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
160.00	C4S3-00:diss	9.74	ns	ns	9.74		C4S3-00:tot	14.20	ns	ns	14.20
170.00	C4S3-10:diss	11.35	11.31	11.27	11.31		C4S3-10:tot	17.16	17.41	17.01	17.19
190.00	C4S3-30:diss	10.81	ns	ns	10.81		C4S3-30:tot	15.80	ns	ns	15.80
210.00	C4S3-50:diss	9.85	ns	ns	9.85		C4S3-50:tot	16.99	ns	ns	16.99
230.00	C4S3-70:diss	9.92	ns	ns	9.92		C4S3-70:tot	20.44	ns	ns	20.44
240.00	C4S4-00:diss	9.75	ns	ns	9.75		C4S4-00:tot	35.16	ns	ns	35.16
250.00	C4S4-10:diss	9.61	9.61	ns	9.61		C4S4-10:tot	37.19	37.62	37.59	37.47
270.00	C4S4-30:diss	10.85	ns	ns	10.85		C4S4-30:tot	32.23	ns	ns	32.23
290.00	C4S4-50:diss	9.10	ns	ns	9.10		C4S4-50:tot	27.04	ns	ns	27.04
310.00	C4S4-70:diss	10.73	ns	ns	10.73		C4S4-70:tot	22.73	ns	ns	22.73
320.00	C4S5-00:diss		ns	ns			C4S5-00:tot	ns	ns	ns	
330.00	C4S5-10:diss		ns	ns			C4S5-10:tot	ns	ns	ns	
350.00	C4S5-30:diss		ns	ns			C4S5-30:tot	ns	ns	ns	
370.00	C4S5-50:diss		ns	ns			C4S5-50:tot	ns	ns	ns	
390.00	C4S5-70:diss		ns	ns			C4S5-70:tot	ns	ns	ns	
				average =	10.17					average =	23.92

Field Column Effluent Metal Concentrations

Column 4 - Field Column											
	Dissolved Copper						**Total Copper**				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C4S1-00:diss	6.67	ns	ns	6.67		C4S1-00:tot	11.99	ns	ns	11.99
10	C4S1-10:diss	6.27	ns	ns	6.27		C4S1-10:tot	9.32	ns	ns	9.32
30	C4S1-30:diss	5.73	ns	ns	5.73		C4S1-30:tot	7.93	ns	ns	7.93
50	C4S1-50:diss	5.72	ns	ns	5.72		C4S1-50:tot	7.77	ns	ns	7.77
70	C4S1-70:diss	6.12	ns	ns	6.12		C4S1-70:tot	9.27	ns	ns	9.27
80	C4S2-00:diss	3.78	ns	ns	3.78		C4S2-00:tot	5.14	ns	ns	5.14
90	C4S2-10:diss	3.62	ns	ns	3.62		C4S2-10:tot	5.47	ns	ns	5.47
110	C4S2-30:diss	3.73	ns	ns	3.73		C4S2-30:tot	5.36	ns	ns	5.36
130	C4S2-50:diss	3.71	ns	ns	3.71		C4S2-50:tot	5.27	ns	ns	5.27
150	C4S2-70:diss	3.68	ns	ns	3.68		C4S2-70:tot	5.38	ns	ns	5.38
160	C4S3-00:diss	14.73	ns	ns	14.73		C4S3-00:tot	9.15	ns	ns	9.15
170	C4S3-10:diss	14.51	14.44	14.43	14.46		C4S3-10:tot	9.15	10.07	9.36	9.52
190	C4S3-30:diss	14.42	ns	ns	14.42		C4S3-30:tot	9.38	ns	ns	9.38
210	C4S3-50:diss	15.28	ns	ns	15.28		C4S3-50:tot	10.73	ns	ns	10.73
230	C4S3-70:diss	16.08	ns	ns	16.08		C4S3-70:tot	11.58	ns	ns	11.58
240	C4S4-00:diss	14.61	ns	ns	14.61		C4S4-00:tot	9.35	ns	ns	9.35
250	C4S4-10:diss	14.79	14.70	14.76	14.75		C4S4-10:tot	9.49	9.49	9.54	9.50
270	C4S4-30:diss	14.3	ns	ns	14.3		C4S4-30:tot	8.79	ns	ns	8.79
290	C4S4-50:diss	14.51	ns	ns	14.51		C4S4-50:tot	9.00	ns	ns	9.00
310	C4S4-70:diss	14.93	ns	ns	14.93		C4S4-70:tot	9.65	ns	ns	9.65
320	C4S5-00:diss		ns	ns			C4S5-00:tot	ns	ns	ns	
330	C4S5-10:diss		ns	ns			C4S5-10:tot	ns	ns	ns	
350	C4S5-30:diss		ns	ns			C4S5-30:tot	ns	ns	ns	
370	C4S5-50:diss		ns	ns			C4S5-50:tot	ns	ns	ns	
390	C4S5-70:diss		ns	ns			C4S5-70:tot	ns	ns	ns	
				average =	9.86						8.48

