Assessing the feasibility of using permeable reactive barriers for phosphorus removal from stormwater

Spent lime treatment system

Prepared for
Ramsey-Washington Metro Watershed District
to fulfill the reporting requirements of the U.S. EPA 319 Grant

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1.0 Introduction

Engineers and scientists are currently faced with the challenge of finding innovative, effective, and environmentally friendly approaches that can meet lower phosphorus standards being promulgated in Minnesota and throughout the U.S. Traditional phosphorus removal approaches such as settling ponds and wetlands may not be capable of removing phosphorus from stormwater to the degree needed to meet phosphorus standards. These traditional settling approaches may not be able to remove small particles upon which the phosphorus is often concentrated in stormwater (Pilgrim, 2002). Other approaches have limitations—sand filters have the potential to clog (Barrett et. al., 2003); biological filter performance may be limited by season, temperature, and light availability (Dodds, 2003); and chemical treatment can generate substantial hydrated floc that eventually must be disposed (Pilgrim, 2002).

To effectively and permanently remove phosphorus, phosphate must be incorporated into recalcitrant organic material or be bound to cations such as calcium, magnesium, or unreducible trace metals such as aluminum. Spent lime is an abundant waste byproduct of drinking water treatment and the primary component of spent lime is calcium carbonate. Fortunately, calcium chemically prefers to be bound to phosphate over carbonate, and phosphate is readily converted into calcium phosphate in the presence of high concentrations of calcium carbonate (Stumm and Morgan, 1996). Spent lime has an advantage over limestone in that it consists of recently precipitated and hence more available calcium carbonate. The use of spent lime for stormwater treatment is a new concept. A treatment cell with spent lime is not precipitating or flocculating phosphate (e.g., like alum), and it is not necessarily intended to filter as do sand filters. Rather, it is a chemical "substitution" reaction whereby the newly formed calcium phosphate simply resides in the cell where the calcium carbonate once resided. There are several beneficial attributes of spent lime:

- A waste material—a "green" material that is also potentially free
- Rapid reaction time between phosphate and calcium means high treatment capacity
- High hydraulic conductivity; a treatment cell with spent lime can treat relatively large volumes of stormwater in a relatively small footprint
- Removes both particulate phosphorus and dissolved phosphorus (phosphate)
- Removes aluminum, calcium, iron, zinc, and lead from stormwater
- Can be used to adjust the pH of low pH water
- Easy maintenance consisting simply of annually mixing the lime in the cell to maintain the porosity and hydraulic conductivity of the spent lime and to expose new spent lime surfaces to stormwater

This document serves to fulfill the final reporting requirement of the Section 319-10 Nonpoint Source Management Grant (project ID # 7132) provided to the grantee (the Ramsey-Washington Metro Watershed District) by the State of Minnesota (Minnesota Pollution Control Agency). This grant provided funding to evaluate the capacity of spent lime to remove phosphorus from stormwater. This study included a laboratory evaluation and a pilot-scale study. Laboratory experiments were completed by spring 2011. The pilot scale study included the design and construction of a treatment cell that contained spent lime and treated stormwater runoff. The pilot scale treatment system was designed in 2011 and constructed in the fall of that year. The treatment system was operational in 2012 and 2013. Performance monitoring of the treatment system was conducted in 2012 and 2013.

2.0 Description of grant elements

The grant provided for a series of laboratory experiments and a pilot-scale field study. The laboratory study included column tests whereby stormwater was passed through different lime configurations (described in more detail in Section 4.0). Measurements taken for column-treated and untreated stormwater included: total phosphorus, total dissolved phosphorus, ortho-phosphate measured as soluble reactive phosphorus, total suspended solids, volatile suspended solids, pH, specific conductance, and one set of metals analysis (aluminum, calcium, copper, iron, lead, and zinc). The pilot-scale field study (Sections 5.0 and 6.0) included site identification, design, permitting, construction, and monitoring of a pilot-scale lime treatment cell. Monitoring included stormwater flow into and out of the cell, water level in the cell, water chemistry, and aquatic toxicity. All laboratory and field work was complete by December 2013.

3.0 Calcium phosphate chemistry

The primary components of spent lime (see Figure 3-1 for a photograph of spent lime) used in this study (from the St. Paul Water Utility) are water (59%), calcium (33%), magnesium (3.55%), aluminum (0.53%), and iron (0.51%). The mineral components are provided on a dry weight basis. The other component (not shown in Table 3-1) is carbonate, which is the corresponding anion to calcium and magnesium.

With respect to phosphorus removal, calcium carbonate is the primary and most abundant active ingredient. According to Stumm and Morgan, 1996, calcium will preferentially bind to phosphate with excess (high concentrations) calcite and pH near 7.0 or greater. Higher pH favors calcium phosphate formation for a given concentration of calcium carbonate (calcite).

Eq. 1: $10CaCO_3 + 2H^+ + 6(HPO_4)^{2-} + 2H_20 = Ca_{10}(PO_4)_6(OH)_{2(s)} + 10HCO_3^-$

The above reaction shows that the conversion of calcite to apatite (calcium phosphate) consumes acidity (H+). Hence, with an excess of calcite, the appropriate pH will be achieved to foster the formation of apatite. For a given stormwater volume, greater apatite formation should lead to greater acidity consumption and a more pronounced pH increase. Also, the reaction will increase the bicarbonate concentration for water (e.g., treated stormwater) in which this reaction occurs. An increase in bicarbonate is evidence that apatite is being formed.

Figure 3-1 Spent lime from the St. Paul Water Utility

Table 3-1 Composition of spent lime material from the St. Paul Water Utility

Parameter	Concentration (mg/kg dry weight)	Parameter	Concentration (mg/kg dry weight)
% Moisture	59.3	Magnesium	35,700
Aluminum	5,350	Manganese	115
Ammonia as N	74.4	Mercury	<0.046
Arsenic	<10.9	Molybdenum	<8.2
Barium	122	Nickel	116
Boron	<81.6	Nitrate as N	<7.4
Cadmium	<1.6	Total Phosphorus	117
Calcium	333,000	Potassium	<1350
Chloride	113	Selenium	<8.2
Chromium	184	Silver	<5.4
Copper	15.3	Sodium	<533
Cyanide	<1.3	Sulfate	<98.9
Iron	5,080	Total Kjeldahl Nitrogen	831
Lead	<10.9	Zinc	<10.9

4.0 Laboratory experiments

Laboratory experiments were conducted to help identify the key design parameters and constraints of the planned full-scale pilot treatment system that uses spent lime. Because spent lime has the consistency of partially dried clay, there was some initial concern about how the spent lime may hold up in a treatment cell. Focus was placed on finding some kind of binder that could create structure for the spent lime as well as control the rate of spent lime dissolution. Several experiments were conducted using mixtures of spent lime and organic polymers (binders) as well as simply using unmodified spent lime. The second aspect of these experiments was quantification of phosphorus removal as a function of contact time between stormwater and spent lime.

The following laboratory experiments were conducted:

1. Simple jar test with dried spent lime added to 1-liter jars with stormwater followed by rapid mixing for approximately five minutes (Figure 4-1). The purpose of this experiment was simply to confirm that spent lime can bind and remove phosphorus from stormwater.

2. Column test with a fixed flow-through rate of approximately 1.8 liters per hour and mixtures of lime and poly vinyl alcohol, poly acrylamide, Chemloc 411, polyacrylic acid, and polyvinyl alcohol.

3. Column test with a range of flow-through rates ranging from 0.1 to 1.8 liters per hour and dried lime that was *not* mixed with any binder.

4. Column test with a range of flow-through rates ranging from 0.2 to 1.0 liters per hour and dried lime that was *not* mixed with any binder and a layer of crushed limestone called CC17 on the bottom of the column to prevent breakthrough of lime into the collection jars (i.e., as a filtering media).

5. Column test with a range of flow-through rates ranging from 0.2 to 4.8 liters per hour and dried lime that was mixed with polyvinyl alcohol (lime to polymer mass ratio of about 3:1) and a layer of crushed limestone called CC17 on the bottom of the column to prevent breakthrough of lime into the collection jars.

6. Column test with a range of flow-through rates ranging from 0.15 to 5.0 liters per hour and dried lime that was mixed with polyvinyl alcohol (lime to polymer mass ratio of about 10:1) and a layer of crushed limestone called CC17 on the bottom of the column to prevent breakthrough of lime into the collection jars.

7. Column test with a range of flow-through rates ranging from 0.37 to 3.59 liters per hour and dried lime that was mixed with polyvinyl alcohol (lime to polymer mass ratio of about 6:1) and a layer of crushed limestone called CC17 on the bottom of the column to prevent breakthrough of lime into the collection jars.

8. Column test with a range of flow-through rates ranging from 0.2 to 4.3 liters per hour and dried lime that was *not* mixed with any binder and a layer of crushed limestone called CC17 on the bottom of the column to prevent breakthrough of lime into the collection jars (i.e., as a filtering media).

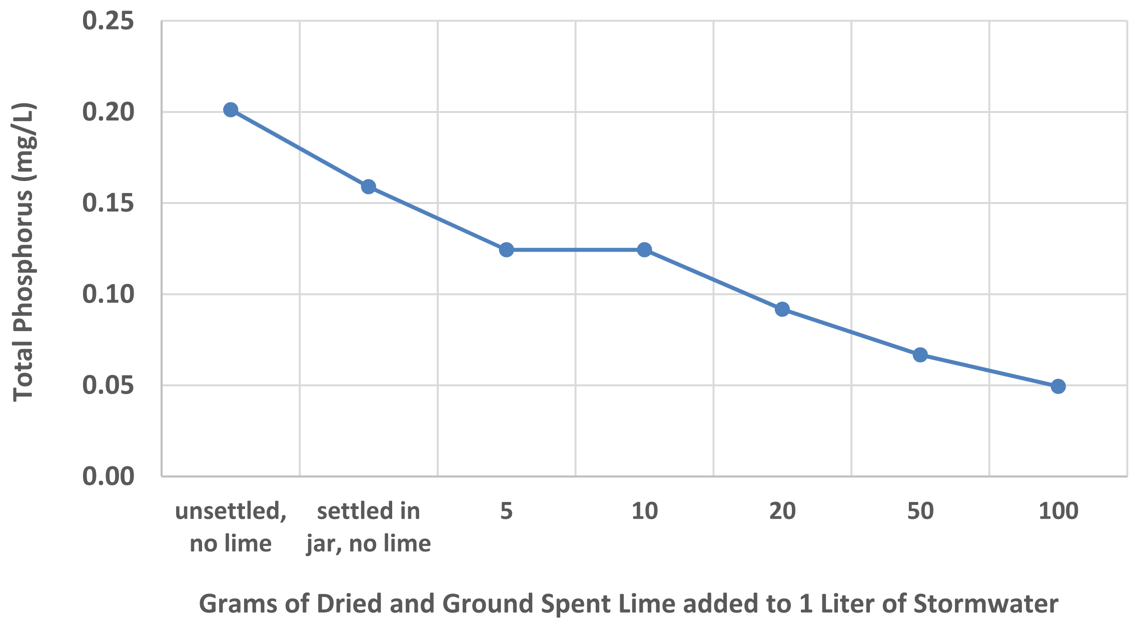


Figure 4-1 Results of jar tests conducted in 1-liter jars with stormwater and ground and dried spent lime added for treatment

The results of these tests are provided in Appendix A. Upon review of the column test results, it was concluded that mixing spent lime with some sort of binder did not provide any better control of treatment rates, and in some cases, it appears that the binder either inhibited or enhanced dissolution of spent lime in an unpredictable manner. The column experiments demonstrated that spent lime could be used to treat stormwater without a binder or any other type of pre-processing requirements. The following observations and conclusions were derived from the column tests:

- Spent lime is capable of removing a significant percentage of ortho-phosphate (measured as soluble reactive phosphorus) from stormwater; however, a treatment cell with spent lime may not be capable of removing particulate phosphorus.
- The hydraulic conductivity of spent lime is high even when wet and does not readily clog.

- The spent lime used in the column was dried, and hence, it may not be as reactive as spent lime that is not dried. (See Section 6.0 for pilot system monitoring results with undried spent lime.)
- Contact time appears to be a critical design parameter. Phosphorus removal increased with greater contact time. Greater contact time also led to a greater increase in the pH of treated stormwater. Hence, pH effects will need to be considered as part of the design process.

Because spent lime without the addition of a binder was capable of reducing soluble reactive phosphorus by greater than 80 percent in some of the tests (see Figure 4-2), it was concluded that spent lime would be used “as is” in the pilot-scale treatment cell.

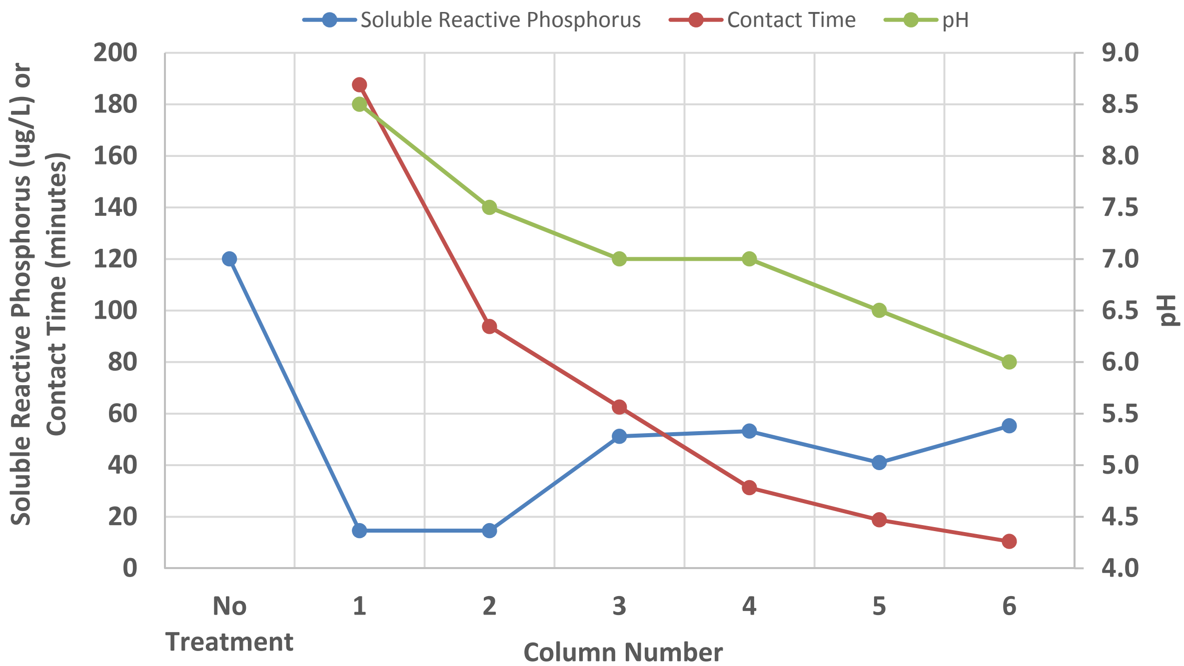


Figure 4-2 **Concentration of soluble reactive phosphorus and pH of water treated in columns loosely packed with spent lime. Test conducted on January 13, 2011, item number three in the list of laboratory studies above.**

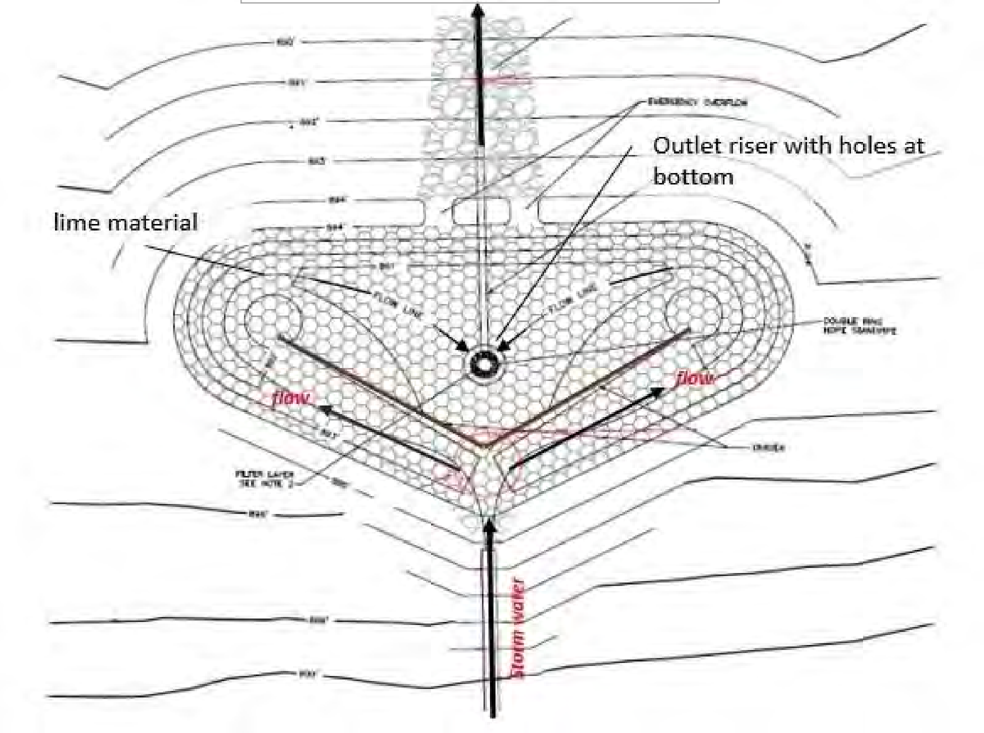
5.0 Pilot-scale spent lime barrier system design and construction

Using knowledge gained from the column experiments, a site was identified in the Ramsey Washington Metro Watershed District and a treatment cell (or barrier) was conceptually designed that would allow stormwater to contact spent lime in a controlled manner. Although it was originally envisioned that stormwater would pass through a sort of subsurface barrier with lime, the ultimate design of the system is more aptly described as a treatment cell. There were several key considerations with the design of the lime treatment cell:

- In order for phosphorus removal to occur, thorough and even contact between the spent lime material and storm water needs to occur.
- The contact time between stormwater and lime needed to be controlled to allow phosphorus removal but to minimize calcium carbonate dissolution and minimize the potential that the pH of treated stormwater would exceed water quality standards.
- The treatment system required enough head to facilitate rapid draining of the cell after the completion of each storm event.
- The treatment cell path was chosen to facilitate flow through the entire length of the treatment system.
- Easy access for maintenance.

Design drawings of the spent lime treatment cell are shown in Figure 5-1 and Appendix B. The plan view figure shows stormwater entering the cell and then splitting into two lobes of the cell, each lobe having a path of approximately 30 feet. The cell is filled with spent lime, and as soon as stormwater enters the cell, it beings to infiltrate through the spent lime material. The outlet consists of a riser (see side view in Figure 5-1) with 1-inch diameter holes beginning at the bottom (total of 12 holes) and extending about 1 foot upwards. As stormwater rises in the cell, it contacts the spent lime, and the higher the stormwater rises in the cell the greater the outflow rate.

Lime barrier plan view



Lime barrier side view

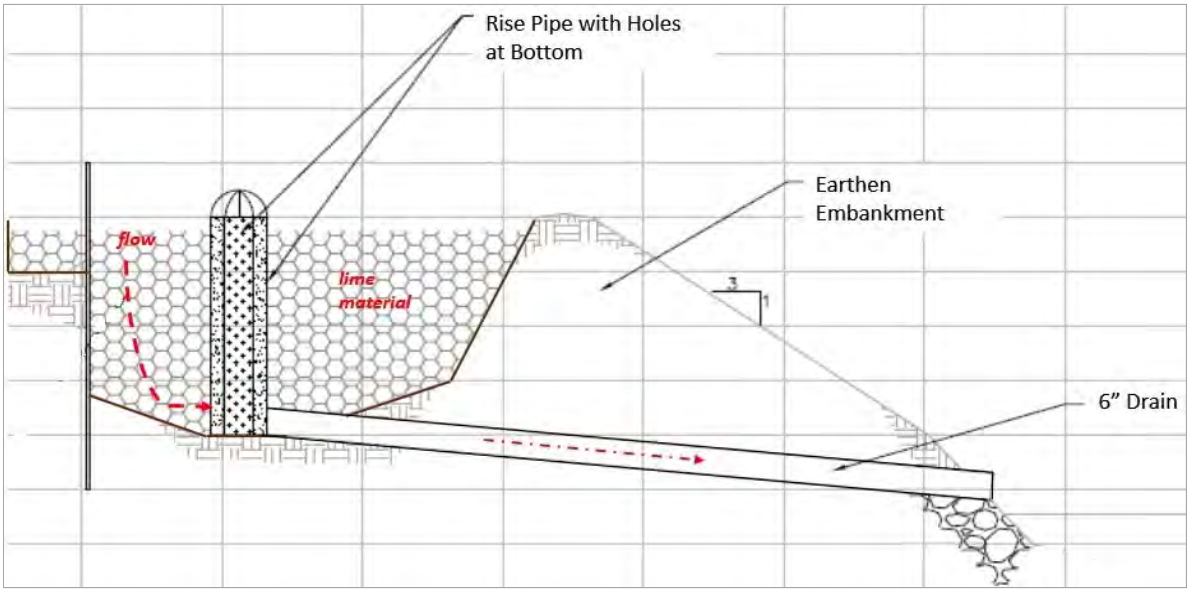


Figure 5-1 Conceptual design drawings of the permeable reactive barrier. Final design in Appendix B.

The surface area of the treatment cell at Larpenteur Avenue and Wakefield Lake (Maplewood, Minnesota) is 475 square feet, with a maximum depth of 3 feet and an average width of 7.9 feet for the entire cell. The elevation difference between the lime material surface and the elevation of the riser overflow outlet was approximately 3 inches; hence, there was minimal freeboard to allow ponding above the material. With these design dimensions, the maximum flow through the cell was around 1.0 cubic feet per second. More flow could have been pushed through the cell with a greater freeboard and ponding depth above the spent lime material.