Column 4 - Field Column											
	Dissolved Zinc						Total Zinc				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C4S1-00:diss	4.35	ns	ns	4.35		C4S1-00:tot	15.43	ns	ns	15.425
10	C4S1-10:diss	7.3	ns	ns	7.3		C4S1-10:tot	13.36	ns	ns	13.36
30	C4S1-30:diss	12.25	ns	ns	12.25		C4S1-30:tot	17.89	ns	ns	17.89
50	C4S1-50:diss	15.28	ns	ns	15.28		C4S1-50:tot	21.52	ns	ns	21.52
70	C4S1-70:diss	17.58	ns	ns	17.58		C4S1-70:tot	27.91	ns	ns	27.91
80	C4S2-00:diss	4.74	ns	ns	4.74		C4S2-00:tot	10.00	ns	ns	10.00
90	C4S2-10:diss	4.34	ns	ns	4.34		C4S2-10:tot	11.70	ns	ns	11.70
110	C4S2-30:diss	4.13	ns	ns	4.13		C4S2-30:tot	10.59	ns	ns	10.59
130	C4S2-50:diss	4.14	ns	ns	4.14		C4S2-50:tot	10.85	ns	ns	10.85
150	C4S2-70:diss	4.39	ns	ns	4.39		C4S2-70:tot	12.54	ns	ns	12.54
160	C4S3-00:diss	4.84	ns	ns	4.84		C4S3-00:tot	7.59	ns	ns	7.59
170	C4S3-10:diss	4.91	4.53	4.91	4.78		C4S3-10:tot	10.79	10.07	11.80	10.88
190	C4S3-30:diss	6.17	ns	ns	6.17		C4S3-30:tot	11.59	ns	ns	11.59
210	C4S3-50:diss	12.57	ns	ns	12.57		C4S3-50:tot	17.94	ns	ns	17.94
230	C4S3-70:diss	17.29	ns	ns	17.29		C4S3-70:tot	27.68	ns	ns	27.68
240	C4S4-00:diss	3.85	ns	ns	3.85		C4S4-00:tot	8.55	ns	ns	8.55
250	C4S4-10:diss	3.16	2.80	2.85	2.94		C4S4-10:tot	8.71	9.16	8.99	8.95
270	C4S4-30:diss	2.23	ns	ns	2.23		C4S4-30:tot	6.95	ns	ns	6.95
290	C4S4-50:diss	3.67	ns	ns	3.67		C4S4-50:tot	15.15	ns	ns	15.15
310	C4S4-70:diss	6.6	ns	ns	6.60		C4S4-70:tot	11.67	ns	ns	11.67
320	C4S5-00:diss		ns	ns			C4S5-00:tot	ns	ns	ns	
330	C4S5-10:diss		ns	ns			C4S5-10:tot	ns	ns	ns	
350	C4S5-30:diss		ns	ns			C4S5-30:tot	ns	ns	ns	
370	C4S5-50:diss		ns	ns			C4S5-50:tot	ns	ns	ns	
390	C4S5-70:diss		ns	ns			C4S5-70:tot	ns	ns	ns	
				average =	7.172					average =	13.9348

Column 4 - Field Column											
	Dissolved Lead						Total Lead				
Overall Run		Concentration (µg/L)						Concentration (µg/L)			
Time (min)	Sample ID	sample a	sample b	sample c	average		Sample ID	sample a	sample b	sample c	average
0	C4S1-00:diss	0.7	ns	ns	0.7		C4S1-00:tot	5.31	ns	ns	5.31
10	C4S1-10:diss	0.2	ns	ns	0.2		C4S1-10:tot	1.13	ns	ns	1.13
30	C4S1-30:diss	0.04	ns	ns	0.04		C4S1-30:tot	0.60	ns	ns	0.60
50	C4S1-50:diss	0.16	ns	ns	0.16		C4S1-50:tot	0.59	ns	ns	0.59
70	C4S1-70:diss	0.21	ns	ns	0.21		C4S1-70:tot	1.01	ns	ns	1.01
80	C4S2-00:diss	1.29	ns	ns	1.29		C4S2-00:tot	1.79	ns	ns	1.79
90	C4S2-10:diss	0.26	ns	ns	0.26		C4S2-10:tot	2.07	ns	ns	2.07
110	C4S2-30:diss	0.54	ns	ns	0.54		C4S2-30:tot	2.08	ns	ns	2.08
130	C4S2-50:diss	0.15	ns	ns	0.15		C4S2-50:tot	1.91	ns	ns	1.91
150	C4S2-70:diss	0.09	ns	ns	0.09		C4S2-70:tot	2.03	ns	ns	2.03
160	C4S3-00:diss	8.55	ns	ns	8.55		C4S3-00:tot	4.74	ns	ns	4.74
170	C4S3-10:diss	8.39	8.38	8.37	8.38		C4S3-10:tot	4.84	4.91	4.90	4.88
190	C4S3-30:diss	8.42	ns	ns	8.42		C4S3-30:tot	4.75	ns	ns	4.75
210	C4S3-50:diss	8.53	ns	ns	8.53		C4S3-50:tot	4.96	ns	ns	4.96
230	C4S3-70:diss	8.52	ns	ns	8.52		C4S3-70:tot	5.31	ns	ns	5.31
240	C4S4-00:diss	8.47	ns	ns	8.47		C4S4-00:tot	4.87	ns	ns	4.87
250	C4S4-10:diss	8.60	8.58	8.59	8.59		C4S4-10:tot	4.71	4.60	4.56	4.62
270	C4S4-30:diss	8.46	ns	ns	8.46		C4S4-30:tot	4.72	ns	ns	4.72
290	C4S4-50:diss	8.38	ns	ns	8.38		C4S4-50:tot	4.54	ns	ns	4.54
310	C4S4-70:diss	8.33	ns	ns	8.33		C4S4-70:tot	4.72	ns	ns	4.72
320	C4S5-00:diss		ns	ns			C4S5-00:tot	ns	ns	ns	
330	C4S5-10:diss		ns	ns			C4S5-10:tot	ns	ns	ns	
350	C4S5-30:diss		ns	ns			C4S5-30:tot	ns	ns	ns	
370	C4S5-50:diss		ns	ns			C4S5-50:tot	ns	ns	ns	
390	C4S5-70:diss		ns	ns			C4S5-70:tot	ns	ns	ns	
				average =	4.41					average =	3.33

Laboratory Column Percent Metal Concentration Reduction

Column 1 - Copper	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	59.98	1050.75	7.51	16.82	87.47%	98.40%
2	48.90	983.00	15.16	32.56	68.99%	96.69%
3	39.85	1022.67	25.03	57.30	37.18%	94.40%
4	49.34	904.83	14.82	36.26	69.96%	95.99%
5	41.25	974.67	33.05	114.23	19.89%	88.28%
6	47.26	914.17	9.92	26.36	79.01%	97.12%
7	53.50	896.67	26.99	84.30	49.56%	90.60%
8	49.68	905.00	13.92	35.26	71.98%	96.10%
9	51.48	980.67	28.10	95.27	45.41%	90.29%
10	57.97	959.67	18.59	75.08	67.93%	92.18%
11	48.79	898.33	11.27	23.32	76.90%	97.40%
				Avg.	61.30%	94.31%

Column 1 - Zinc	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	96.28	1811.50	11.22	26.38	88.35%	98.54%
2	116.80	2124.17	26.50	54.51	77.31%	97.43%
3	127.40	2317.83	36.80	86.98	71.11%	96.25%
4	96.77	1396.83	18.42	49.33	80.97%	96.47%
5	113.20	1925.17	60.67	119.59	46.40%	93.79%
6	77.00	1467.50	6.58	14.77	91.46%	98.99%
7	80.16	1387.67	24.02	75.37	70.04%	94.57%
8	113.43	1508.33	12.67	33.89	88.83%	97.75%
9	86.02	1482.00	27.13	83.77	68.47%	94.35%
10	57.97	1636.83	22.93	62.69	60.44%	96.17%
11	103.43	1599.17	8.30	26.80	91.98%	98.32%
				Avg.	75.94%	96.60%