The treatment cell was primarily earthen with wooden barriers to direct flow and minimize cell short circuiting (Figure 5-2). Figure 5-2 also shows the treatment cell with and without the placement of approximately 35 cubic yards of spent lime material. The lime, provided directly from the City of St. Paul Water Utility after dewatering in a belt press, was placed in the cell with a backhoe.

Annual maintenance has consisted of removal of accumulated material on the top of the cell and mixing the top 1-foot of the lime material with a shovel. Mixing takes about 1 to 2 hours. Other mixing tools may be useful such as a compost aeration tool. Rototillers have not been used successfully.

Figure 5-2 Spent lime treatment cell with and without spent lime. Riser pipe was installed after the photograph on the right was taken. The dark spots in the treatment cell are leaves.

6.0 Lime barrier monitoring results

6.1 Water quality

In 2012 and 2013, storm event water monitoring was conducted using an ISCO auto-sampler at the inlet and outlet (post treatment) of the spent lime cell. Area velocity meters were also installed to measure flow at the inlet and outlet, and a level sensor (In-Situ Level TROLL) placed within the treatment cell measured water level in the cell. Water samples from a total 13 storm events were collected from May 2012 through October 2013. Samples were not collected in the winter. Monitoring results for samples collected for chemical analysis are provided in Table 6-1 below and in Appendix C.

Although removal of ortho-phosphate was the intended target of the spent lime treatment system, the treatment system also removed particulate phosphorus as well as suspended solids. Removal of ortho-phosphate was high (74.4 percent), and the average concentration leaving the treatment cell was 0.031 mg/L. However, in 2012 the concentration of ortho-phosphorus in treated stormwater was <0.020 mg/L for nearly all storm events. It is likely that in 2013, several storms were large enough to bypass treatment through the top of the rise pipe and that the untreated water subsequently mixed with treated stormwater. This likely led to the appearance of reduced performance compared to 2012.

Table 6-1 Average concentration of several constituents in stormwater prior to and after treatment by the spent lime treatment cell

Parameter	Number of Storm Event Samples	Into Cell (untreated)	Out of Cell (treated)	% Removal
Total Phosphorus (mg/L)	13	0.360	0.124	65.6
Total Dissolved Phosphorus (mg/L)	11	0.151	0.054	63.9
Ortho Phosphate (mg/L)	12	0.121	0.031	74.4
Total Suspended Solids (mg/L)	12	117	50	57.1
Aluminum (mg/L)	13	2.41	1.03	57.2
Calcium (mg/L)	13	9.01	6.71	25.5
Iron (mg/L)	13	2.78	1.11	60.2
Lead (µg/L)	4	8.30	1.13	86.4
Zinc (µg/L)	4	97.1	32.6	66.4
Copper (µg/L)	4	19.7	13.5	31.4

It is estimated that 66 percent of the particulate phosphorus was also removed from stormwater. Any organic phosphorus that is captured by the cell as a particulate and subsequently decays into ortho-phosphate will likely be readily bound by calcium. This is an additional benefit of this system in that it is not likely that the treatment cell will be a net contributor of phosphorus during the lifetime of the cell. This is unlike many pond and wetland systems that eventually become net contributors of phosphorus at some point in the best management practice (BMP) lifecycle.

It is notable that the treatment system was also capable of removing metals. Aluminum, calcium, and iron were removed from stormwater even though these constituents were the primary chemical constituents of the spent lime material. There was also significant removal of lead, zinc, and copper. It is hypothesized that the high pH in the spent lime cell facilitates metal carbonate complex formation. These results suggest that spent lime may also be specifically used to control metals in runoff from highways and other roadways.

Examining the data provided in Appendix C, one can observe that for certain constituents the treatment cell appeared to behave differently in 2012—the year immediately following the placement of spent lime in the cell—compared to 2013. In 2012, the treatment cell removed predominantly dissolved otho-phosphorus while it removed very little particulate phosphorus. In that year, it did not appear that much TSS, calcium, aluminum, or iron were removed. It appears that in 2012, most of the calcium, aluminum, and iron entering the treatment cell was dissolved. In 2013, the treatment cell removed suspended solids, both total and dissolved phosphorus, calcium, aluminum, iron, copper, lead, and zinc. There was a strong correlation between total suspended solids and metals (i.e., calcium, aluminum, iron, copper, lead, and zinc) concentration. It is possible that the maintenance performed on the treatment system (see Figure 6-1) had the effect of changing the structure of the lime in the barrier, leading to greater filtration capacity. An additional hypothesis is that when the material was initially placed with the backhoe, the open spaces between lime chunks were large. After periods of wetting and drying, settling time, and mixing with maintenance, the pore spaces perhaps decreased, causing the lime to act as a better filter.

Figure 6-1 Maintenance of the treatment cell with the use of a shovel to mix the lime.

6.2 Aquatic toxicity

Because the spent lime material had not been previously used as a stormwater treatment medium, treated and untreated stormwater was collected during two storm events and tested in a laboratory for aquatic toxicity. Standard U.S. Environmental Protection Agency (EPA) methodologies were followed to test for chronic aquatic toxicity using a sensitive test species called *Ceriodaphnia dubia* (e.g., a zooplankton, often described as a water flea). For the May 21, 2012 test, mean young production (see Table 6-2 for definition) was greater for treated stormwater than for untreated stormwater. This indicates that the treated stormwater was slightly less toxic than the untreated stormwater. For the June 19, 2012 test, mean young production was lower for treated stormwater than for untreated stormwater. In both cases, however, the spent lime material did not produce unwanted toxic conditions in the treated stormwater. Overall, these tests suggest that the use of spent lime will not cause unintended aquatic toxicity in water receiving spent lime-treated stormwater as long as the contact time is maintained at an appropriate level.

Table 6-2 Results of chronic seven-day laboratory toxicity tests conducted with *Ceriodaphnia dubia* and stormwater collected at the inlet and the outlet of the spent lime treatment cell

Stormwater Sampling Date	Water Source	% Survival	Mean Young Production[1]	Average pH During Testing	Total Hardness (mg/L as $CaCO_3$)	Total Alkalinity (mg/L as $CaCO_3$)	Specific Conductance (µmhos/cm)
5/21/2012	Laboratory Control	90	18.7	7.42	104	88	227
	Stormwater In[2]	100	20.3	6.78	20	8	95
	Stormwater Out[3]	100	25.9	7.34	92	92	576
6/19/2012	Laboratory Control	100	17.7	7.59	112	84	222
	Stormwater In[2]	100	26.9	6.91	8	24	42
	Stormwater Out[3]	90	24.8	7.42	116	108	469

(1) **Mean young production** is the number *Ceriodaphnia dubia* neonates produced per female adult during the course of the test.

(2) **Stormwater In** is stormwater that enters the spent lime treatment cell.

(3) **Stormwater Out** is treated stormwater at the outlet of the spent lime treatment cell.

Toxicity testing conducted in accordance with US EPA methodologies (Short-Term Methods For Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013, October 2002).

6.3 Hydrology and hydraulics

According to Darcy's Law, flow through a medium such as spent lime is largely a function of the hydraulic conductivity of the media, hydraulic head, and flow path length. Hence, the dimensions of a treatment cell as well as the hydraulic conductivity of spent lime (discussed in more detail in Section 6.3.1) dictate the maximum flow-through capacity of the treatment cell as well as the water level in the cell at a given time during a storm event. The porosity and hydraulic conductivity of spent lime coupled with the cell dimensions determine contact time (Tc) between the stormwater and the lime.

Just prior to maintenance of the treatment cell in spring 2013, a core tube was pushed into the lime material of the spent lime cell and an intact core sample of lime was collected. The volume of the whole sample was estimated by the core dimensions and the depth of lime collected. The volume of the solids in the core sample was estimated by solids displacement of water when submerged in a graduated cylinder. The measurements were used to calculate the porosity of the material, which was 0.45. Porosity was needed to calculate contact time between water and spent lime in accordance with the following equation:

$$\boldsymbol{Eq.\,2}: Tc = \frac{A * D * n}{Q}$$

where:

Tc	=	contact time
A	=	L_cW_c
D	=	water depth in the cell
N	=	porosity of lime in the cell
Q	=	flow into the cell
Lc	=	cell length
Wc	=	average cell width

Hence, the dimensions of a treatment cell must be designed to facilitate maximum flow but also allow for enough contact time for calcium to react with ortho-phosphate. For the treatment cell constructed in the Ramsey-Washington Metro watershed (Maplewood), examples are provided below for the relationship between flow and water level in the treatment cell (Figure 6-2) as well as flow, water level, and contact time (Figure 6-3). The relationship between peak water level in the cell and flow will be different for the range of treatment cell designs that may be considered. The relationship below is applicable only to cells with the same dimensions and design as the one in this manuscript. Figure 6-3 shows that contact time changes throughout the course of each storm event. Contact time will vary also by storm event and the characteristic shape of the event (Table 6-3).

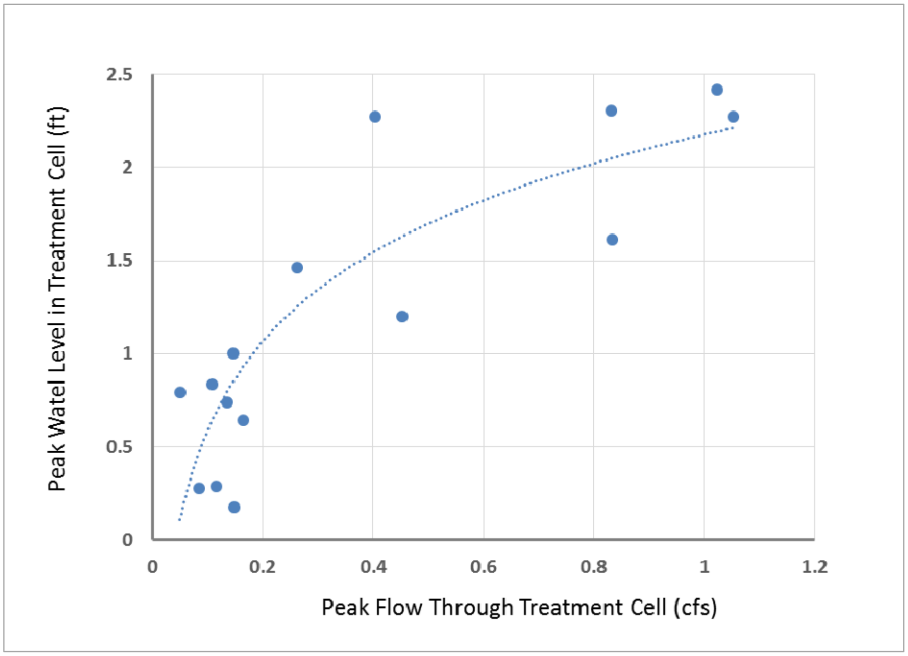


Figure 6-2 **Relationship between peak water level in the spent lime treatment cell and peak flow through the cell**

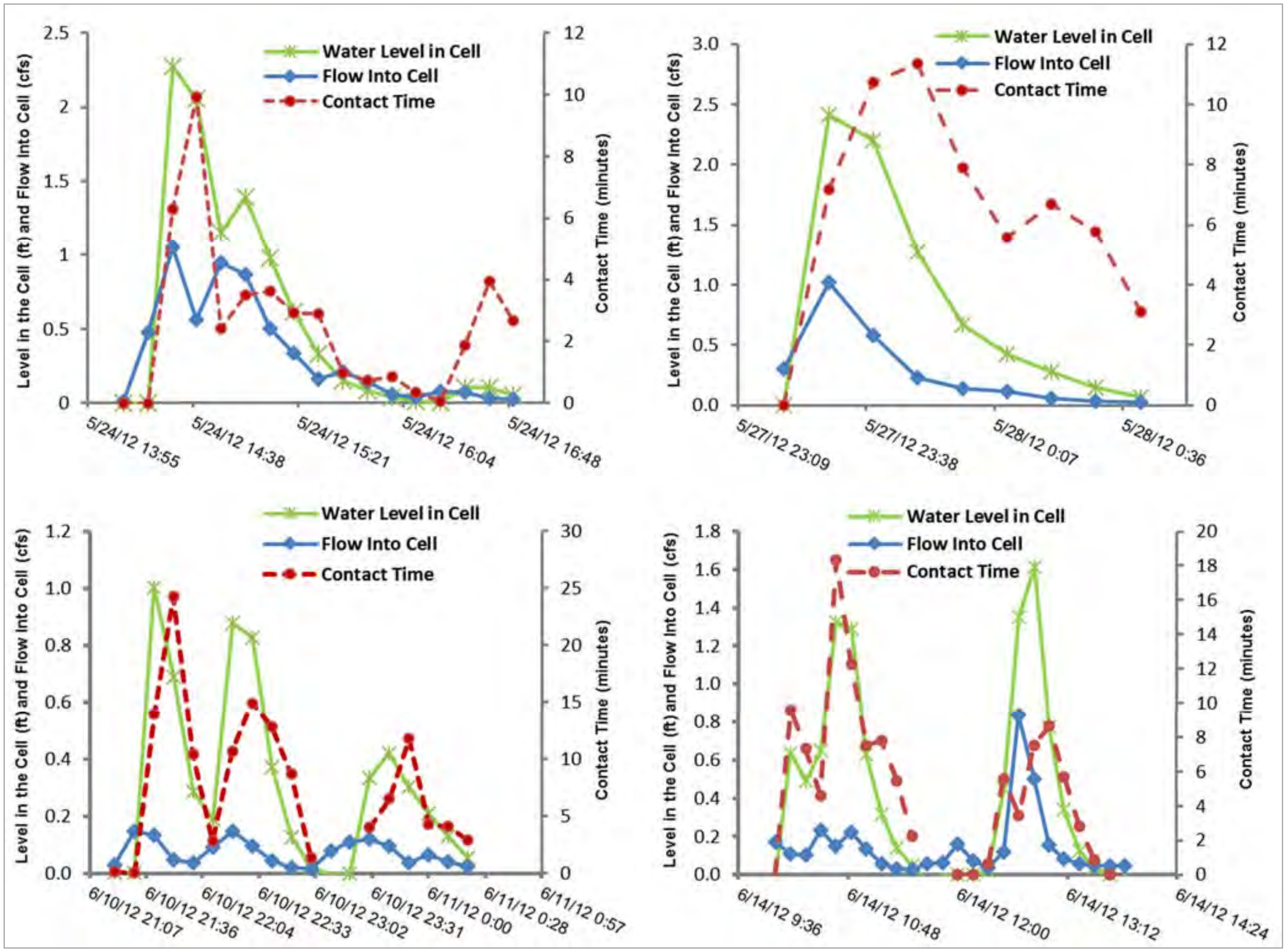


Figure 6-3 **For selected storm events, graphical examples of the relationship between measured water level in the spent lime cell, flow into the cell, and the contact time of the stormwater and the spent lime material in the cell**

Table 6-3 Hydrologic characteristics of the treatment cell for measured storm events in 2012

Storm Event Date	Water Quality Monitoring Date	Storm Event Length (h)	Flow (cfs) into Cell		Water Level (ft) in Cell		Contact Time (minutes)		
			Average	Peak	Average	Peak	Average	Maximum	Minimum
5/19/2012	5/21/2012	0.83	0.18	0.71	no data	no data	no data	no data	no data
5/24/2012	5/25/2012	2.33	0.34	1.05	0.62	2.27	2.86	9.93	0.05
5/26/2012	none	1.50	0.11	0.26	0.62	1.47	9.02	14.26	2.40
5/27/2012	none	1.33	0.28	1.02	0.83	2.42	7.29	11.35	3.11
6/10/2012	6/11/2012	3.00	0.07	0.15	0.31	1.00	7.86	24.27	0.03
6/14/2012	none	3.83	0.14	0.83	0.44	1.61	5.53	18.35	0.01
6/16/2012	none	2.67	0.08	0.14	0.33	0.74	5.60	10.99	0.03
6/18/2012	6/19/2012	2.00	0.09	0.40	0.52	2.27	8.48	38.37	1.02
7/3/2012	none	0.50	0.06	0.15	0.05	0.17	1.94	6.59	0.01
7/13/2012	none	0.50	0.20	0.45	0.70	1.20	9.53	17.19	5.39
7/18/2012	none	1.33	0.22	0.83	1.20	2.31	14.69	27.57	1.24
7/24/2012	none	1.50	0.06	0.09	0.14	0.28	3.42	7.73	0.31
7/28/2012	none	0.33	0.06	0.11	0.44	0.83	9.32	13.46	4.21
7/29/2012	none	4.83	0.09	0.16	0.36	0.64	6.49	13.73	1.12
8/15/2012	none	0.50	0.03	0.05	0.38	0.79	19.84	27.44	7.42
9/17/2012	none	0.67	0.07	0.12	0.09	0.29	1.80	4.57	0.01

*One storm event for July 13, 2012 was evaluated; the other events were omitted.

*Flow through the overflow outlet was likely on July 21, 2012 with peak flow of 2.18 cfs measured downstream of the treatment cell. This flow includes infiltrated stormwater as well as water that bypassed the lime barrier and discharged through the overflow outlet.

*Width of treatment cell as a function of depth in the cell is: width (ft) = 0.154*Depth^2+1.3*Depth+2.7177

*Effective cell length estimated to be 60 feet total including both sides of the cell.

*Porosity of the in-place spent lime is 0.45.

*The water quality monitoring date is the date at which samples were collected and recorded.

Table 6-3 shows that contact time varied widely by storm event and during each storm event. The average contact time was less than 20 minutes for storms in 2012, but the average more typically ranged from 5 to 10 minutes.

6.3.1 Hydraulic conductivity

Fluid flow through porous media can be described by Darcy's Law which requires estimates of the hydraulic conductivity of the porous media. For the pilot scale field study in Maplewood, MN, the water level within the cell was recorded along with the flow rate out of the treatment system. The hydraulic conductivity of the in-place spent lime material was estimated by creating a model based on Darcy's Law (Equation 3 below) and using the available hydraulic monitoring data.

$\boldsymbol{Eq.3}: Q = KiA$

where:

Q	=	flow at a given location within the cell (volume/time)
A	=	hW (distance^2)
h	=	water height at a given location within the cell (distance)
K	=	hydraulic conductivity (distance/time)
i	=	hydraulic gradient at a given location within the cell (unitless)
W	=	flow width parameter (circumference in polar coordinates), (distance)

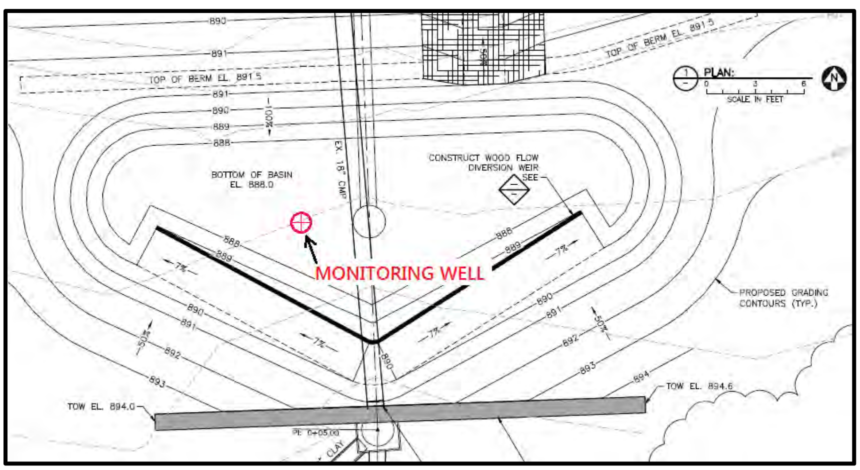


Figure 6-4 Construction plans for the spent lime treatment cell with the monitoring well location added

The model created is an unsteady model based on Darcy's Law in an unconfined, homogeneous porous media, in polar coordinates. The treatment cell system includes two inlets, divergent from each other, and one outlet in the center of the treatment cell (see Figure 6-5). The outlet is a 12-inch diameter hollow riser pipe with 12 1-inch diameter holes drilled in the wall near the bottom. The monitoring well was placed approximately 3 feet from the outlet riser pipe. The water surface within the spent lime material is assumed to be radially symmetric about the center of the outlet riser pipe. The model domain is between the water level sensor in the monitoring well and the wall of the outlet riser pipe. The upstream (outer) boundary condition is the measured water level at the monitoring well. The downstream (inner) boundary condition is a calculated flow rate through the holes drilled in the riser pipe using an orifice flow equation. This equation uses a flow area of 9.4 square inches (12 1-inch diameter holes), 0.6 for the flow coefficient, and the water level above the holes at the wall of the outlet riser pipe to determine the flow into the pipe (out of the model domain). Within the model domain, velocity and flow are based on the hydraulic gradient in the system. As discussed previously, the porosity of the spent lime material is estimated to be 0.45, based on lab results of a core taken from the treatment system.

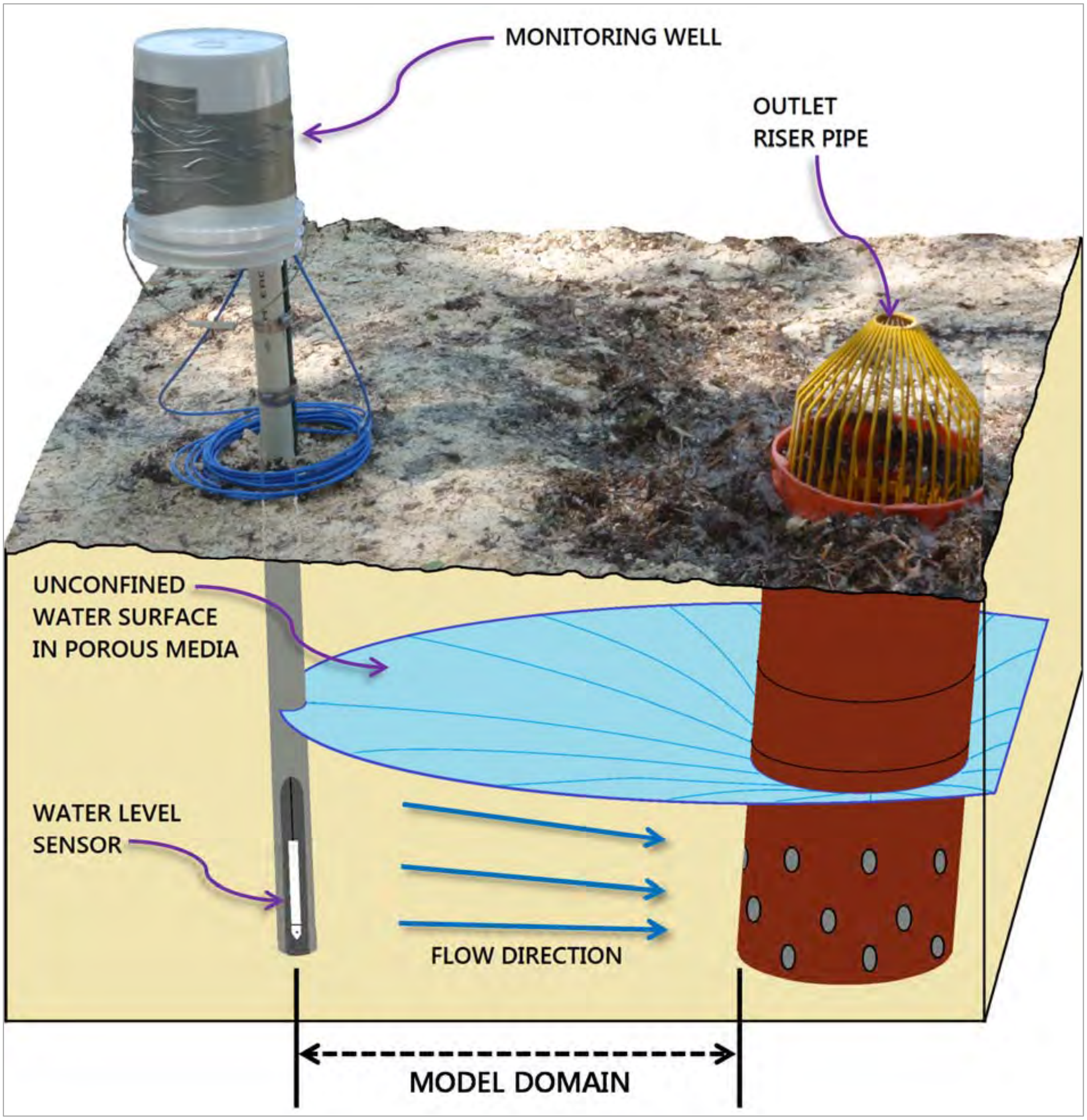


Figure 6-5 Schematic of the unconfined Darcy's Law model in polar coordinates including the actual monitoring well, outlet riser pipe, and spent lime material

Figure 6-6 shows a schematic of the developed model. The model was fixed at the upstream boundary by the measured water level. The flow leaving the system was calculated by the model and compared to the measured flow leaving the outlet riser pipe. The hydraulic conductivity was the unknown parameter that was modified to calibrate the model to the measured flow rate. If the hydraulic conductivity in the model was too high, the hydraulic gradient through the spent lime material would be shallow. If the upper boundary is fixed by the measured water level, the model would calculate a relatively high water level at the outlet riser pipe and therefore a relatively high flow rate leaving the riser pipe. Conversely, if the hydraulic conductivity in the model was too low, the hydraulic gradient through the spent lime material would be steep, and the model would calculate a relatively low water level at the outlet riser pipe and therefore a relatively low flow rate leaving the riser pipe. Multiple storm events are observed in both the water level data and flow data. A few storms were selected for calibration of the hydraulic conductivity, which included both high and low flow rates and water levels. The hydraulic conductivity value that best fit the measured data ranged from approximately 0.1 to 0.35 feet per second. Figure 6-7 through Figure 6-9 show the comparison of the model to the measured flow rate data. On the right side is the time-series flow data in gallons per minute compared to the model results. The red line shows the model results, and the black open circles are the measured flow rates. On the left side is the elevation of the modeled water surface (phreatic surface) at the point in time of the end of the red line. The hydraulic conductivity is critical for appropriate sizing of future treatment cells.

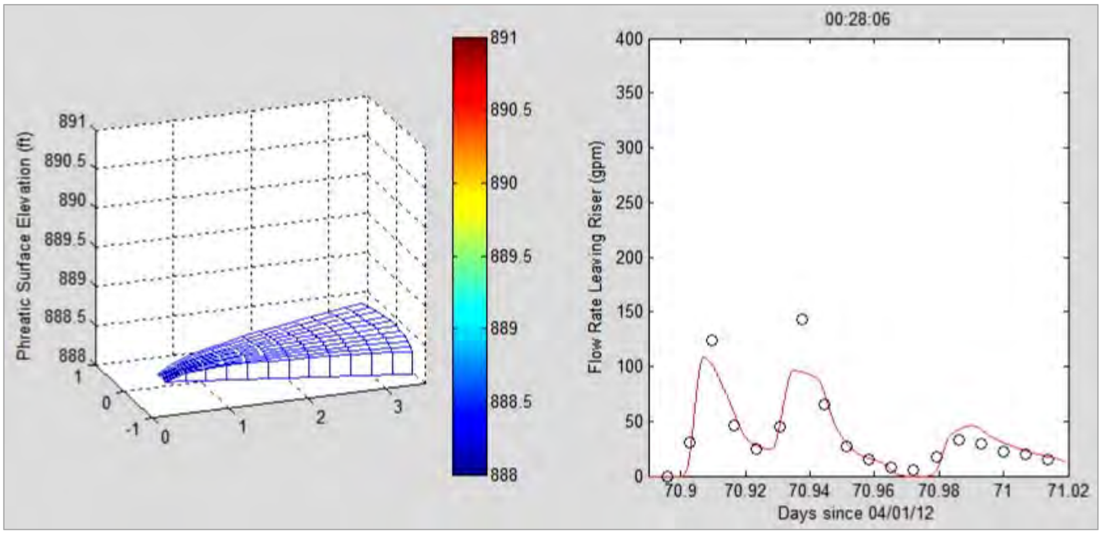


Figure 6-6 Model results compared to measured data around June 11, 2012

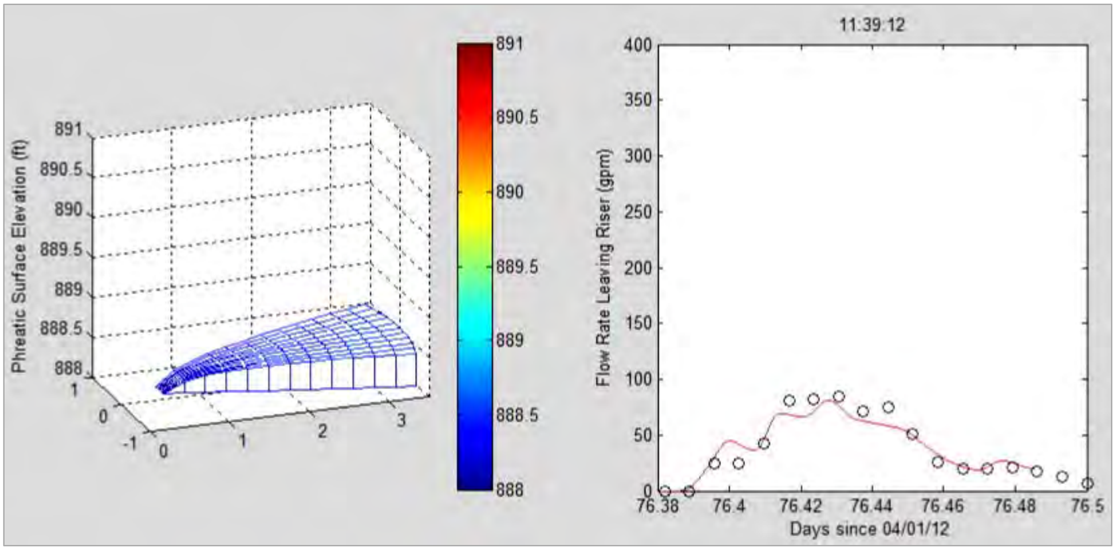


Figure 6-7 Model results compared to measured data around June 16, 2012

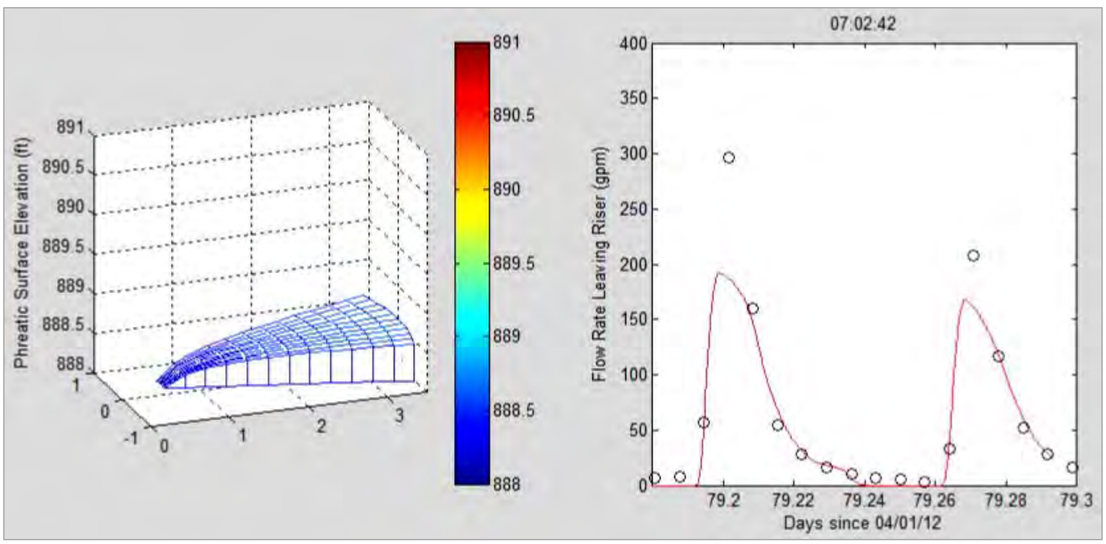


Figure 6-8 Model results compared to measured data around June 19, 2012

6.4 Sediment

Prior to initiation of this study, it was hypothesized that there may be some solid lime material or dissolved metals that may be transported out and subsequently downstream of the spent-lime cell. To evaluate the potential of downstream effects with the operation of the spent lime cell, sediment cores were taken in 2012 (two cores) and 2014 (four cores) in a pond that directly receives stormwater after treatment in the spent lime cell. Cores were sliced into 1 to 2 centimeter increments and analyzed for four phosphorus fractions (iron-bound phosphorus, calcium-bound phosphorus, aluminum-bound phosphorus, and organically bound phosphorus), aluminum, calcium, and iron (Appendix C). With respect to calcium-bound, aluminum-bound, and organically bound phosphorus, it does not appear that the operation of the spent lime treatment cell for two years had any notable effect on these phosphorus fractions. Mobile phosphorus increased; however, this is likely due to the reduced flow through the pond during this study (flows were diverted from all other sources except the treatment cell) that then also led to reduced washout of phosphorus from sediments. Decaying organic phosphorus was then converted to mobile phosphorus and mobile phosphorus built up on the sediments. Iron and aluminum was not higher in the sediments collected in 2014, while calcium was actually lower in the 2014 sediments. This seems reasonable, given that the lime treatment cell actually reduced aluminum, iron, and calcium concentrations in the treated stormwater.

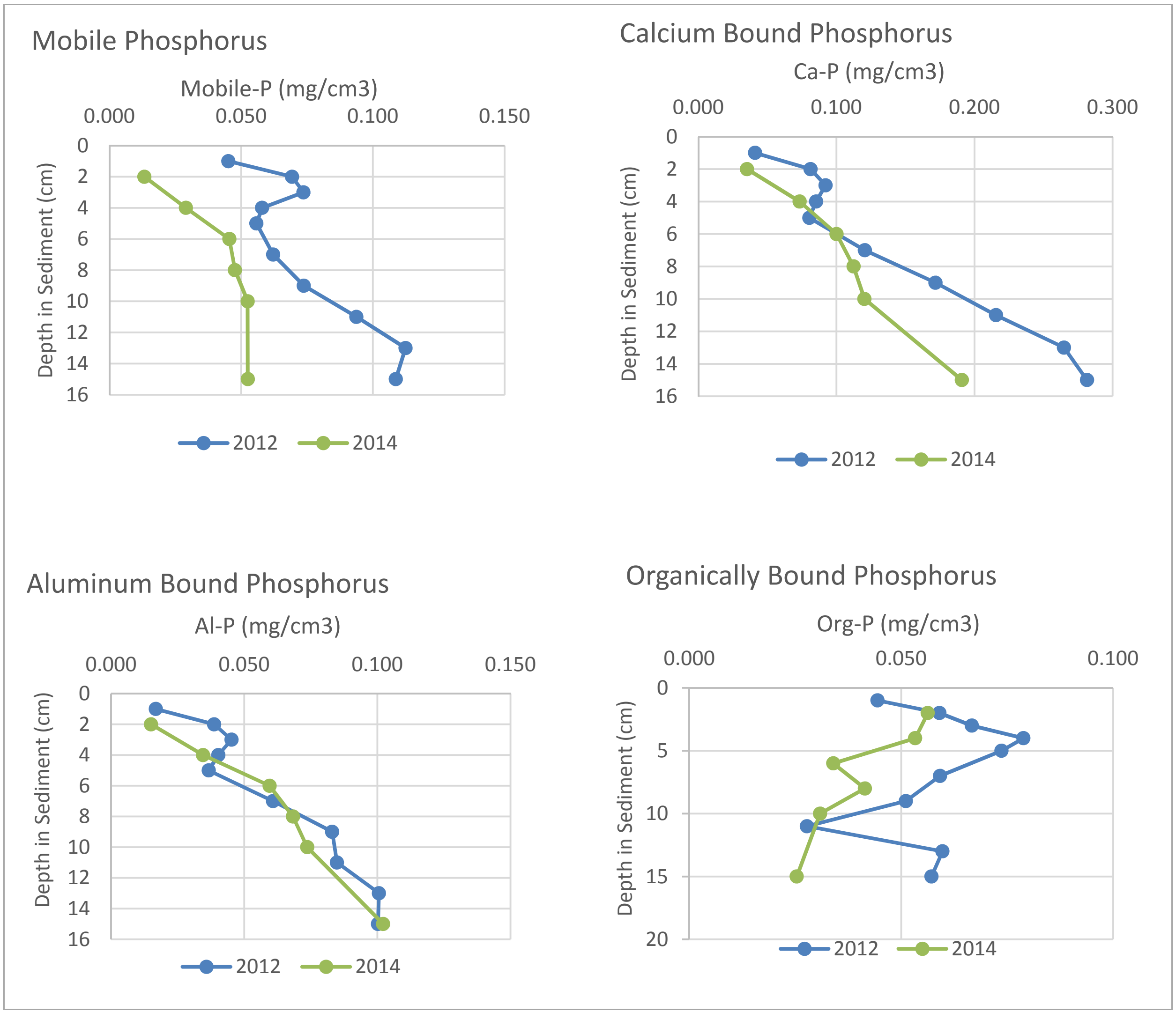


Figure 6-9 Phosphorus fractions in sediment collected in a pond downstream of the spent lime treatment cell

7.0 Conclusions and discussion

Spent lime, a byproduct of drinking water treatment, has properties enabling the material to bind or remove dissolved phosphorus (ortho-phosphate), particulate phosphorus, suspended solids, and metals. From monitoring data collected at a treatment cell with spent lime, it can be concluded that this material can remove phosphorus and metals to low levels, and in some cases, to levels below typical detection levels (ortho-phosphate). Based on aquatic toxicity tests using treated stormwater, it also appears that treated water will not be toxic to aquatic life if the treatment cells with spent lime are designed properly. The primary design parameters are hydraulic head and flow path length (cell length) and the condition that all water must drain out of the cell between storm events. Contact time between the spent lime and stormwater in the Maplewood, Minnesota, treatment cell varied throughout each storm event, with an average contact time of 5 to 10 minutes.

It is expected that spent lime can be used in a wide range of treatment designs and configurations. Future designs should consider the use of a pond or plunge pool to settle out sand, leaves, and sticks. This may help minimize the accumulation of material on the surface of the spent lime and also reduce the frequency of maintenance.

7.1 Acknowledgements

We would like to acknowledge the invaluable contribution of Cliff Aichinger, Eric Korte, and Dave Vlassen of the Ramsey-Washington Metro Watershed District in Saint Paul, Minnesota. Without Cliff Aichinger's willingness to test new and innovative stormwater treatment approaches, this project would not have occurred. Eric Korte and Dave Vlassen provided invaluable service in verifying that stormwater monitoring design and tasks were completed correctly.

8.0 References

Dodds, W. K. 2003. The role of periphyton in phosphorus retention in shallow freshwater aquatic systems. J. Phycol. Vol. 39. pp. 840-849.

Pilgrim, K. M. 2002. Evaluation of the potential benefits and adverse effects of alum treatment to remove phosphorus from lake inflows. Ph.D. Thesis. University of Minnesota.

Barrett, M. (2003). Performance, cost, and maintenance requirements of Austin sand filters. *J. Water Resour. Plann. Manage.*, 129(3), 234–242.

Stumm, W, and J. J. Morgan. 1996. Aquatic chemistry. Chemical equilibria and rates in natural waters. Third Edition. John Wiley and Sons.

U.S. Environmental Protection Agency. October 2002. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms.* EPA-812-R-02-013.

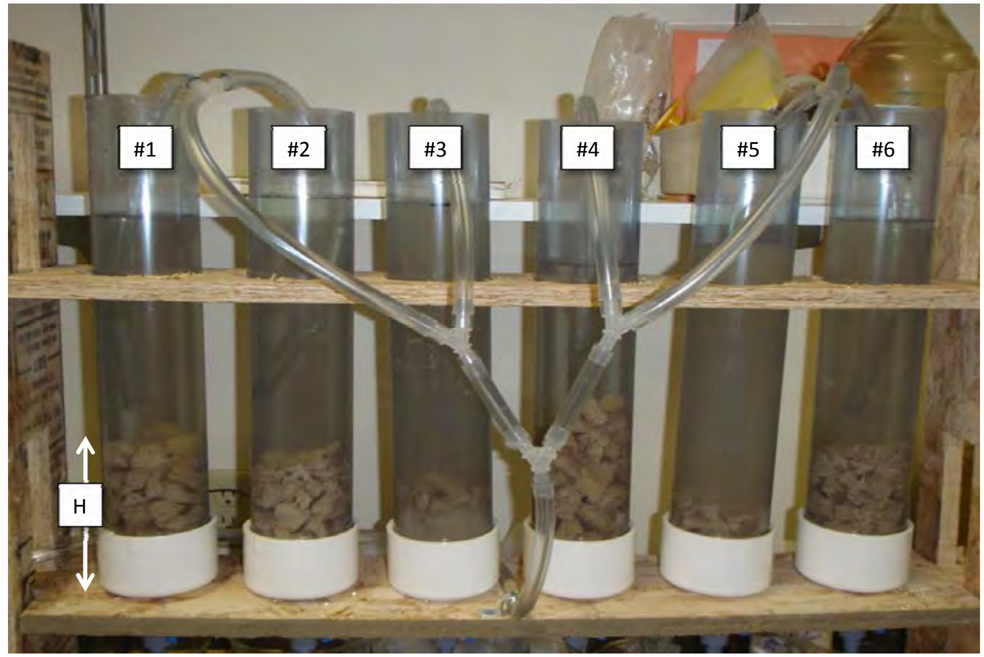
Appendices

Appendix A

Data from the laboratory column test study

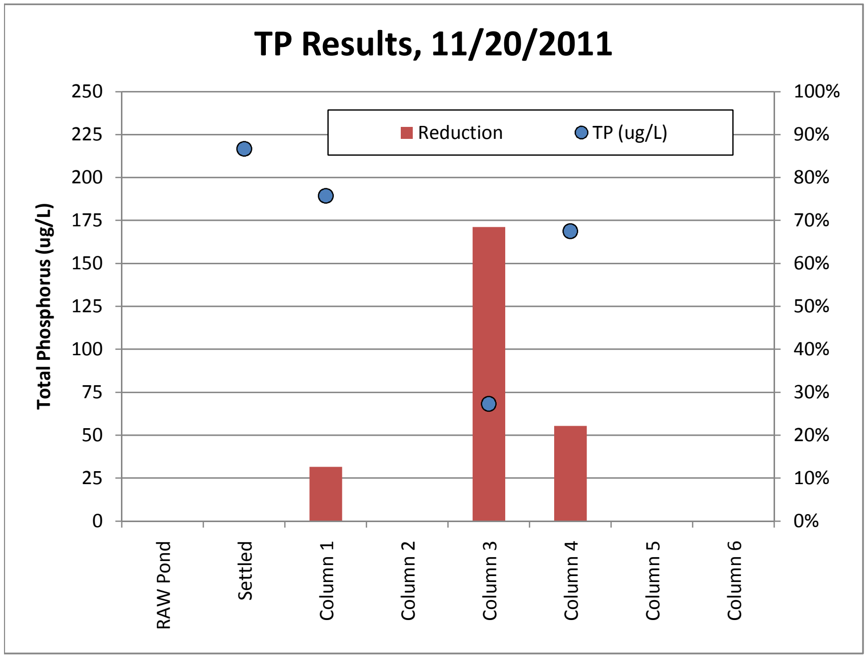
Test Details Test #1

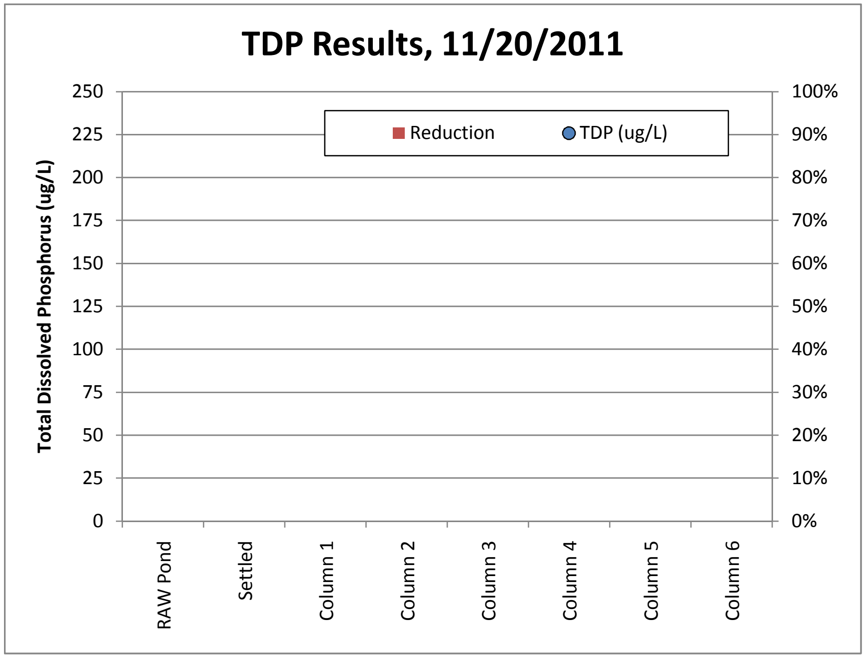
Test Date:	November 20, 2010	
Inner Diameter	*(in)*	3
Flow Area	*(in^2)*	7.07
RAW Pond Water TP	*(ug/L)*	N/A
RAW Pond Water TDP	*(ug/L)*	N/A
RAW Pond Water TRP	*(ug/L)*	N/A
RAW Pond Water SRP	*(ug/L)*	N/A
Settled TP	*(ug/L)*	217
Settled TDP	*(ug/L)*	N/A
Settled TRP	*(ug/L)*	136
Settled SRP	*(ug/L)*	34
Pond Water Turbidity	*(NTU)*	2.51
Pond Water pH	*(--)*	7