Column 1 - Lead	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	57.62	909.25	3.20	6.61	94.45%	99.27%
2	45.22	905.33	10.15	19.49	77.56%	97.85%
3	50.71	968.67	19.33	35.60	61.88%	96.32%
4	62.39	851.50	10.15	23.08	83.72%	97.29%
5	50.59	903.83	24.22	48.63	52.13%	94.62%
6	48.98	912.67	6.39	18.25	86.95%	98.00%
7	56.14	830.67	15.20	49.61	72.92%	94.03%
8	52.00	893.67	6.92	20.91	86.70%	97.66%
9	54.38	937.83	11.92	48.68	78.09%	94.81%

10	42.84	914.17	7.88	35.83	81.60%	96.08%
11	56.83	892.17	4.39	13.14	92.27%	98.53%
				Avg.	78.93%	96.77%

Column 2 - Copper	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	84.92	936.83	0.00	5.58	100.00%	99.40%
2	48.30	903.17	0.00	3.07	100.00%	99.66%
3	75.82	948.50	4.34	18.55	94.28%	98.04%
4	42.67	975.17	6.62	12.55	84.50%	98.71%
5	46.36	928.67	8.09	30.40	82.55%	96.73%
6	45.26	922.50	0.49	4.13	98.92%	99.55%
				Avg.	93.37%	98.68%
Column 2 - Zinc	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	161.00	1644.50	1.31583	14.85375	99.18%	99.10%
2	90.30	1454.00	1.055	7.00125	98.83%	99.52%
3	130.60	1535.00	6.17417	17.02542	95.27%	98.89%
4	73.60	1723.17	1.6225	12.33542	97.80%	99.28%
5	72.85	1502.00	7.72267	21.57667	89.40%	98.56%
6	97.02	1501.17	3.55083	12.19833	96.34%	99.19%
				Avg.	96.14%	99.09%
Column 2 - Lead	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	96.88	906.17	1.02	4.22	98.94%	99.53%
2	48.83	910.00	0.16	1.83	99.68%	99.80%
3	74.99	909.50	4.58	13.25	93.89%	98.54%
4	45.90	1023.00	5.45	11.15	88.12%	98.91%
5	55.03	899.00	4.84	13.63	91.20%	98.48%
6	45.39	872.83	0.73	2.43	98.40%	99.72%
				Avg.	95.04%	99.17%

Column 3 - Copper	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	41.70	876.00	2.88	21.52	93.08%	97.54%
2	45.54	1047.50	2.04	14.67	95.53%	98.60%
3	40.36	1259.67	1.69	5.69	95.80%	99.55%

4	126.37	1046.33	1.32	5.81	98.95%	99.44%
5	46.54	971.50	2.06	11.15	95.57%	98.85%
6	49.14	965.67	1.24	8.03	97.47%	99.17%
7	89.45	902.83	20.88	41.75	76.66%	95.38%
8	46.52	910.17	7.34	15.70	84.22%	98.28%
9	60.29	914.83	8.43	15.38	86.01%	98.32%
10	57.64	996.50	5.71	10.58	90.10%	98.94%
11	42.50	861.50	4.40	11.75	89.66%	98.64%
12	58.86	3755.00	3.47	11.85	94.11%	99.68%
13	57.94	3851.67	5.95	18.05	89.73%	99.53%
14	61.68	3986.67	2.60	12.69	95.79%	99.68%
15	48.11	3804.17	6.25	9.03	87.01%	99.76%
				Avg.	91.31%	98.76%

Column 3 - Zinc	Average Influent Concentration (µg/L)		Peak Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	52.86	1766.83	0.58	16.61	98.90%	99.06%
2	87.56	2104.50	0.00	13.99	100.00%	99.34%
3	86.32	2458.83	0.00	2.40	100.00%	99.90%
4	78.71	2270.33	0.00	1.03	100.00%	99.95%
5	101.20	1882.50	3.92	9.10	96.13%	99.52%
6	91.33	1702.00	1.57	8.72	98.28%	99.49%
7	145.37	1448.67	5.48	21.52	96.23%	98.51%
8	95.00	1489.17	0.02	7.54	99.98%	99.49%
9	95.44	1531.17	3.32	9.88	96.52%	99.36%
10	71.97	1608.67	2.76	15.13	96.16%	99.06%
11	43.52	1378.33	1.54	16.97	96.46%	98.77%
12	45.1	5639.17	0.51	10.55	98.87%	99.81%
13	65.34	5752.50	0.94	10.05	98.57%	99.83%
14	80.94	6068.33	0.00	16.34	100.00%	99.73%
15	75.04	5792.50	2.47	8.56	96.71%	99.85%
				Avg.	98.19%	99.44%

Column 3 - Lead	Average Influent Concentration (µg/L)		Average Effluent Concentration (µg/L)		% Reduction	
Run	Dissolved	Total	Dissolved	Total	Dissolved	Total
1	36.51	864.83	2.44	5.84	93.31%	99.32%
2	46.02	954.00	1.72	5.94	96.26%	99.38%
3	40.08	1187.00	0.71	2.72	98.22%	99.77%
4	72.32	944.33	0.97	3.19	98.66%	99.66%
5	38.03	665.00	2.22	6.42	94.17%	99.03%
6	53.19	951.00	1.29	3.54	97.58%	99.63%
7	94.06	866.17	4.58	15.94	95.14%	98.16%
8	59.88	910.17	0.40	3.21	99.33%	99.65%

9	71.42	899.83	3.50	11.84	95.11%	98.68%
10	52.42	984.00	1.88	6.57	96.42%	99.33%
11	51.75	854.33	0.00	0.93	100.00%	99.89%
12	181.90	3650.00	0.00	1.38	100.00%	99.96%
13	134.53	3437.50	0.32	4.96	99.76%	99.86%
14	66.80	3806.67	0.00	5.75	100.00%	99.85%
15	92.91	3700.00	0.65	2.73	99.30%	99.93%
				Avg.	97.55%	99.47%

Multicomponent Isotherm Data

Column 1 - Sand Isotherm Data						
Sample	Ce (ug/L)			qe (mg/Kg)		
	cu	zn	pb	cu	zn	pb
stock:diss	802.60	3088.00	815.90	na	na	na
s-0	0.00	0.00	0.00	0.00	0.00	0.00
s-0.5	633.40	3069.00	500.50	33.84	3.80	63.08
s-1.0	613.10	3065.00	408.90	18.95	2.30	40.70
s-1.75	460.90	2982.00	231.50	19.53	6.06	33.39
s-1.75	595.50	3091.00	404.70	11.83	-0.17	23.50
s-1.75	593.20	3160.00	393.40	11.97	-4.11	24.14
s-1.75avg	549.87	3077.67	343.20	11.90	-2.14	23.82
s-2.5	462.50	2958.00	193.10	13.60	5.20	24.91
s-3.25	417.30	2930.00	148.40	11.86	4.86	20.54
s-4.0	407.90	2897.00	140.90	9.87	4.78	16.88
s-4.0	357.70	2814.00	119.80	11.12	6.85	17.40
s-4.0	357.70	2799.00	120.20	11.12	7.23	17.39
s-4.0avg	340.93	2881.33	40.45	77.24	27.31	73.50
s-5.0	388.70	2818.00	123.20	8.28	5.40	13.85
s-6.0	362.80	2687.00	92.88	7.33	6.68	12.05

Column 2 - Sand/Clay Isotherm Data						
Sample	Ce (ug/L)			qe (mg/Kg)		
	cu	zn	pb	cu	zn	pb
DDI	1.25	11.44	0.27	na	na	na
stock:tot	2370.00	3703.00	2131.00	na	na	na
stock:diss	2272.00	3564.00	1878.00	na	na	na
scm-0	0.00	0.00	0.00	0.00	0.00	0.00
sc-0.2	1855.00	3493.00	1374.00	208.50	35.50	252.00
sc-0.5	1459.00	3401.00	1000.00	162.60	32.60	175.60
sc-1.0avg	866.25	3238.00	354.60	140.58	32.60	152.34
sc-1.5	733.60	3116.00	44.61	102.56	29.87	122.23
sc-2.0	627.60	3157.00	95.42	82.22	20.35	89.13
sc-2.5avg	340.93	2881.33	40.45	77.24	27.31	73.50
sc-3.0	148.30	2576.00	7.08	70.79	32.93	62.36
sc-3.5avg	297.45	2730.00	24.57	56.42	23.83	52.96