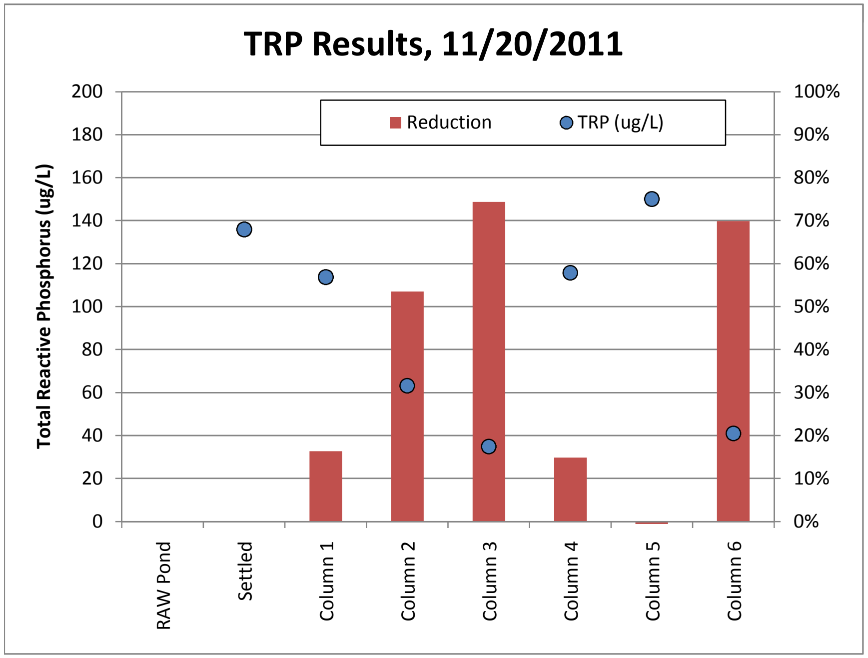


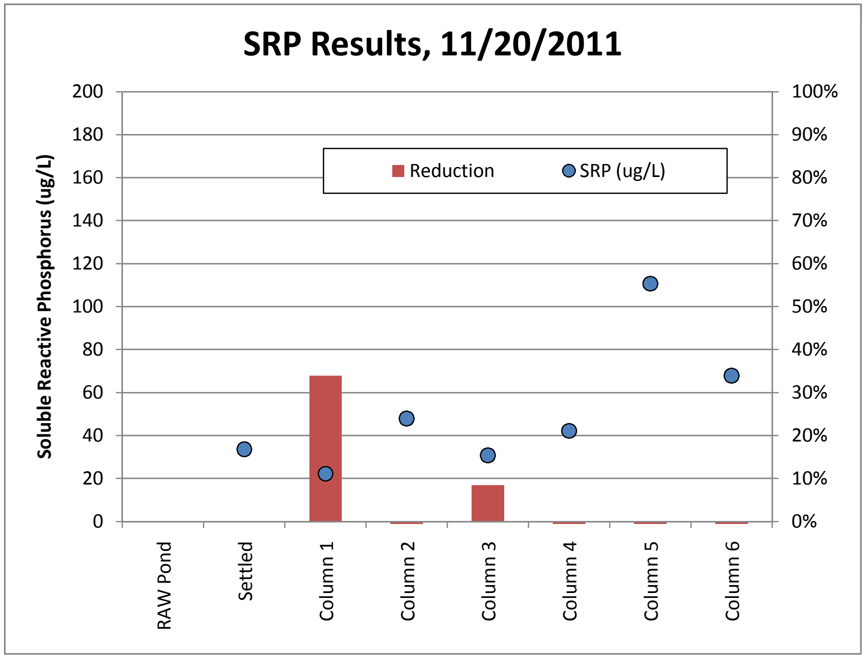
Variable	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Material	*(--)*	Dried Lime	PVA ~40,000	Poly Acrylamide	Chemloc 411	Polyacrylic Acid	PVA ~6,000
Mass into Column	*(g)*	300	320	400	330	240	340
Material Height	*(in)*	5.3	4.9	4.4	6.9	3.4	5.4
Time to 2 Liters	*(min)*	66.0	62.3	62.0	64.0	63.0	61.3
Flow Rate	*(L/hr)*	1.8	1.9	1.9	1.9	1.9	2.0
Flow Rate	*(gpm)*	8.01E-03	8.48E-03	8.52E-03	8.26E-03	8.39E-03	8.62E-03
Infiltration Rate	*(in/hr)*	15.7	16.6	16.7	16.2	16.4	16.9
Residence Time	*(min)*	20.3	17.7	15.8	25.6	12.4	19.2
Residual Mass	*(g)*	300	295	215	330	170	325
Lime:Polymer Ratio	*(X:1)*	N/A	2.98	1.12	4.14	4.05	3.03
Lime Delivery Rate	*(g/hr)*	0	24	179	0	67	15
Lime Delivery Rate	*(g/L)*	0	13	93	0	35	8
Dissolution Rate	*(%/hr)*	0%	8%	60%	0%	33%	4%

Final TP Conc.	*(ug/L)*	**189.3**	**N/A**	**68.3**	**168.8**	**N/A**	**N/A**
Final TDP Conc.	*(ug/L)*	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Final TRP Conc.	*(ug/L)*	**113.7**	**63.2**	**34.9**	**115.7**	**150.1**	**41.0**
Final SRP Conc.	*(ug/L)*	**22.2**	**47.9**	**30.8**	**42.2**	**110.7**	**67.9**
TP Reduction	*(%)*	**13%**	**0%**	**68%**	**22%**	**0%**	**0%**
TDP Reduction	*(%)*	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
TRP Reduction	*(%)*	**16%**	**54%**	**74%**	**15%**	**0%**	**70%**
SRP Reduction	*(%)*	**34%**	**0%**	**8%**	**0%**	**0%**	**0%**
Turbidity	*(NTU)*	2.72	18.9	231	2.07	582	32.3
pH	*(--)*	7	6	9	6	11	6


TP Results, 11/20/2011
Total Phosphorus (ug/L)
Reduction
TP (ug/L)
250
225
200
175
150
125
100
75
50
25
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

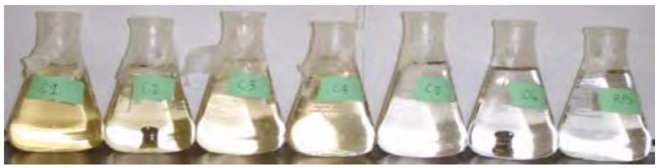

TDP Results, 11/20/2011
Total Dissolved Phosphorus (ug/L)
Reduction
TDP (ug/L)
250
225
200
175
150
125
100
75
50
25
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

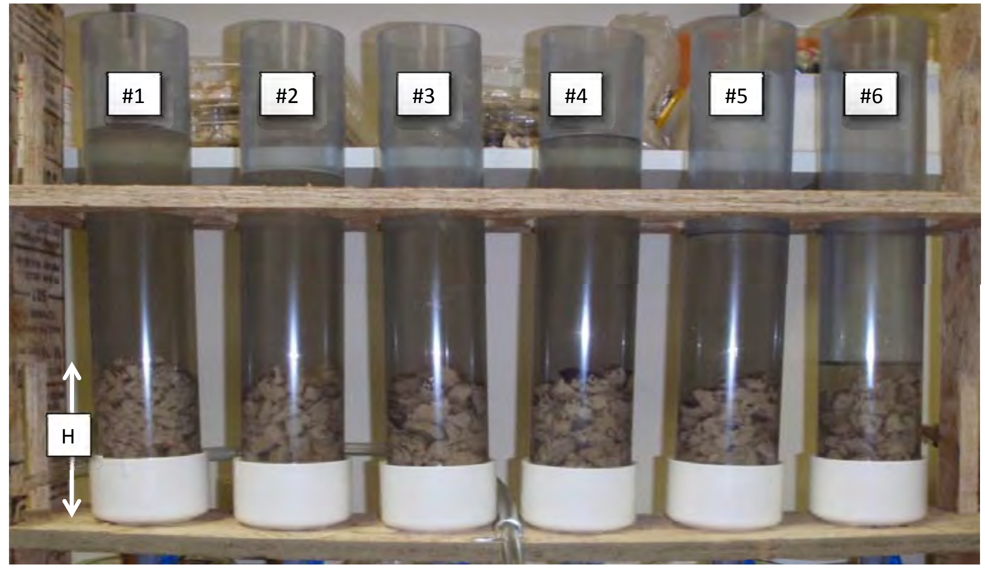

TRP Results, 11/20/2011
Total Reactive Phosphorus (ug/L)
Reduction
TRP (ug/L)
200
180
160
140
120
100
80
60
40
20
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


SRP Results, 11/20/2011
Soluble Reactive Phosphorus (ug/L)
Reduction
SRP (ug/L)
200
180
160
140
120
100
80
60
40
20
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

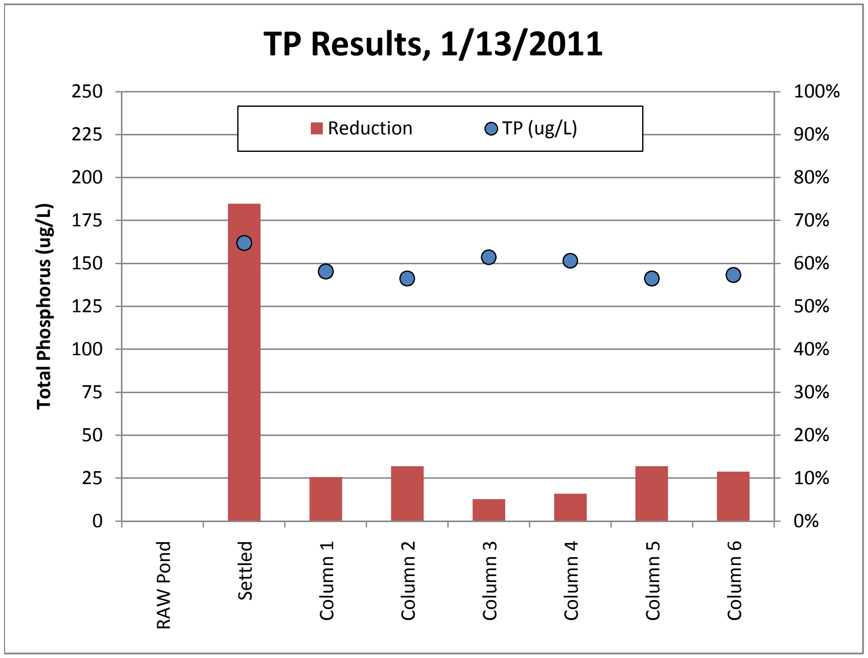
Test Details Test #2

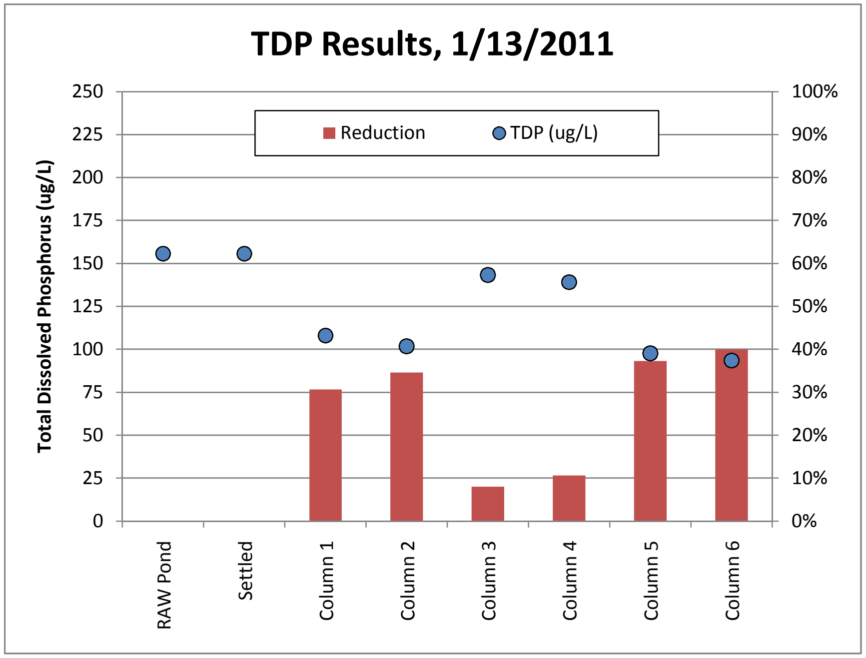
Test Date:	January 13, 2011	
Inner Diameter	*(in)*	3
Flow Area	*(in^2)*	7.07
RAW Pond Water TP	*(ug/L)*	620
RAW Pond Water TDP	*(ug/L)*	156
RAW Pond Water TRP	*(ug/L)*	57
RAW Pond Water SRP	*(ug/L)*	126
Settled TP	*(ug/L)*	162
Settled TDP	*(ug/L)*	156
Settled TRP	*(ug/L)*	69
Settled SRP	*(ug/L)*	120
Pond Water Turbidity	*(NTU)*	
Pond Water pH	(--)	6

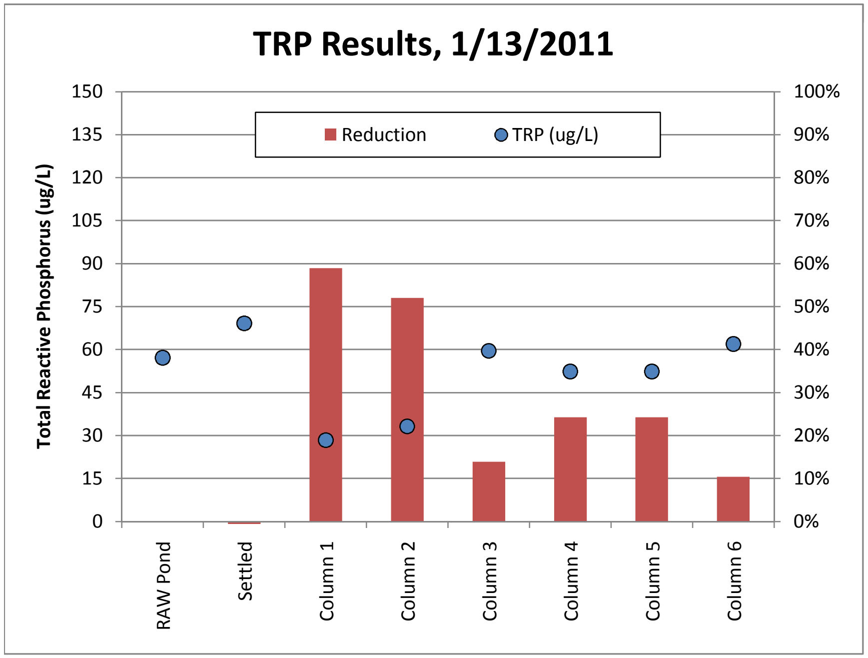


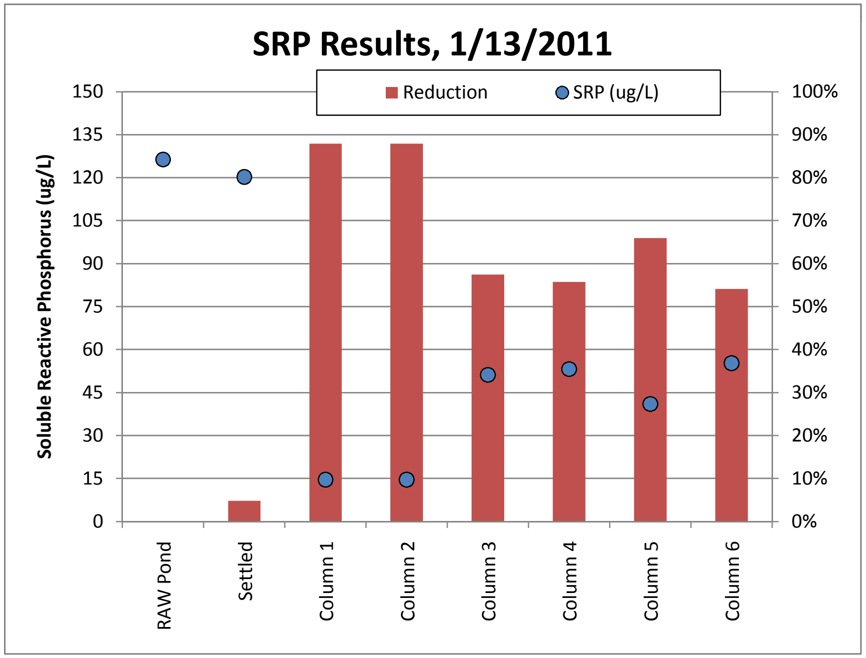


Variable	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Material	*(--)*	Dried Lime	Dried Lime	Dried Lime	Dried Lime	Dried Lime	Dried Lime
Mass into Column	*(g)*	300	300	300	300	300	300
Material Height	*(in)*	6	6	6	6	6	6
Time to 2 Liters	*(min)*	1200	600	400	200	120	66.7
Flow Rate	*(L/hr)*	0.1	0.2	0.3	0.6	1.0	1.8
Flow Rate	*(gpm)*	4.40E-04	8.81E-04	1.32E-03	2.64E-03	4.40E-03	7.92E-03
Infiltration Rate	*(in/hr)*	0.9	1.7	2.6	5.2	8.6	15.5
Residence Time	*(min)*	417.0	208.5	139.0	69.5	41.7	23.2
Residual Mass	*(g)*						
Lime:Polymer Ratio	*(X:1)*	NA	NA	NA	NA	NA	NA
Lime Delivery Rate	*(g/hr)*	15	30	45	90	150	270
Lime Delivery Rate	*(g/L)*	150	150	150	150	150	150
Dissolution Rate	*(%/hr)*	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
Final TP Conc.	*(ug/L)*	**145.3**	**141.2**	**153.6**	**151.5**	**141.2**	**143.2**
Final TDP Conc.	*(ug/L)*	**108.0**	**101.8**	**143.2**	**139.1**	**97.6**	**93.5**
Final TRP Conc.	*(ug/L)*	**28.4**	**33.2**	**59.5**	**52.4**	**52.4**	**61.9**
Final SRP Conc.	*(ug/L)*	**14.6**	**14.6**	**51.2**	**53.2**	**41.0**	**55.2**
TP Reduction	*(%)*	**10%**	**13%**	**5%**	**6%**	**13%**	**12%**
TDP Reduction	*(%)*	**31%**	**35%**	**8%**	**11%**	**37%**	**40%**
TRP Reduction	*(%)*	**59%**	**52%**	**14%**	**24%**	**24%**	**10%**
SRP Reduction	*(%)*	**88%**	**88%**	**57%**	**56%**	**66%**	**54%**
Turbidity	*(NTU)*						
pH	*(--)*	8.5	7.5	7	7	6.5	6


TP Results, 1/13/2011
Reduction
TP (ug/L)
Total Phosphorus (ug/L)
250
225
200
175
150
125
100
75
50
25
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