Column 3 - Sand/Clay/Compost (SPRIB) Isotherm Data						
Sample	Ce (ug/L)			qe (mg/Kg)		
	cu	zn	pb	cu	zn	pb
Tap:tot	4.37	146.6	6.16	na	na	na
stock:tot	3667	5740	2767	na	na	na
stock:diss	2188	3539	1572	na	na	na
scm-0	0.0	0.0	0.0	0.0	0.0	0.00
scm-0.1	1732.0	3422.0	931.3	456.0	117.0	640.70
scm-0.2	1406.0	3387.0	576.2	391.0	76.0	497.90
scm-0.5avg	1013.3	3360.0	292.0	234.9	35.8	256.01
scm-0.75avg	665.05	3222.5	110.84	203.06	42.2	194.82
scm-1.0	429.1	2881	58.06	175.89	65.8	151.39
scm-1.6avg	1046.0	2269.7	502.5	282.3	64.3	379.53
scm-2.3	210.0	2671.0	14.7	86.0	37.7	67.71
scm-3.0	115.3	1992.0	4.0	90.1	67.3	68.18

Total Recoverable Metal Concentrations in Column Cores

Total Recoverable Metals Concentrations in Column Cores

Column 1 - Sand

Depth (inches	Copper Concentration (ug/g)			Zinc Concentration (ug/g)			Lead Concentration (ug/g)		
	Core A	Core B	Core C	Core A	Core B	Core C	Core A	Core B	Core C
top	465650	427050	228400	870500	874000	426400	452200	421700	231400
0 - 3	25065	3759.5	24270	46940	6005	40860	28335	4707.5	26465
3 - 6	2224.5	1814	3907.5	2766.5	2491	5095	2158	2067.5	3762
6 - 9	1477	1294	2228.5	437	417.5	1687.5	1341	1190	2074
9 - 12	1145	1012.5	1334.5	689	8.5	1131.5	1137.5	916.5	1214.5
12 - 15	2056.5	812.5	1113.5	1756	0	0	2041.5	722	1064.5
15 - 18	1035.5	819.5	1909.5	0	0	1047.5	998	726	1873

Depth (inches below	Averages Concentration			Standard Deviation			95% Confidence Interval		
	Copper	Zinc	Lead	Copper	Zinc	Lead	Copper	Zinc	Lead
top	373700	723633	368433	127305.0	257417.6	119650.2	144056.3	291289.6	135394.2
0 - 3	17698	31268	19836	12077.8	22088.9	13134.8	13667.0	24995.4	14863.2
3 - 6	2649	3451	2663	1109.3	1430.5	953.3	1255.3	1618.8	1078.7
6 - 9	1667	847	1535	495.2	727.7	472.9	560.4	823.4	535.1
9 - 12	1164	610	1090	161.8	565.7	154.7	183.1	640.1	175.0
12 - 15	1328	585	1276	649.0	1013.8	684.7	734.4	1147.2	774.8
15 - 18	1255	349	1199	577.2	604.8	599.3	653.1	684.4	678.2

Column 3 -SPRIB

Depth (inches below	Copper Concentration (ug/g)			Zinc Concentration (ug/g)			Lead Concentration (ug/g)		
	Core A	Core B	Core C	Core A	Core B	Core C	Core A	Core B	Core C
top	1212000	830000	1898500	1803000	1471000	2895000	1150500	878500	1804000
0 - 3	42180	16430	22140	78150	32190	53600	43350	18245	22575
3 - 6	4323.5	4486	3715	7150	6815	5640	4662.5	4554	3564.5
6 - 9	3200.5	2379	2478.5	4347.5	2166.5	2476	3476	2413.5	2532
9 - 12	2590.5	1720.5	2322.5	1811.5	730	2231	2504	1569	2093
12 - 15	1985.5	2165	1745	1441.5	1691.5	1394.5	1887	1877.5	1493.5
15 - 18	1457.5	1516.5	1848	307.5	947.5	1406	1547	1326	1447.5

Depth (inches below surface)	Averages Concentration			Standard Deviation			95% Confidence Interval		
	Copper	Zinc	Lead	Copper	Zinc	Lead	Copper	Zinc	Lead
top	1313500	2056333	1277667	541433.1	745035.1	475674.3	612677.0	843069.9	538265.5
0 - 3	26917	54647	28057	13523.2	22997.9	13420.2	15302.7	26024.0	15186.1
3 - 6	4175	6535	4260	406.4	793.0	605.0	459.9	897.3	684.7
6 - 9	2686	2997	2807	448.3	1180.0	582.2	507.3	1335.3	658.9
9 - 12	2211	1591	2055	445.6	774.4	468.6	504.2	876.4	530.3
12 - 15	1965	1509	1753	210.7	159.6	224.5	238.5	180.7	254.0
15 - 18	1607	887	1440	210.5	551.7	110.7	238.2	624.3	125.2