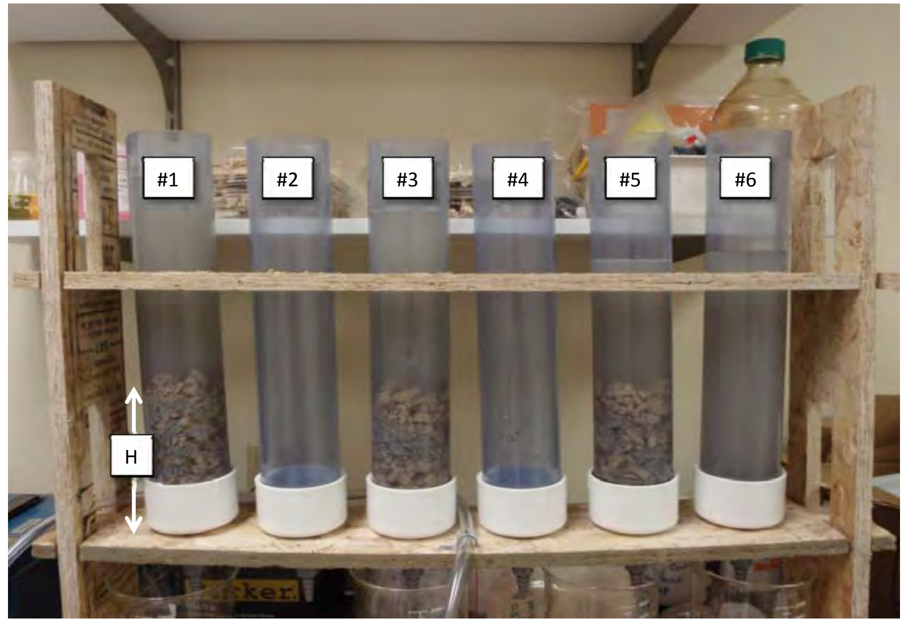

TDP Results, 1/13/2011
Reduction
TDP (ug/L)
Total Dissolved Phosphorus (ug/L)
250
225
200
175
150
125
100
75
50
25
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


TRP Results, 1/13/2011
Reduction
TRP (ug/L)
Total Reactive Phosphorus (ug/L)
150
135
120
105
90
75
60
45
30
15
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

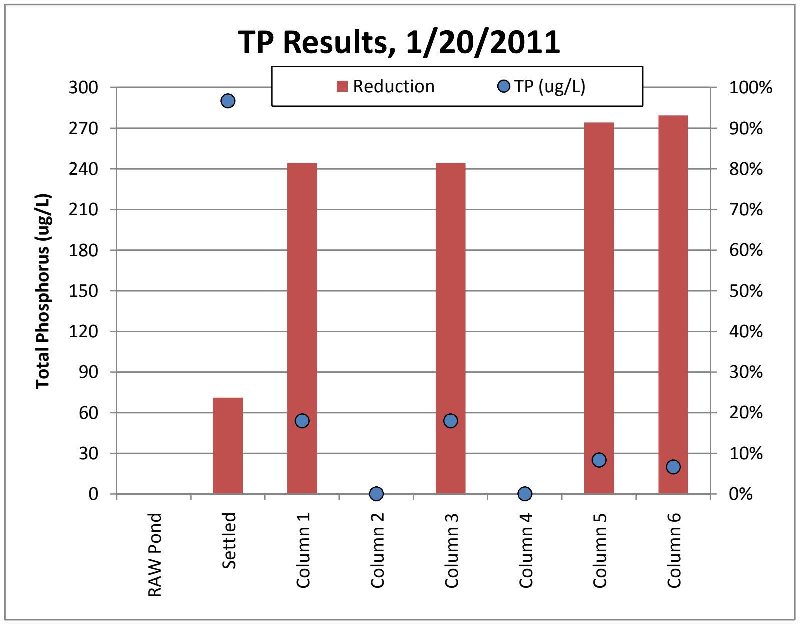

SRP Results, 1/13/2011
Reduction
SRP (ug/L)
Soluble Reactive Phosphorus (ug/L)
150
135
120
105
90
75
60
45
30
15
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

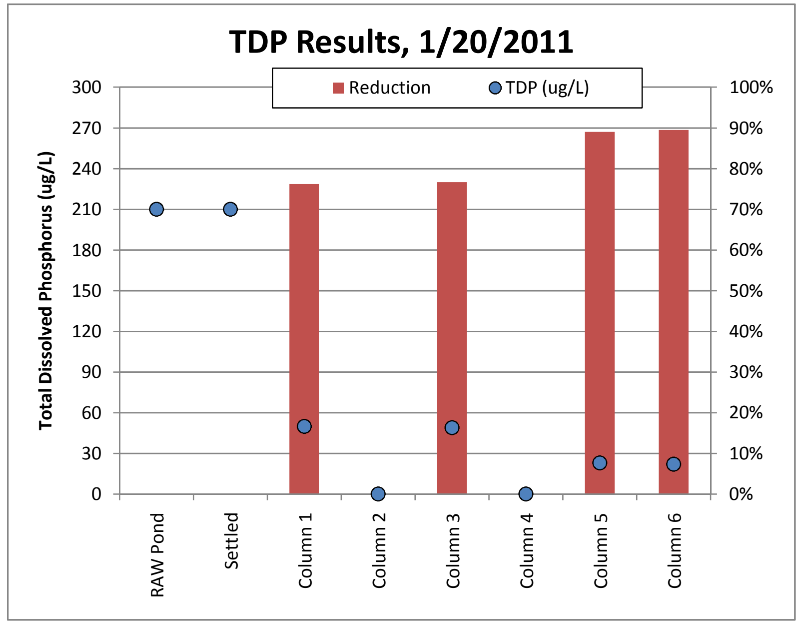
Test Details Test #3

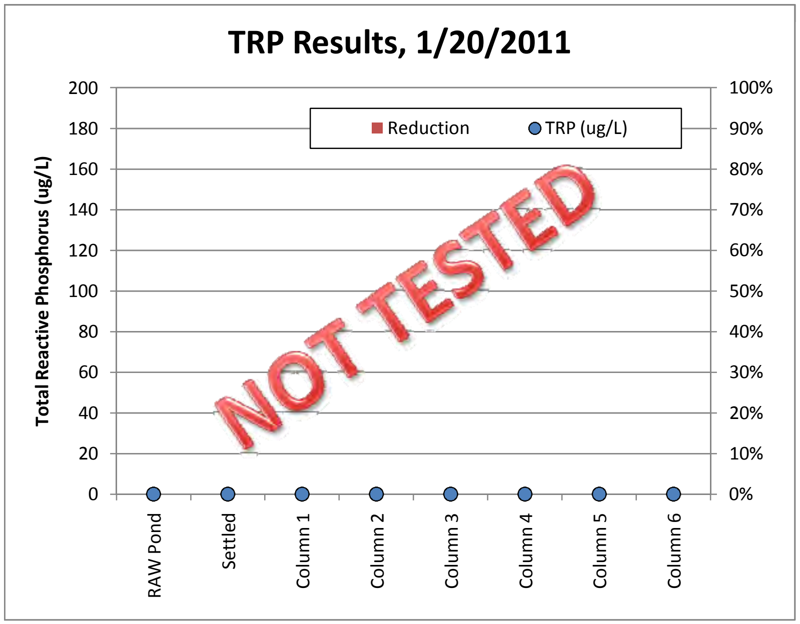
Test Date:	January 20, 2011	
Inner Diameter	*(in)*	3
Flow Area	*(in^2)*	7.07
RAW Pond Water TP	*(ug/L)*	**380**
RAW Pond Water TDP	*(ug/L)*	**210**
RAW Pond Water TRP	*(ug/L)*	**NOT TESTED**
RAW Pond Water SRP	*(ug/L)*	**NOT TESTED**
Settled TP	*(ug/L)*	**290**
Settled TDP	*(ug/L)*	**210**
Settled TRP	*(ug/L)*	**NOT TESTED**
Settled SRP	*(ug/L)*	**NOT TESTED**
Pond Water TSS	*(mg/L)*	**36**
Pond Water VSS	(mg/L)	**14**
Pond Water pH	*(--)*	**7.7**

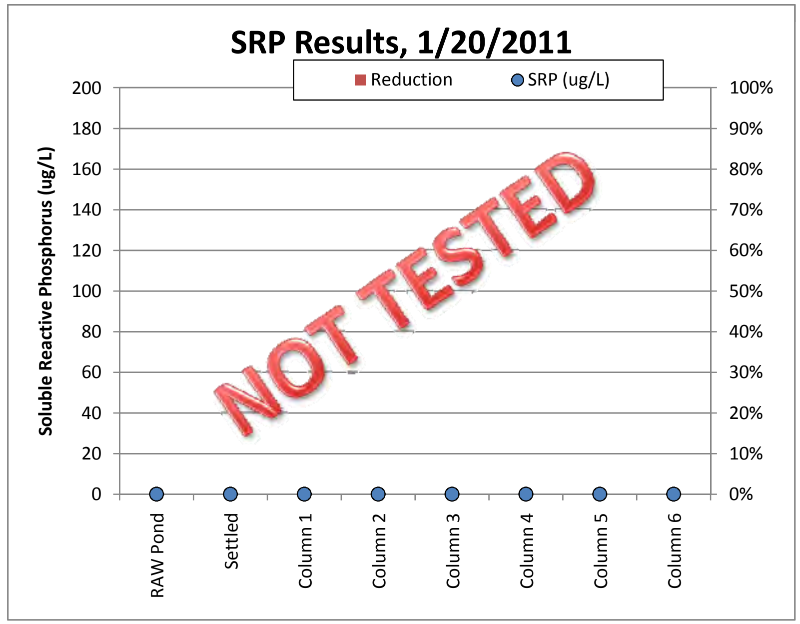


Variable	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Material	*(--)*	Lime / CC17	X	Lime / CC17	X	Lime / CC17	CC17
Mass of Material	*(g)*	300	X	300	X	300	0
Mass of CC-17	*(g)*	340	X	340	X	340	340
Material Height	*(in)*	6	X	6	X	6	6
Time to 2 Liters	*(min)*	600	X	300	X	120	240.0
Flow Rate	*(L/hr)*	0.2	X	0.4	X	1.0	0.5
Flow Rate	*(gpm)*	8.81E-04	X	1.76E-03	X	4.40E-03	2.20E-03
Infiltration Rate	*(in/hr)*	1.7	X	3.5	X	8.6	4.3
Residence Time	*(min)*	208.5	X	104.2	X	41.7	83.4
Residual Mass	*(g)*		X		X		
Lime:Polymer Ratio	*(X:1)*	NA	X	NA	X	NA	NA
Lime Delivery Rate	*(g/hr)*	30	X	60	X	150	0
Lime Delivery Rate	*(g/L)*	150	X	150	X	150	0
Dissolution Rate	*(%/hr)*	#NUM!	X	#NUM!	X	#NUM!	#DIV/0!
Final TP Conc.	*(ug/L)*	**54.0**	**X**	**54.0**	**X**	**25.0**	**20.0**
Final TDP Conc.	*(ug/L)*	**50.0**	**X**	**49.0**	**X**	**23.0**	**22.0**
Final TRP Conc.	*(ug/L)*	**NOT TESTED**	**X**	**NOT TESTED**	**X**	**NOT TESTED**	**NOT TESTED**
Final SRP Conc.	*(ug/L)*	**NOT TESTED**	**X**	**NOT TESTED**	**X**	**NOT TESTED**	**NOT TESTED**
TP Reduction	*(%)*	**81%**	**X**	**81%**	**X**	**91%**	**93%**
TDP Reduction	*(%)*	**76%**	**X**	**77%**	**X**	**89%**	**90%**
TRP Reduction	*(%)*	**NOT TESTED**	**X**	**NOT TESTED**	**X**	**NOT TESTED**	**NOT TESTED**
SRP Reduction	*(%)*	**NOT TESTED**	**X**	**NOT TESTED**	**X**	**NOT TESTED**	**NOT TESTED**
TSS	*(mg/L)*	2.5	X	5	X	3.3	3.3
VSS	*(mg/L)*	2.5	X	2.5	X	3.3	3.3
pH	*(--)*	7.9	X	7.8	X	7.6	8.1


TP Results, 1/20/2011
Reduction
TP (ug/L)
Total Phosphorus (ug/L)
300
270
240
210
180
150
120
90
60
30
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

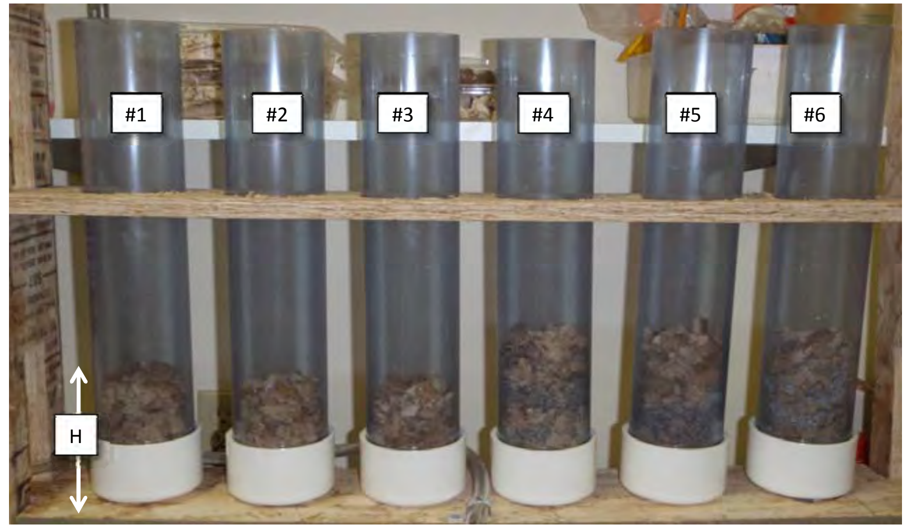

TDP Results, 1/20/2011
Reduction
TDP (ug/L)
Total Dissolved Phosphorus (ug/L)
300
270
240
210
180
150
120
90
60
30
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

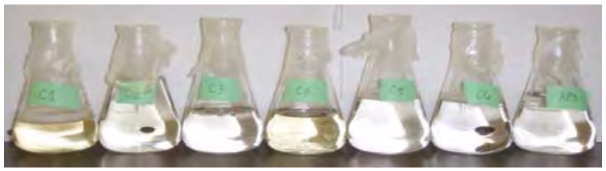

TRP Results, 1/20/2011
Reduction
TRP (ug/L)
NOT TESTED
Total Reactive Phosphorus (ug/L)
200
180
160
140
120
100
80
60
40
20
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


SRP Results, 1/20/2011
Reduction
SRP (ug/L)
NOT TESTED
Soluble Reactive Phosphorus (ug/L)
200
180
160
140
120
100
80
60
40
20
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

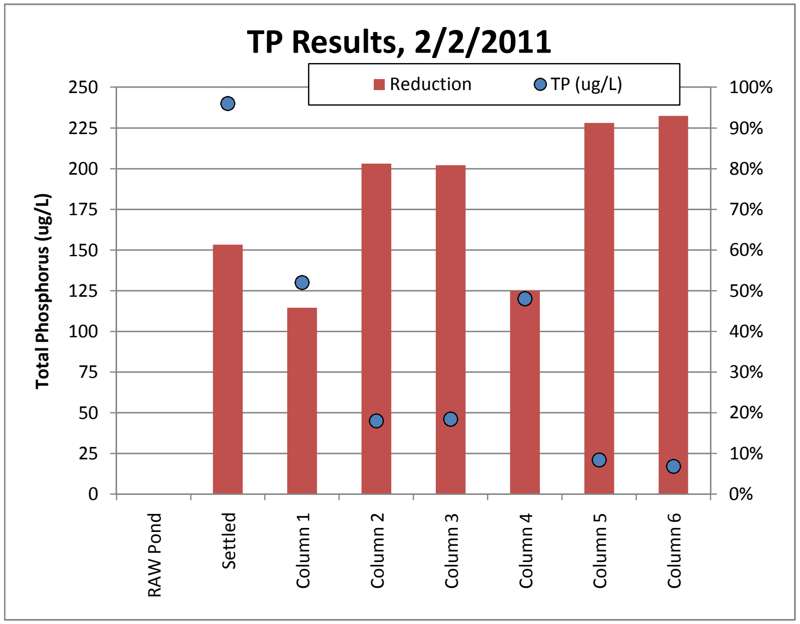
Test Details Test #4

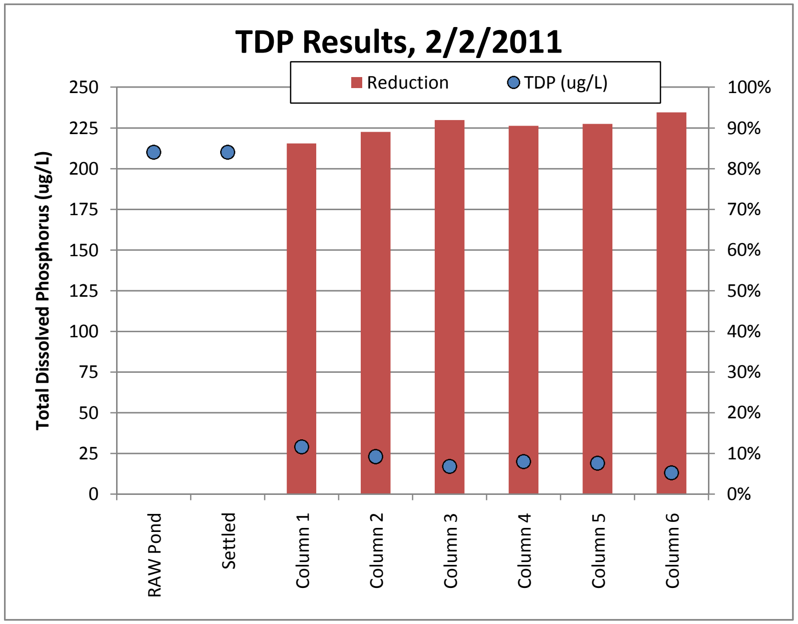
Test Date:	February 2, 2011	
Inner Diameter	*(in)*	3
Flow Area	*(in^2)*	7.07
RAW Pond Water TP	*(ug/L)*	620
RAW Pond Water TDP	*(ug/L)*	210
RAW Pond Water TRP	*(ug/L)*	NOT TESTED
RAW Pond Water SRP	*(ug/L)*	NOT TESTED
Settled TP	*(ug/L)*	240
Settled TDP	*(ug/L)*	210
Settled TRP	*(ug/L)*	NOT TESTED
Settled SRP	*(ug/L)*	NOT TESTED
Pond Water TSS	*(mg/L)*	**78**
Pond Water VSS	(mg/L)	**25**
Pond Water pH	(--)	**8.0**

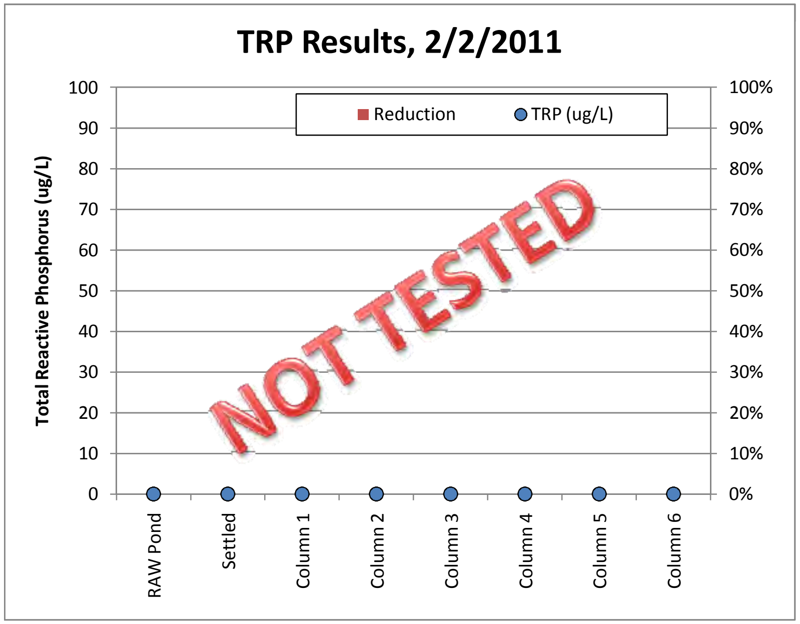


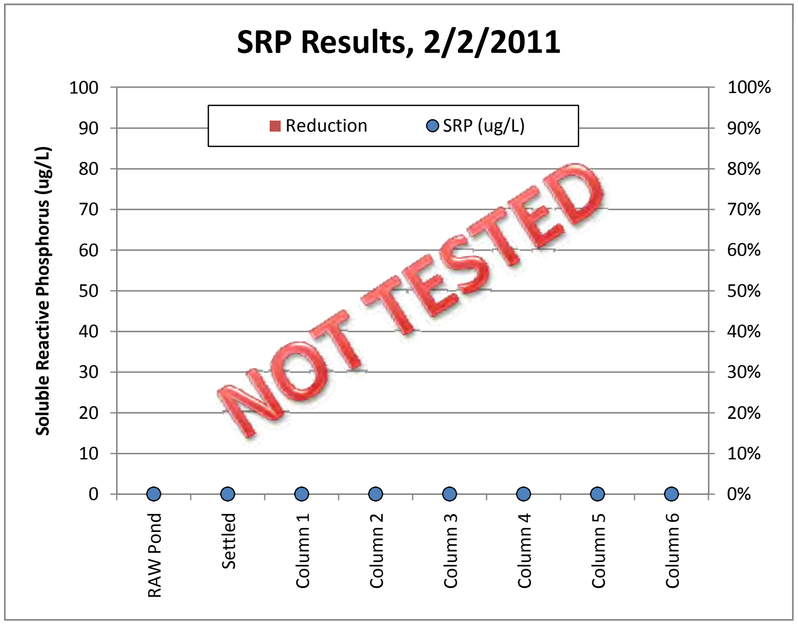


Variable	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Material	*(--)*	PVA40	PVA40	PVA40	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17
Mass of Material	*(g)*	245	245	245	245	245	245
Mass of CC-17	*(g)*	0	0	0	500	500	500
Material Height	*(in)*	6	6	6	6	6	6
Time to 2 Liters	*(min)*	600	120	40	600	120	25.0
Flow Rate	*(L/hr)*	0.2	1.0	3.0	0.2	1.0	4.8
Flow Rate	*(gpm)*	8.81E-04	4.40E-03	1.32E-02	8.81E-04	4.40E-03	2.11E-02
Infiltration Rate	*(in/hr)*	1.7	8.6	25.9	1.7	8.6	41.4
Residence Time	*(min)*	208.5	41.7	13.9	208.5	41.7	8.7
Residual Mass	*(g)*						
Lime:Polymer Ratio	*(X:1)*	3	3	3	3	3	3
Lime Delivery Rate	*(g/hr)*	25	123	368	25	123	588
Lime Delivery Rate	*(g/L)*	123	123	123	123	123	123
Dissolution Rate	*(%/hr)*	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
Final TP Conc.	*(ug/L)*	**130.0**	**45.0**	**46.0**	**120.0**	**21.0**	**17.0**
Final TDP Conc.	*(ug/L)*	**29.0**	**23.0**	**17.0**	**20.0**	**19.0**	**13.0**
Final TRP Conc.	*(ug/L)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
Final SRP Conc.	*(ug/L)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
TP Reduction	*(%)*	**46%**	**81%**	**81%**	**50%**	**91%**	**93%**
TDP Reduction	*(%)*	**86%**	**89%**	**92%**	**90%**	**91%**	**94%**
TRP Reduction	*(%)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
SRP Reduction	*(%)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
TSS	*(mg/L)*	62	10	5	38	13	5
VSS	*(mg/L)*	62	5	5	38	5	2.5
pH	*(--)*	7.2	8	7.5	7.2	7.2	7.6


TP Results, 2/2/2011
Reduction
TP (ug/L)
Total Phosphorus (ug/L)
250
225
200
175
150
125
100
75
50
25
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

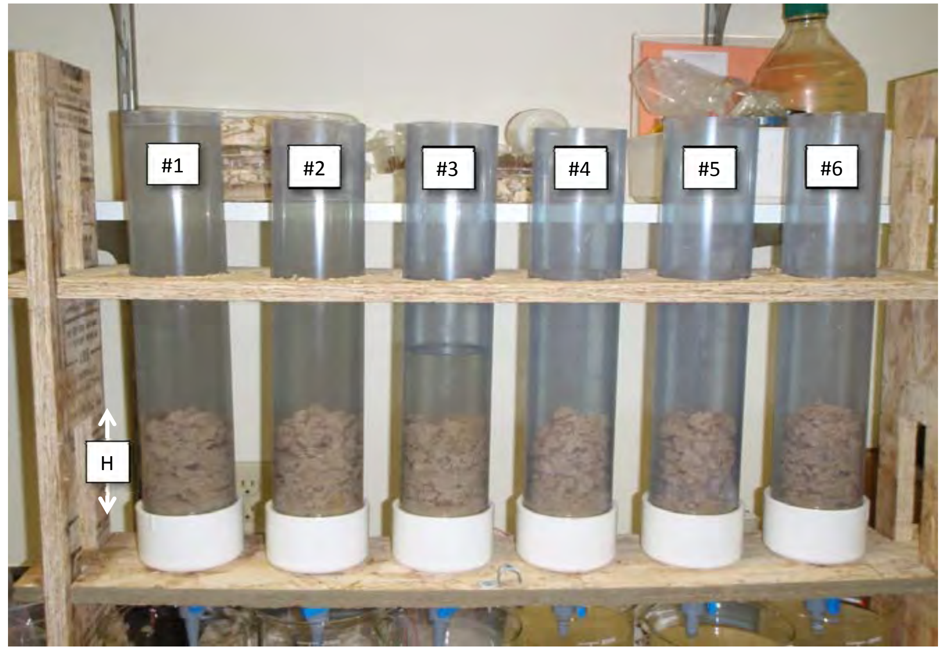

TDP Results, 2/2/2011
Reduction
TDP (ug/L)
Total Dissolved Phosphorus (ug/L)
250
225
200
175
150
125
100
75
50
25
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


TRP Results, 2/2/2011
Reduction
TRP (ug/L)
Total Reactive Phosphorus (ug/L)
NOT TESTED
100
90
80
70
60
50
40
30
20
10
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


SRP Results, 2/2/2011
Reduction
SRP (ug/L)
Soluble Reactive Phosphorus (ug/L)
NOT TESTED
100
90
80
70
60
50
40
30
20
10
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

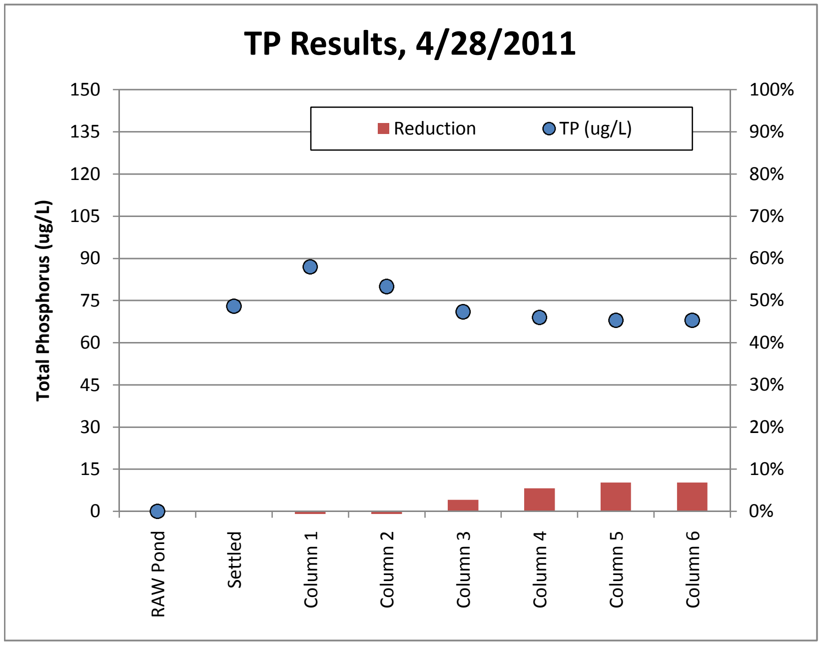
Test Details Test #5

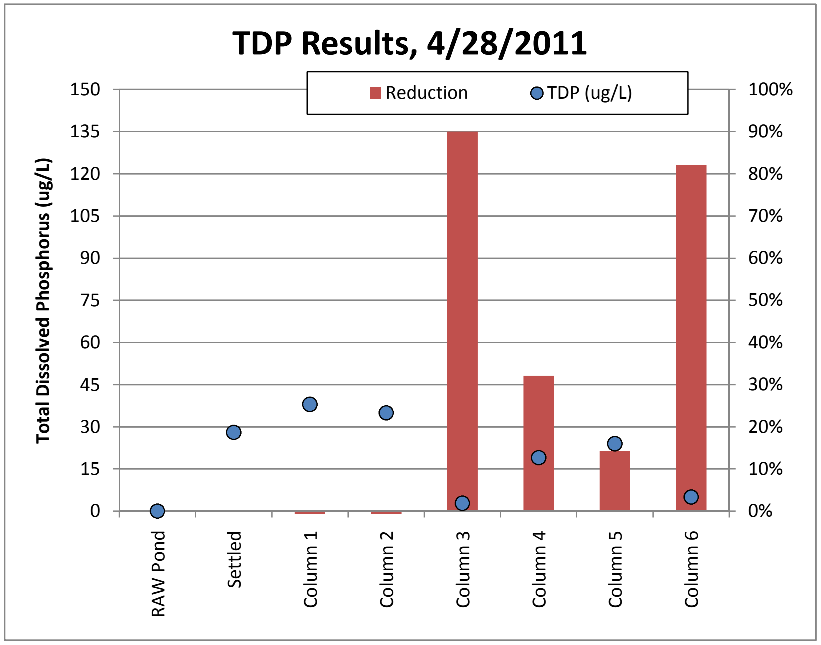
Test Date:	April 28, 2011	
Inner Diameter	*(in)*	3
Flow Area	*(in^2)*	7.07
RAW Pond Water TP	*(ug/L)*	NOT TESTED
RAW Pond Water TDP	*(ug/L)*	NOT TESTED
RAW Pond Water TRP	*(ug/L)*	NOT TESTED
RAW Pond Water SRP	*(ug/L)*	NOT TESTED
Settled TP	*(ug/L)*	73
Settled TDP	*(ug/L)*	28
Settled TRP	*(ug/L)*	NOT TESTED
Settled SRP	*(ug/L)*	28
Pond Water Turbidity	*(NTU)*	
Pond Water pH	*(--)*	

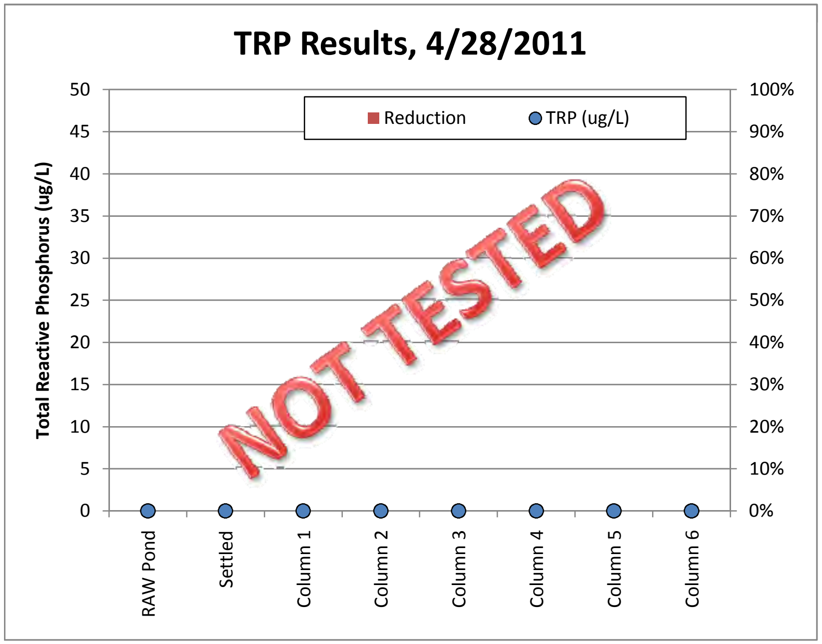


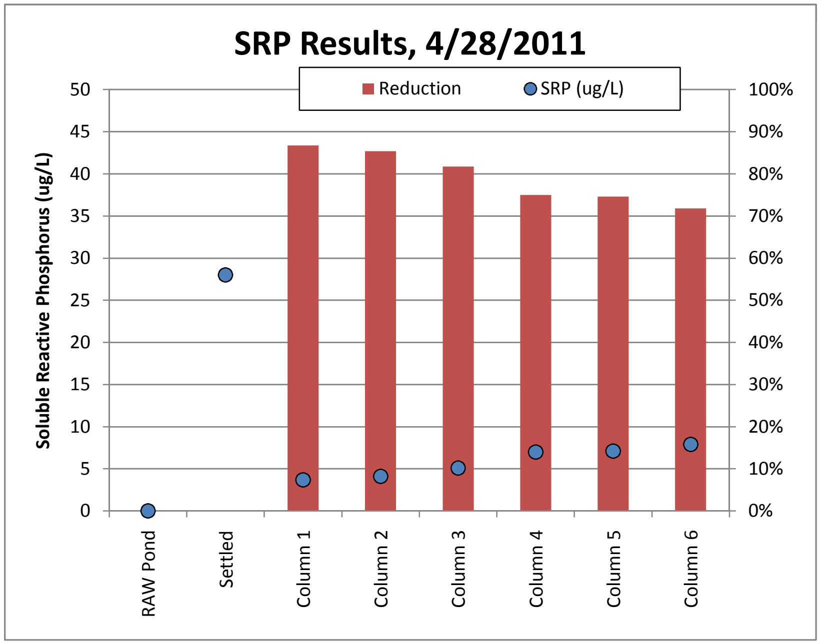
Variable	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Material	*(--)*	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17
Mass of Material	*(g)*	254.91	254.94	254.96	254.93	254.78	255.01
Mass of CC-17	*(g)*	358.5	357.4	355.6	357.8	356.5	358.1
Material Height	*(in)*	3.5	3.5	3.5	3.5	3.5	3.5
Time to 2 Liters	*(min)*	790	260	112	65	40	24.0
Flow Rate	*(L/hr)*	0.15	0.46	1.07	1.85	3.00	5.00
Flow Rate	*(gpm)*	6.69E-04	2.03E-03	4.72E-03	8.13E-03	1.32E-02	2.20E-02
Infiltration Rate	*(in/hr)*	1.3	4.0	9.2	15.9	25.9	43.2
Residence Time	*(min)*	160.1	52.7	22.7	13.2	8.1	4.9
Residual Mass	*(g)*	250	250	250	250	250	250
Lime:Polymer Ratio	*(X:1)*	10	10	10	10	10	10
Lime Delivery Rate	*(g/hr)*	0	1	3	5	7	13
Lime Delivery Rate	*(g/L)*	2	2	2	2	2	3
Dissolution Rate	*(%/hr)*	0%	0%	1%	2%	3%	5%

Final TP Conc.	*(ug/L)*	**87.0**	**80.0**	**71.0**	**69.0**	**68.0**	**68.0**
Final TDP Conc.	*(ug/L)*	**38.0**	**35.0**	**2.8**	**19.0**	**24.0**	**5.0**
Final TRP Conc.	*(ug/L)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
Final SRP Conc.	*(ug/L)*	**3.7**	**4.1**	**5.1**	**7.0**	**7.1**	**7.9**
TP Reduction	*(%)*	**0%**	**0%**	**3%**	**5%**	**7%**	**7%**
TDP Reduction	*(%)*	**0%**	**0%**	**90%**	**32%**	**14%**	**82%**
TRP Reduction	*(%)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
SRP Reduction	*(%)*	**87%**	**85%**	**82%**	**75%**	**75%**	**72%**
Turbidity	*(NTU)*						
pH	*(--)*						


TP Results, 4/28/2011
Total Phosphorus (ug/L)
Reduction
TP (ug/L)
150
135
120
105
90
75
60
45
30
15
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

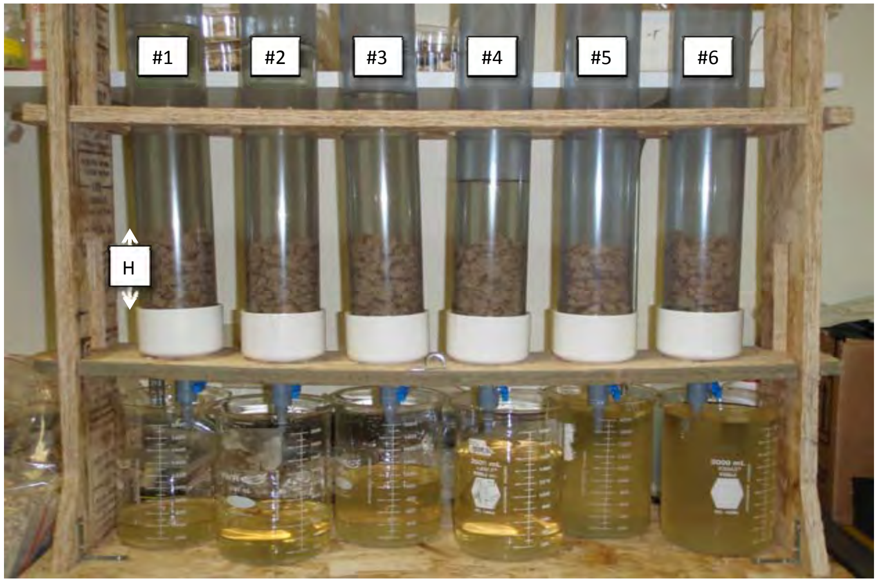

TDP Results, 4/28/2011
Total Dissolved Phosphorus (ug/L)
Reduction
TDP (ug/L)
150
135
120
105
90
75
60
45
30
15
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


TRP Results, 4/28/2011
Total Reactive Phosphorus (ug/L)
Reduction
TRP (ug/L)
NOT TESTED
50
45
40
35
30
25
20
15
10
5
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

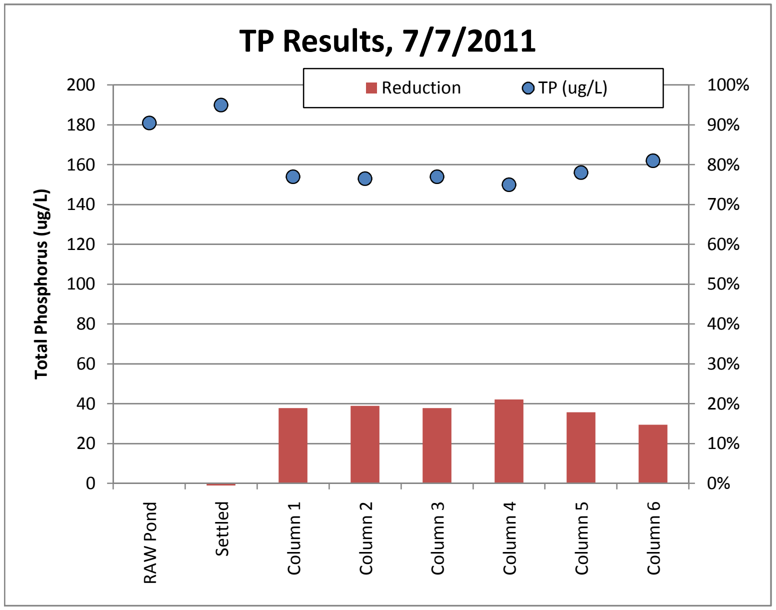

SRP Results, 4/28/2011
Soluble Reactive Phosphorus (ug/L)
Reduction
SRP (ug/L)
50
45
40
35
30
25
20
15
10
5
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

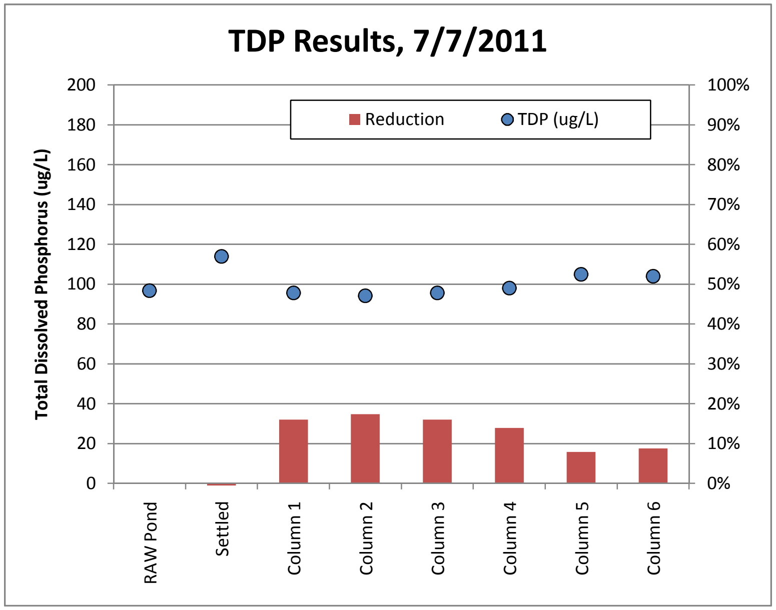
Test Details Test #6

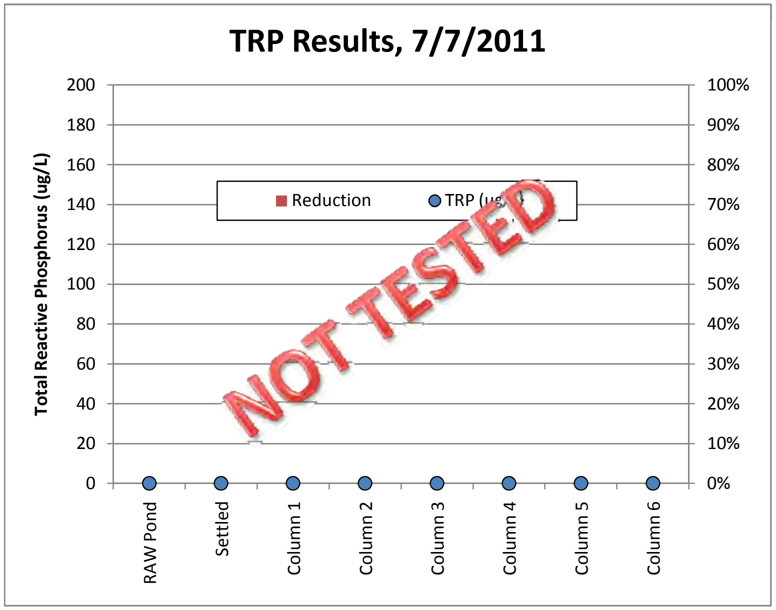
Test Date:	July 7, 2011	
Inner Diameter	*(in)*	3
Flow Area	*(in^2)*	7.07
RAW Pond Water TP	*(ug/L)*	181
RAW Pond Water TDP	*(ug/L)*	97
RAW Pond Water TRP	*(ug/L)*	NOT TESTED
RAW Pond Water SRP	*(ug/L)*	15
Settled TP	*(ug/L)*	190
Settled TDP	*(ug/L)*	114
Settled TRP	*(ug/L)*	NOT TESTED
Settled SRP	*(ug/L)*	19
Pond Water TSS	*(mg/L)*	5.5
Pond Water VSS	*(mg/L)*	< 5.0
Pond Water pH	*(--)*	7.3
Pond Conductivity	*(uS)*	1309

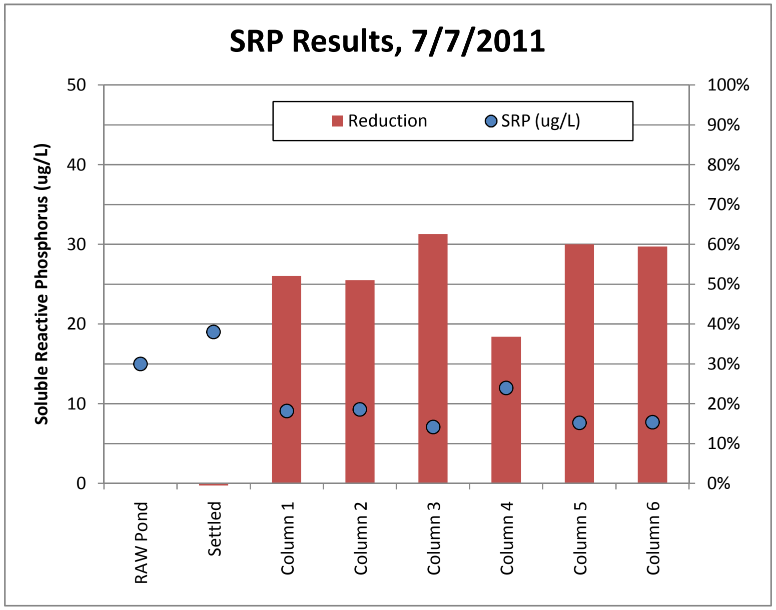


Variable	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Material	*(--)*	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17	PVA40 / CC17
Mass of Material	*(g)*	242.68	242.63	242.66	242.68	242.65	242.65
Mass of CC-17	*(g)*	330	330	330	330	330	330
Material Height	*(in)*	3.5	3.5	3.5	3.5	3.5	3.5
Time to 2 Liters	*(min)*	326	213	163	106	57.8	33.4
Flow Rate	*(L/hr)*	0.37	0.56	0.74	1.13	2.08	3.59
Flow Rate	*(gpm)*	1.62E-03	2.48E-03	3.24E-03	4.98E-03	9.14E-03	1.58E-02
Infiltration Rate	*(in/hr)*	3.2	4.9	6.4	9.8	17.9	31.0
Residence Time	*(min)*	66.1	43.2	33.0	21.5	11.7	6.8
Residual Mass	*(g)*						
Lime:Polymer Ratio	*(X:1)*	6	6	6	6	6	6
Lime Delivery Rate	*(g/hr)*	38	59	77	118	216	374
Lime Delivery Rate	*(g/L)*	104	104	104	104	104	104
Dissolution Rate	*(%/hr)*	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
Final TP Conc.	*(ug/L)*	**154.0**	**153.0**	**154.0**	**150.0**	**156.0**	**162.0**
Final TDP Conc.	*(ug/L)*	**95.7**	**94.2**	**95.7**	**98.1**	**105.0**	**104.0**
Final TRP Conc.	*(ug/L)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
Final SRP Conc.	*(ug/L)*	**9.1**	**9.3**	**7.1**	**12.0**	**7.6**	**7.7**
TP Reduction	*(%)*	**19%**	**19%**	**19%**	**21%**	**18%**	**15%**
TDP Reduction	*(%)*	**16%**	**17%**	**16%**	**14%**	**8%**	**9%**
TRP Reduction	*(%)*	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
SRP Reduction	*(%)*	**52%**	**51%**	**63%**	**37%**	**60%**	**59%**
TSS	*(mg/L)*	6.5	< 5.0	6.5	6.5	8.0	6.5
VSS	*(mg/L)*	6.0	< 5.0	< 5.0	< 5.0	5.0	< 5.0
pH	*(--)*	9.2	9.2	9.1	9.0	8.5	8.1
Conductivity	*(uS)*	2845	2560	2405	2245	1912	1752


TP Results, 7/7/2011
Reduction
TP (ug/L)
Total Phosphorus (ug/L)
0
20
40
60
80
100
120
140
160
180
200
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


TDP Results, 7/7/2011
Reduction
TDP (ug/L)
Total Dissolved Phosphorus (ug/L)
0
20
40
60
80
100
120
140
160
180
200
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


TRP Results, 7/7/2011
Reduction
TRP (ug/L)
NOT TESTED
Total Reactive Phosphorus (ug/L)
0
20
40
60
80
100
120
140
160
180
200
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6


SRP Results, 7/7/2011
Reduction
SRP (ug/L)
Soluble Reactive Phosphorus (ug/L)
0
10
20
30
40
50
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
RAW Pond
Settled
Column 1
Column 2
Column 3
Column 4
Column 5
Column 6

Test Details Test #7

Test Date:	September 13, 2011	
Inner Diameter	(in)	3
Flow Area	(in^2)	7.07
RAW Pond Water TP	(ug/L)	250
RAW Pond Water TDP	(ug/L)	120
RAW Pond Water TRP	(ug/L)	NOT TESTED
RAW Pond Water SRP	(ug/L)	27
Settled TP	(ug/L)	180
Settled TDP	(ug/L)	120
Settled TRP	(ug/L)	NOT TESTED
Settled SRP	(ug/L)	28
Pond Water TSS	(mg/L)	7.5
Pond Water VSS	(mg/L)	5
Pond Water pH	(--)	7.2
Pond Conductivity	(uS)	747

Variable	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Material	(--)	Lime	Lime	Lime	Lime	Lime	Lime
Mass of Material	(g)	300	300	300	300	300	300
Mass of CC-17	(g)	500	500	500	500	500	500
Material Height	(in)	6	6	6	6	6	6
Time to 2 Liters	(min)	560	360	158	106	72.0	28.0
Flow Rate	(L/hr)	0.21	0.33	0.76	1.13	1.67	4.29
Flow Rate	(gpm)	9.44E-04	1.47E-03	3.34E-03	4.98E-03	7.34E-03	1.89E-02
Infiltration Rate	(in/hr)	1.8	2.9	6.6	9.8	14.4	37.0
Residence Time	(min)	194.6	125.1	54.9	36.8	25.0	9.7
Residual Mass	(g)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Lime:Polymer Ratio	(X:1)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Lime Delivery Rate	(g/hr)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Lime Delivery Rate	(g/L)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Dissolution Rate	(%/hr)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Final TP Conc.	(ug/L)	**150.0**	**120.0**	**120.0**	**130.0**	**160.0**	**130.0**
Final TDP Conc.	(ug/L)	**110.0**	**92.0**	**91.0**	**95.0**	**100.0**	**92.0**
Final TRP Conc.	(ug/L)	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
Final SRP Conc.	(ug/L)	**41.0**	**6.3**	**20.0**	**17.0**	**19.0**	**20.0**
TP Reduction	(%)	**17%**	**33%**	**33%**	**28%**	**11%**	**28%**
TDP Reduction	(%)	**8%**	**23%**	**24%**	**21%**	**17%**	**23%**
TRP Reduction	(%)	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**	**NOT TESTED**
SRP Reduction	(%)	**0%**	**78%**	**29%**	**39%**	**32%**	**29%**
TSS	(mg/L)	5.0	5.00	6.0	5.5	8.5	10.0
VSS	(mg/L)	5.0	5.0	5.0	5.0	5.0	5.0
pH	(--)	9.3	9.3	9.3	9.3	9.2	9.0
Conductivity	(uS)	1247	1210	1080	1081	1001	892

Toxicity tests results conducted with treated water from the April 28, 2011 column tests with polyvinyl alcohol, test number 5

TOXICITY TEST RESULTS

PERMEABLE REACTIVE SPENT LIME BARRIER

Report Date: May 12, 2011

Project No. 11-106

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

ENVIRONMENTAL TOXICITY CONTROL INC.

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

PROJECT: <u>ACUTE TOXICITY TESTING</u>
<u>PERMEABLE REACTIVE SPENT LIME BARRIER</u>

PROJECT NUMBER: 11-106

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on water samples received by Environmental Toxicity Control (ETC) on May 2, 2011. The samples were water samples from the Permeable Reactive Spent Lime Project. Mr. Keith Pilgrim of Barr Engineering requested that we conduct acute toxicity tests on the samples. The scope of our services was limited to conducting 48-hour static renewal acute toxicity tests using the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

SUMMARY:

All *C. dubia* survived the 48 hour acute tests.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in <u>Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms</u>, Fourth Edition, EPA-821-R-02-013.

Testing was started on 5/03/11.

RESULTS:

Toxicity test results are summarized in Table 1 and test conditions are summarized in Table 2.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference tests are shown in the following table:

Reference Toxicity Test		
Species	LC_{50}	Test Date
Ceriodaphnia dubia	2.14 g/L NaCl	4/26/11

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst
Bioassay Manager

Table 1. Survival of *Ceriodaphnia dubia*

Sample ID	% Survival
Control	100
Raw Storm Water	100
Column 1	100
Column 2	100
Column 3	100
Column 4	100
Column 5	100
Column 6	100
Organism Age:	<24 hours

Table 2. Summary of Chemical and Physical Data of Toxicity Tests

Test: Effluent w/o CO_2						
Sample ID	**pH**	**Dissolved Oxygen (mg/L)**	**°C**	**Total Hardness (mg/L)**	**Total Alkalinity (mg/L)**	**Conductivity (µmhos/cm)**
Control	7.99 - 8.13	8.1 - 8.6	25	96	64	326
Raw Storm	7.64 - 8.32	8.2 - 11.3	25	176	116	634
Column 1	8.04 - 8.33	7.9 - 10.0	25	1088	500	1943
Column 2	8.17 - 8.58	7.8 - 10.5	25	812	400	1580
Column 3	8.23 - 8.42	7.6 - 10.3	25	656	320	1354
Column 4	8.23 - 8.39	7.7 - 10.2	25	540	332	1205
Column 5	8.07 - 8.34	7.6 - 10.6	25	416	240	1038
Column 6	8.09 - 8.37	7.4 - 10.3	25	388	232	977

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 11-106
Test Type: Acute	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Sample ID: Recon	Raw Storm	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Remarks
Day: 0	pH	7.99	7.64	8.33	8.58	8.42	8.39	8.12	8.14	
	Dissolved Oxygen (mg/l)	8.6	11.3	10.0	10.5	10.3	10.2	10.6	10.3	
Date: 5/3/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)	326	634	1943	1580	1354	1205	1038	977	
Analyst: KM	Total Alkalinity (mg/l)	64	116	500	400	320	332	240	232	
	Total Hardness (mg/l)	96	176	1088	812	656	540	416	388	
	Total Ammonia (mg/l)									
Day: 1 old	pH	8.06	8.28	8.04	8.17	8.23	8.25	8.27	8.30	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.3	8.2	8.2	8.2	8.2	8.1	
Date: 5/4/11	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 1 New	pH	8.13	7.90	8.14	8.43	8.30	8.29	8.07	8.09	
	Dissolved Oxygen (mg/l)	8.6	9.6	9.3	9.2	9.2	9.2	9.1	9.1	
Date: 5/4/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 2 Final	pH	8.11	8.32	8.09	8.18	8.29	8.23	8.34	8.37	
	Dissolved Oxygen (mg/l)	8.1	8.2	7.9	7.8	7.6	7.7	7.6	7.4	
Date: 5/5/11	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (μmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day:	pH									
	Dissolved Oxygen (mg/l)									
Date: / /	Temperature (°C)									
	Conductivity (μmhos)									
Analyst:	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									

Reviewed by: [signature] Date: 5/11/11

ACUTE TOXICITY TEST SURVIVAL DATA

Client: Barr Engineering | Project # 11-106 | Species/Age: Ceriodaphnia dubia / <24h

Date/Time/Analyst		0 Hour	24 Hour (1415 5/4/11 KM)		48 Hour (1415 5/5/11 KM)		72 Hour		96 Hour		Remarks/Observations
Conc.	Rep	# of Org.	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	
Control	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
Raw storm	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
Column 1	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
Column 2	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
Column 3	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
Column 4	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
Column 5	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
Column 6	A	5	5	0	5	0					
	B	5	5	0	5	0					
	C	5	5	0	5	0					
	D	5	5	0	5	0					
	A										
	B										
	C										
	D										

KEY TO OBSERVATIONS:
N = Normal behavior
L = Lethargic behavior
P = Pigmentation change

Test start: 1415 5/3/11
Test termination: 1415 5/5/11
Reviewed by: WK

BARR

Chain of Custody

4700 West 77th Street
Minneapolis, MN 55435-4803
(952) 832-2600

COC 1 of 1

Project Number: 23/62-1021.01

Project Name: PERMEABLE REACTIVE BARRIER

№ 24929

Project Manager: KMP

Project Contact: CDA

Sampled by: CDA

Laboratory: ENVIRONMENTAL TOXICITY

Number of Containers/Preservative — Water: Volatile Organics (Pres.) *1; Semivolatile Organics *2; Dissolved Metals (HNO_3); Total Metals (HNO_3); General (Unpreserved) *3; Cyanide (NaOH); Nutrients (H_2SO_4) *4; Oil and Grease (H_2SO_4); Sulfide (Zn Acetate); Methane; Bacteria ($Na_2S_2O_3$); DRO (HCl). Soil: VOCs (2-oz tared MeOH) *1; GRO, BTEX (2-oz tared MeOH) *1; DRO (2-oz tared) - 25 grams; Metals (2-oz unpreserved); SVOCs (2 or 4-oz unpres.) *2; % Moisture (plastic vial, unpres.)

#	Sample Identification	Collection Date	Collection Time	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	General (Unpreserved) *3	Total No. Of Containers	Remarks
1.	RAW STORM WATER	04/22/11	12:00	X		X			1	1	TEST FOR ACUTE, C. DUBIA, SINGLE CONCENTRATION
2.	COLUMN 1	04/28/11	12:00	X		X			1	1	↓
3.	COLUMN 2	04/28/11	12:00	X		X			1	1	↓
4.	COLUMN 3	04/28/11	12:00	X		X			1	1	↓
5.	COLUMN 4	04/28/11	12:00	X		X			1	1	↓
6.	COLUMN 5	04/28/11	12:00	X		X			1	1	↓
7.	COLUMN 6	04/28/11	12:00	X		X			1	1	↓
8.											
9.											
10.											
11.											
12.											

Common Parameter/Container - Preservation Key

*1 - *Volatile Organics = BTEX, GRO, TPH, Full List*
*2 - *Semivolatile Organics = PAHs, PCP, Dioxins, Full List, Herbicide/Pesticide/PCBs*
*3 - *General = pH, Chloride, Flouride, Alkalinity, TSS, TDS, TS, Sulfate*
*4 - *Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN*

Relinquished By	On Ice?	Date	Time	Received by	Date	Time
CDA	(Y) N	05/02/11	14:00	[signature]	5/2/11	1545
	Y N					

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other ______

Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

H:RLG\STDFORMS\Chain Of Custody Form RLG Rev. 07/01/05

Toxicity test results conducted with treated water from the July 7, 2011 column tests with polyvinyl alcohol, test number 6.

TOXICITY TEST RESULTS

PERMEABLE REACTIVE SPENT LIME BARRIER

Report Date: July 20, 2011

Project No. 11-183

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

PROJECT: **CHRONIC TOXICITY TESTING**
PERMEABLE REACTIVE SPENT LIME BARRIER

PROJECT NUMBER: 11-183

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on water samples received by Environmental Toxicity Control (ETC) on July 8, 2011. The samples were water samples from the Permeable Reactive Spent Lime Project. Mr. Keith Pilgrim of Barr Engineering requested that we conduct chronic toxicity tests on the samples. The scope of our services was limited to conducting 7-day static renewal chronic toxicity tests using the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition, EPA-821-R-02-013.

Testing was started on 7/08/11.

RESULTS:

Toxicity test results are summarized in Table 1 and test conditions are summarized in Table 2.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference tests are shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.664 g/L NaCl	7/05/11

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst
Bioassay Manager

Table 1. **Survival of *Ceriodaphnia dubia***

Sample ID	48 Hour Survival (%)	7 day Survival (%)	Mean # Young Produced
Reconstituted Water	100	100	14.8
Raw Pond Water	100	100	21.6
C 1	100	30	0.1
C 2	100	90	4.4
C 3	100	90	7.2
C 4	100	100	13.1
C 5	100	100	13.0
C 6	100	100	12.9

Table 2. Summary of Chemical and Physical Data of Toxicity Tests

Test: Effluent w/o CO_2						
Sample ID	pH	Dissolved Oxygen (mg/L)	°C	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (μmhos/cm)
Recon H_2O	8.01 - 8.37	7.5 - 8.3	25	80	60	286
Raw Pond	7.34 - 8.32	7.4 - 9.1	25	172	124	1210
C 1	7.96 - 8.45	4.7 - 8.0	25	1332	440	2750
C 2	8.01 - 8.48	4.0 - 10.0	25	1112	408	2400
C 3	7.70 - 8.43	4.0 - 8.8	25	1008	416	2400
C 4	8.08 - 8.34	5.2 - 8.8	25	804	296	2190
C 5	7.96 - 8.27	4.3 - 10.1	25	600	256	1822
C 6	7.86 - 8.30	4.1 - 8.8	25	496	236	1670

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 11-183

Test Dates/Time ● Initiation: 1415 7/8/11 Termination: 1430 7/15/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
Raw Pond	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	2	0	0	0	0	0	2	
	4	4	2	0	0	0	0	0	0	4	0	
	5	0	8	8	3	6	4	6	4	6	6	
	6	7	0	0	9	12	6	14	7	0	8	
	7	13	5	6	0	10	4	20	16	14	0	
	Total	24	15	14	14	28	14	40	27	24	16	$\bar{X} = 21.6$
C1	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	1	0	0	0	0	0	0	0	0	
	4	0	0	0	0	0	0	0	0	0	0	
	5	0	0	X	0	0	0	0	X	0	X	
	6	0	0		X	X	X	0		0		
	7	0	0					X		0		
	Total	0	1	0	0	0	0	0	0	0	0	$\bar{X} = 0.1$
C2	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	0	1	1	0	0	1	0	0	1	0	
	5	0	4	0	0	0	2	0	1	0	0	
	6	0	0	0	2	X	0	0	3	3	3	
	7	1	1	0	8		0	2	10	0	0	
	Total	1	6	1	10		3	2	14	4	3	$\bar{X} = 4.4$

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM/WK Reviewed By: Walter Kounty

Bio.105

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: BARR Engineering Project No.: 11-183
Test Dates/Time • Initiation: 1415 7/8/11 Termination: 1430 7/15/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
C3	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	0	2	0	0	2	0	0	0	0	0	
	5	2	3	1	2	6	2	0	3	2	1	
	6	5	0	0	4	0	0	2	0	X	2	
	7	6	2	3	4	7	0	7	0		4	
	Total	13	7	4	10	15	2	9	3	2	7	X̄ = 7.2
C4	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	0	2	0	1	0	0	0	1	0	0	
	5	4	2	3	1	3	4	4	2	3	4	
	6	7	0	5	0	2	7	4	4	4	6	
	7	10	0	6	6	6	7	8	0	7	8	
	Total	21	4	14	8	11	18	16	7	14	18	X̄ = 13.1
C5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	2	0	0	0	0	0	0	0	0	
	4	4	0	0	0	2	0	0	2	0	2	
	5	0	5	4	4	0	6	3	1	4	2	
	6	6	4	5	5	0	4	5	0	6	0	
	7	4	0	6	9	5	8	8	4	6	4	
	Total	14	11	15	18	7	18	16	7	16	8	X̄ = 13.0

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM/WK Reviewed By: Walter Koenst

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 11-183
Test Dates/Time ● Initiation: 1415 7/8/11 Termination: 1430 7/15/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
C6	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	0	2	1	0	0	0	2	1	0	
	5	2	4	4	0	2	3	5	3	0	4	
	6	0	6	7	1	4	4	5	0	6	6	
	7	5	10	0	0	0	8	8	6	9	9	
	Total	9	20	13	2	6	15	18	11	16	19	X̄ = 13.9
Recon	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	0	2	0	0	2	0	3	5	1	
	4	0	4	0	0	4	0	0	0	0	0	
	5	0	0	5	4	2	5	6	6	8	7	
	6	0	6	6	8	0	0	6	8	8	6	
	7	2	10	0	9	3	8	0	0	1	1	
	Total	4	20	13	21	9	15	12	17	22	15	X̄ = 14.8

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM / WK Reviewed By: [signature]

Toxicity Test
Daily Chemistries

Client:	Barr Engineering	Project Number:	11-183
Test Type:	Chronic	Species:	Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Raw Pond	C1	C2	C3	C4	C5	C6	Remarks
Day: 0	pH	7.34	8.45	8.46	8.43	8.34	8.05	7.86	
	Dissolved Oxygen (mg/l)	9.1	7.3	10.0	8.8	8.8	10.1	8.8	
Date: 7/8/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	1210	2750	2400	2400	2190	1822	1670	
Analyst: KM	Total Alkalinity (mg/l)	124	440	408	416	296	256	236	
	Total Hardness (mg/l)	172	1332	1112	1008	804	600	496	
	Total Ammonia (mg/l)								
Day: 1 old	pH	8.29	8.03	8.08	8.09	8.21	8.26	8.29	
	Dissolved Oxygen (mg/l)	8.0	6.2	7.0	6.3	6.3	5.8	6.3	
Date: 7/9/11	Temperature (°C)	25.5	25.5	25.5	25.5	25.5	25.5	25.5	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day: 1 New	pH	7.49	8.43	8.48	8.41	8.32	8.11	7.95	
	Dissolved Oxygen (mg/l)	9.0	7.5	8.5	8.5	8.7	8.7	8.6	
Date: 7/9/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day: 2 old	pH	8.32	8.07	8.12	8.16	8.23	8.26	8.28	
	Dissolved Oxygen (mg/l)	7.9	5.5	6.3	6.1	6.5	5.8	5.8	
Date: 7/10/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day: 2 New	pH	7.60	8.21	8.35	8.29	8.26	8.05	7.96	
	Dissolved Oxygen (mg/l)	8.7	7.6	7.9	8.0	8.3	8.4	8.3	
Date: 7/10/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								

Reviewed by: Walter Kount   Date: 7/20/11

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 11-103
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID: Raw Pond	C1	C2	C3	C4	C5	C6	Remarks
Day: 3 OLD	pH	8.20	7.96	8.05	8.08	8.14	8.27	8.30	
	Dissolved Oxygen (mg/l)	8.2	5.2	5.6	5.5	6.7	4.3	4.1	
Date: 7/11/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)								
Analyst: WK	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
	Total Ammonia (mg/l)								
Day: 3 New	pH	7.96	8.12	8.22	8.18	8.18	8.09	8.04	
	Dissolved Oxygen (mg/l)	8.6	7.3	7.5	7.5	7.8	7.9	7.9	
Date: 7/11/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)								
Analyst: WK	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day: 4 old	pH	8.29	8.01	8.12	8.07	8.15	8.14	8.16	
	Dissolved Oxygen (mg/l)	7.5	5.3	5.3	4.9	5.4	5.2	5.5	
Date: 7/12/11	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day: 4 New	pH	7.71	8.12	8.24	8.16	8.16	8.02	7.92	
	Dissolved Oxygen (mg/l)	9.1	8.0	8.1	8.1	8.4	8.4	8.4	
Date: 7/12/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)				8.03				
Day: 5 old	pH	8.22	8.00	8.05	~~7.69~~	8.11	8.10	8.15	
	Dissolved Oxygen (mg/l)	7.8	5.2	5.1	4.0	5.2	5.1	5.3	
Date: 7/13/11	Temperature (°C)	25.5	25.5	25.5	25.5	25.5	25.5	25.5	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								

Reviewed by: Walter Koenst Date: 7/20/11

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 11-183
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID Raw Pond	C1	C2	C3	C4	C5	C6	Remarks
Day: 5 New	pH	7.65	8.14	8.08	8.15	8.13	7.98	7.94	
	Dissolved Oxygen (mg/l)	8.7	7.8	8.1	8.2	8.3	8.3	8.3	
Date: 7/13/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
	Total Ammonia (mg/l)								
Day: 6 Old	pH	8.23	8.05	8.06	7.95	8.13	8.10	8.13	
	Dissolved Oxygen (mg/l)	7.7	5.8	5.2	5.5	5.5	5.1	5.4	
Date: 7/14/11	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day: 6 New	pH	7.68	8.07	8.04	8.13	8.10	7.96	7.92	
	Dissolved Oxygen (mg/l)	9.0	8.1	8.6	8.5	8.8	8.8	8.7	
Date: 7/14/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day: 7 Final	pH	8.20	7.96	8.01	7.70	8.08	8.11	8.13	
	Dissolved Oxygen (mg/l)	7.4	4.7	4.0	4.6	5.6	4.9	4.6	
Date: 7/15/11	Temperature (°C)	25.5	25.5	25.5	25.5	25.5	25.5	25.5	
	Conductivity (µmhos)								
Analyst: KM	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								
Day:	pH								
	Dissolved Oxygen (mg/l)								
Date: / /	Temperature (°C)								
	Conductivity (µmhos)								
Analyst:	Total Alkalinity (mg/l)								
	Total Hardness (mg/l)								

Reviewed by: [signature] Date: 7/20/11

Toxicity Test
Daily Chemistries

Client: BARR Engineering	Project Number: 11-183
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration: Recon						Remarks
Day: 0	pH	8.01						
	Dissolved Oxygen (mg/l)	8.0						
Date:	Temperature (°C)	25.0						
7/8/11	Conductivity (µmhos)	286						
Analyst:	Total Alkalinity (mg/l)	60						
KM	Total Hardness (mg/l)	80						
	Total Ammonia (mg/l)							
Day: 1	pH	8.25						
old	Dissolved Oxygen (mg/l)	8.3						
Date:	Temperature (°C)	25.5						
7/9/11	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 1	pH	8.37						
New	Dissolved Oxygen (mg/l)	8.3						
Date:	Temperature (°C)	25.0						
7/9/11	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 2	pH	8.22						
old	Dissolved Oxygen (mg/l)	8.0						
Date:	Temperature (°C)	25.4						
7/10/11	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 2	pH	8.22						
New	Dissolved Oxygen (mg/l)	8.2						
Date:	Temperature (°C)	25.0						
7/10/11	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							

Reviewed by: [signature] Date: 7/20/11

Bio.102(2)

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 11-103
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration: Recon					Remarks
Day: 3 Old	pH	8.19					
	Dissolved Oxygen (mg/l)	8.1					
Date: 7/11/11	Temperature (°C)	25.4					
	Conductivity (μmhos)						
Analyst: WK	Total Alkalinity (mg/l)						
	Total Hardness (mg/l)						
	Total Ammonia (mg/l)						
Day: 3 New	pH	8.23					
	Dissolved Oxygen (mg/l)	8.3					
Date: 7/11/11	Temperature (°C)	25.0					
	Conductivity (μmhos)						
Analyst: WK	Total Alkalinity (mg/l)						
	Total Hardness (mg/l)						
Day: 4 old	pH	8.13					
	Dissolved Oxygen (mg/l)	7.6					
Date: 7/12/11	Temperature (°C)	25.3					
	Conductivity (μmhos)						
Analyst: KM	Total Alkalinity (mg/l)						
	Total Hardness (mg/l)						
Day: 4 New	pH	8.19					
	Dissolved Oxygen (mg/l)	7.9					
Date: 7/12/11	Temperature (°C)	25.0					
	Conductivity (μmhos)						
Analyst: KM	Total Alkalinity (mg/l)						
	Total Hardness (mg/l)						
Day: 5 Old	pH	8.05					
	Dissolved Oxygen (mg/l)	7.7					
Date: 7/13/11	Temperature (°C)	25.5					
	Conductivity (μmhos)						
Analyst: KM	Total Alkalinity (mg/l)						
	Total Hardness (mg/l)						

Reviewed by: Walter Kord   Date: 7/20/11

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 11-183
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration: Recon						Remarks
Day: 5 New	pH	8.14						
	Dissolved Oxygen (mg/l)	8.0						
Date:	Temperature (°C)	25.0						
7/13/11	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Old	pH	8.08						
	Dissolved Oxygen (mg/l)	7.6						
Date:	Temperature (°C)	25.2						
7/14/11	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 6 New	pH	8.18						
	Dissolved Oxygen (mg/l)	8.1						
Date:	Temperature (°C)	25.0						
7/14/11	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 7 Final	pH	8.11						
	Dissolved Oxygen (mg/l)	7.5						
Date:	Temperature (°C)	25.5						
7/15/11	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kronk Date: 7/20/11

Chain of Custody

BARR
4700 West 77th Street
Minneapolis, MN 55435-4803
(952) 832-2600

COC 1 of 1

Project Number: 23/62-1021

Project Name: PERMEABLE REACTIVE BARRIER

№ 24933

Project Manager: CDA/KMP

Project Contact: CDA

Sampled by: CDA

Laboratory: ENVIRONMENTAL TOXICITY CONTROL

Number of Containers/Preservative

Sample Identification	Collection Date	Collection Time	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	Water: Volatile Organics (Pres.) *1	Water: Semivolatile Organics *2	Water: Dissolved Metals (HNO_3)	Water: Total Metals (HNO_3)	Water: General (Unpreserved) *3	Water: Cyanide (NaOH)	Water: Nutrients (H_2SO_4) *4	Water: Oil and Grease (H_2SO_4)	Water: Sulfide (Zn Acetate)	Water: Methane	Water: Bacteria ($Na_2S_2O_3$)	Water: DRO (HCl)	Soil: VOCs (2-oz tared MeOH) *1	Soil: GRO, BTEX (2-oz tared MeOH) *1	Soil: DRO (2-oz tared) - 25 grams	Soil: Metals (2-oz unpreserved)	Soil: SVOCs (2 or 4-oz unpres.) *2	Soil: % Moisture (plastic vial, unpres.)	Total No. Of Containers	Remarks
1. RAW POND H_2O	7/7/11	15:00	X		X							2														2	SINGLE CONCENTRATION CHRONIC TOXICITY TEST.
2. C1-7711	↓	↓	X		X							2														2	↓
3. C2-7711	↓	↓	X		X							2														2	↓
4. C3-7711	↓	↓	X		X							2														2	↓
5. C4-7711	↓	↓	X		X							2														2	↓
6. C5-7711	↓	↓	X		X							2														2	↓
7. C6-7711	↓	↓	X		X							2														2	↓
8.																											
9.																											
10.																											
11.																											
12.																											

Relinquished By	On Ice?	Date	Time	Received by	Date	Time
CDA	(Y) N	7/8/11	10:00	[signature]	7/8/11	13:00
	Y N					

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other ______

Air Bill Number:

Common Parameter/Container - Preservation Key
*1 - Volatile Organics = BTEX, GRO, TPH, Full List
*2 - Semivolatile Organics = PAHs, PCP, Dioxins, Full List, Herbicide/Pesticide/PCBs
*3 - General = pH, Chloride, Flouride, Alkalinity, TSS, TDS, TS, Sulfate
*4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

Toxicity test results conducted with treated water from the September 13, 2011 column tests with spent lime only. Test number 7.

TOXICITY TEST RESULTS

PERMEABLE REACTIVE SPENT LIME BARRIER

Report Date: September 23, 2011

Project No. 11-263

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

PROJECT: **CHRONIC TOXICITY TESTING**
PERMEABLE REACTIVE SPENT LIME BARRIER

PROJECT NUMBER: 11-263

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on water samples received by Environmental Toxicity Control (ETC) on September 14, 2011. The samples were water samples from the Permeable Reactive Spent Lime Project. Mr. Keith Pilgrim of Barr Engineering requested that we conduct chronic toxicity tests on the samples. The scope of our services was limited to conducting 7-day static renewal chronic toxicity tests using the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition, EPA-821-R-02-013.

Testing was started on 9/14/11.

RESULTS:

Toxicity test results are summarized in Table 1 and test conditions are summarized in Table 2.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference tests are shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.761 g/L NaCl	9/12/11

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst
Bioassay Manager

Table 1. **Survival of *Ceriodaphnia dubia***

Sample ID	48 Hour Survival (%)	7 day Survival (%)	Mean # Young Produced
Reconstituted Water	100	100	17.0
Raw Pond Water	100	80	17.6
C 1	0	0	0.0
C 2	80	40	2.2
C 3	100	100	8.1
C 4	90	90	6.6
C 5	100	100	16.2
C 6	100	100	17.6

Table 2. Summary of Chemical and Physical Data of Toxicity Tests

Sample ID	pH	Dissolved Oxygen (mg/L)	°C	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Recon H_2O	7.76 - 8.10	7.6 - 8.4	25	88	60	315
Raw Pond	7.18 - 8.04	7.6 - 10.7	25	88	80	747
C 1	8.90 - 9.28	7.7 - 9.0	25	560	400	1247
C 2	8.63 - 9.26	7.5 - 9.4	25	496	320	1210
C 3	8.52 - 9.29	7.4 - 10.3	25	372	248	1080
C 4	8.53 - 9.26	7.3 - 10.3	25	388	240	1081
C 5	8.42 - 9.22	7.4 - 10.7	25	300	192	1001
C 6	8.17 - 8.99	7.5 - 10.9	25	200	220	892

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: BARR ENGINEERING Project No.: 11-263

Test Dates/Time ● Initiation: 1045 9/14/11 Termination: 1115 9/20/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
Recon	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	4	4	4	4	4	4	4	3	4	
	4	0	0	0	0	0	0	0	0	0	0	
	5	6	6	3	5	4	4	6	7	5	6	
	6	8	9	1	8	9	8	10	12	9	6	
	Total	17	19	8	17	17	16	20	23	17	16	$\bar{x}$ = 17.0
Raw Pond	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	4	4	4	3	4	4	4	3	4	
	4	3	0	7	4	0	0	0	6	6	6	
	5	4	5	0	0	3	0	4	0	0	0	
	6	10	11	10	3X	9	X	14	11	10	12	
	Total	21	20	21	11	15	4	22	21	19	22	$\bar{x}$ = 17.6
C1	1	X	X	X	X	X	X	X	X	X	X	
	2											
	3											
	4											
	5											
	6											

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: WK|KM|SW Reviewed By: Walter Koenig

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: BARR ENGINEERING Project No.: 11-263

Test Dates/Time • Initiation: 1645 9/14/11 Termination: 1115 9/20/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
C2	1	✓	X	✓	✓	✓	✓	✓	X	✓	✓	
	2	✓		✓	✓	✓	✓	✓		✓	✓	
	3	1		1	1	0	1	2		1	4	
	4	0		X	0	2X	0	0		0	0	
	5	0			0		0	0		0	0	
	6	4			3X		0	X		0	2	
	Total	5	0	1	4	2	1	2	0	1	6	x̄ = 2.2
C3	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	1	4	2	4	3	4	3	2	2	3	
	4	0	0	0	0	0	0	0	0	0	0	
	5	3	2	1	0	0	2	0	0	3	4	
	6	7	0	5	0	7	1	0	6	6	6	
	Total	11	6	8	4	10	7	3	8	11	13	x̄ = 8.1
C4	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	X	✓	✓	✓	✓	
	3	1	4	2	3	1		4	0	0	3	
	4	5	0	0	0	0		0	0	0	0	
	5	0	0	2	0	0		2	0	4	3	
	6	6	0	0	4	3		5	0	7	7	
	Total	12	4	4	7	4	0	11	0	11	13	x̄ = 6.6

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: WK|KM|SW Reviewed By: [signature]

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: BARR ENGINEERING Project No.: 11-263
Test Dates/Time • Initiation: 1645 9/14/11 Termination: 1115 9/20/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
C5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	3	3	3	4	4	3	3	3	4	
	4	6	6	6	6	0	0	0	0	0	4	
	5	0	0	0	0	0	4	4	4	3	0	
	6	10	10	11	11	0	10	10	6	11	3	
	Total	19	19	20	20	4	18	17	13	17	15	$\bar{x}$ = 16.2
C6	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	4	4	3	4	4	4	3	4	2	
	4	6	0	6	5	0	6	0	0	6	8	
	5	0	4	0	0	3	0	4	6	0	0	
	6	8	12	7	10	8	11	4	10	4	12	
	Total	18	20	17	18	15	21	12	19	14	22	$\bar{x}$ = 17.6

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: WK/KM/SW Reviewed By: [signature]

Toxicity Test
Daily Chemistries

Client: BARR ENGINEERING	Project Number: 11-263
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Sample ID: Recon H2O	Raw Pond	C1	C2	C3	C4	C5	C6	Remarks
Day: 0	pH	8.03	7.18	9.28	9.26	9.29	9.26	9.22	8.99	
	Dissolved Oxygen (mg/l)	8.3	10.7	9.0	9.2	10.3	10.3	10.7	10.9	
Date:	Temperature (°C)	250	25.0	25.0	25.0	25.0	25.0	25.0	25.0	
9/14/11	Conductivity (µmhos)	315	747	1247	1210	1080	1081	1001	892	
Analyst:	Total Alkalinity (mg/l)	60	80	400	320	248	240	192	220	
WK.	Total Hardness (mg/l)	88	88	560	496	372	388	300	200	
	Total Ammonia (mg/l)									
Day: 1 OLD	pH	7.97	8.01	8.90	8.84	8.65	8.69	8.59	8.43	
	Dissolved Oxygen (mg/l)	8.1	7.9	7.7	7.6	8.0	7.8	7.9	8.0	
Date:	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	
9/15/11	Conductivity (µmhos)									
Analyst: JS	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 1 New	pH	7.98	7.56	9.27	9.25	9.22	9.21	9.17	8.89	
	Dissolved Oxygen (mg/l)	8.1	9.4	8.6	8.7	8.9	9.0	9.2	9.4	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	250	250	250	25.0	
9/15/11	Conductivity (µmhos)									
Analyst: JS	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 2 old	pH	7.76	7.99		8.81	8.62	8.62	8.51	8.35	
	Dissolved Oxygen (mg/l)	8.1	8.2		8.2	8.1	8.0	8.0	8.2	
Date:	Temperature (°C)	25.3	25.3		25.3	25.3	25.3	25.3	25.3	
9/16/11	Conductivity (µmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 2 New	pH	7.82	7.62		9.13	9.16	9.15	9.13	8.74	
	Dissolved Oxygen (mg/l)	8.4	9.6		9.4	9.6	9.5	9.7	9.8	
Date:	Temperature (°C)	25.0	25.0		25.0	25.0	25.0	25.0	25.0	
9/16/11	Conductivity (µmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									

Reviewed by: [signature] Date: 9/23/11

Toxicity Test
Daily Chemistries

Client:	Barr Engineering	Project Number:	11-263
Test Type:	Chronic.	Species:	C. dubia

Day/Date/Analyst	Parameter	Recon H2O	Raw Pond	C1	C2	C3	C4	C5	C6	Remarks
Day: 3 OLD	pH	7.94	8.01		8.63	8.54	8.54	8.44	8.17	
	Dissolved Oxygen (mg/l)	7.8	7.9		7.5	7.7	7.8	7.9	7.7	
Date: 9/17/11	Temperature (°C)	25.4	25.4		25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)									
Analyst: WK	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
	Total Ammonia (mg/l)					9.20				
Day: 3 New	pH	8.09	7.59		9.18	~~8.87~~	9.19	9.12	8.87	
	Dissolved Oxygen (mg/l)	8.1	8.6		8.4	8.6	8.6	8.6	8.8	
Date: 9/17/11	Temperature (°C)	25.0	25.0		25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 4 old	pH	7.78	8.04		8.75	8.65	8.66	8.55	8.39	
	Dissolved Oxygen (mg/l)	7.6	7.6		7.5	7.4	7.3	7.4	7.5	
Date: 9/18/11	Temperature (°C)	25.5	25.5		25.5	25.5	25.5	25.5	25.5	
	Conductivity (µmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 4 New	pH	8.10	7.61		9.23	9.27	9.26	9.19	8.91	
	Dissolved Oxygen (mg/l)	7.7	8.9		8.9	9.0	9.1	9.1	9.3	
Date: 9/18/11	Temperature (°C)	25.0	25.0		25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day: 5 old	pH	7.97	8.01		8.63	8.52	8.53	8.42	8.28	
	Dissolved Oxygen (mg/l)	7.9	7.9		7.8	7.5	7.5	7.6	7.6	
Date: 9/19/11	Temperature (°C)	25.4	25.4		25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)									
Analyst: SW	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									

Reviewed by: Walter Koenig   Date: 9/23/11

Toxicity Test
Daily Chemistries

Client:	Barr Engineering	Project Number:	11-263
Test Type:	Chronic	Species:	C. dubia

Day/Date/Analyst	Parameter	Recon H2O	Raw Pond	C1	C2	C3	C4	C5	C6	Remarks
Day: 5 New	pH	7.95	7.73		9.08	9.11	9.09	9.00	8.68	
	Dissolved Oxygen (mg/l)	7.8	8.8		8.3	8.5	8.6	8.6	8.7	
Date: 9/19/11	Temperature (°C)	25.0	25.0		25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)									
Analyst: SW	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
	Total Ammonia (mg/l)									
Day: 6 Final	pH	7.91	7.77		8.67	8.57	8.55	8.42	8.28	
	Dissolved Oxygen (mg/l)	8.0	8.0		7.8	8.0	7.9	8.0	7.8	
Date: 9/20/11	Temperature (°C)	25.4	25.4		25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)									
Analyst: KM	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day:	pH									
	Dissolved Oxygen (mg/l)									
Date: / /	Temperature (°C)									
	Conductivity (µmhos)									
Analyst:	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day:	pH									
	Dissolved Oxygen (mg/l)									
Date: / /	Temperature (°C)									
	Conductivity (µmhos)									
Analyst:	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									
Day:	pH									
	Dissolved Oxygen (mg/l)									
Date: / /	Temperature (°C)									
	Conductivity (µmhos)									
Analyst:	Total Alkalinity (mg/l)									
	Total Hardness (mg/l)									

Reviewed by: Walter Koenst   Date: 9/23/11

BARR

Chain of Custody

4700 West 77th Street
Minneapolis, MN 55435-4803
(952) 832-2600

COC 1 of 1

Project Manager: KMP

Project Contact: CDA

Sampled by: CDA

Laboratory: ENVIRONMENTAL TOXICITY CONTROL

Project Number: 23/62-1021.01

Project Name: PERMEABLE REACTIVE BARRIER

№ 24939

Sample Identification	Collection Date	Collection Time	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	Water: Volatile Organics (Pres.) *1	Water: Semivolatile Organics *2	Water: Dissolved Metals (HNO_3)	Water: Total Metals (HNO_3)	Water: General (Unpreserved) *3	Water: Cyanide (NaOH)	Water: Nutrients (H_2SO_4) *4	Water: Oil and Grease (H_2SO_4)	Water: Sulfide (Zn Acetate)	Water: Methane	Water: Bacteria ($Na_2S_2O_3$)	Water: DRO (HCl)	Soil: VOCs (2-oz tared MeOH) *1	Soil: GRO, BTEX (2-oz tared MeOH) *1	Soil: DRO (2-oz tared) - 25 grams	Soil: Metals (2-oz unpreserved)	Soil: SVOCs (2 or 4-oz unpres.) *2	Soil: % Moisture (plastic vial, unpres.)	Total No. Of Containers	Remarks
1. [illegible]																											
2. RAW POND H_2O	9/13/11	12:00	X		X							2														2	SINGLE CONCENTRATION CHRONIC TOXICITY TEST
3. C1-91311	↓	↓	↓		↓							2														2	↓
4. C2-91311	↓	↓	↓		↓							2														2	↓
5. C3-91311	↓	↓	↓		↓							2														2	↓
6. C4-91311	↓	↓	↓		↓							2														2	↓
7. C5-91311	↓	↓	↓		↓							2														2	↓
8. C6-91311	↓	↓	↓		↓							2														2	↓
9.																											
10.																											
11.																											
12.																											

Common Parameter/Container - Preservation Key

*1 - *Volatile Organics = BTEX, GRO, TPH, Full List*
*2 - *Semivolatile Organics = PAHs, PCP, Dioxins, Full List, Herbicide/Pesticide/PCBs*
*3 - *General = pH, Chloride, Flouride, Alkalinity, TSS, TDS, TS, Sulfate*
*4 - *Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN*

Relinquished By:	On Ice?	Date	Time	Received by:	Date	Time
CDA	(Y) N	9/14/11	15:00	[signature]	9/14/11	1550
	Y N					

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other ______

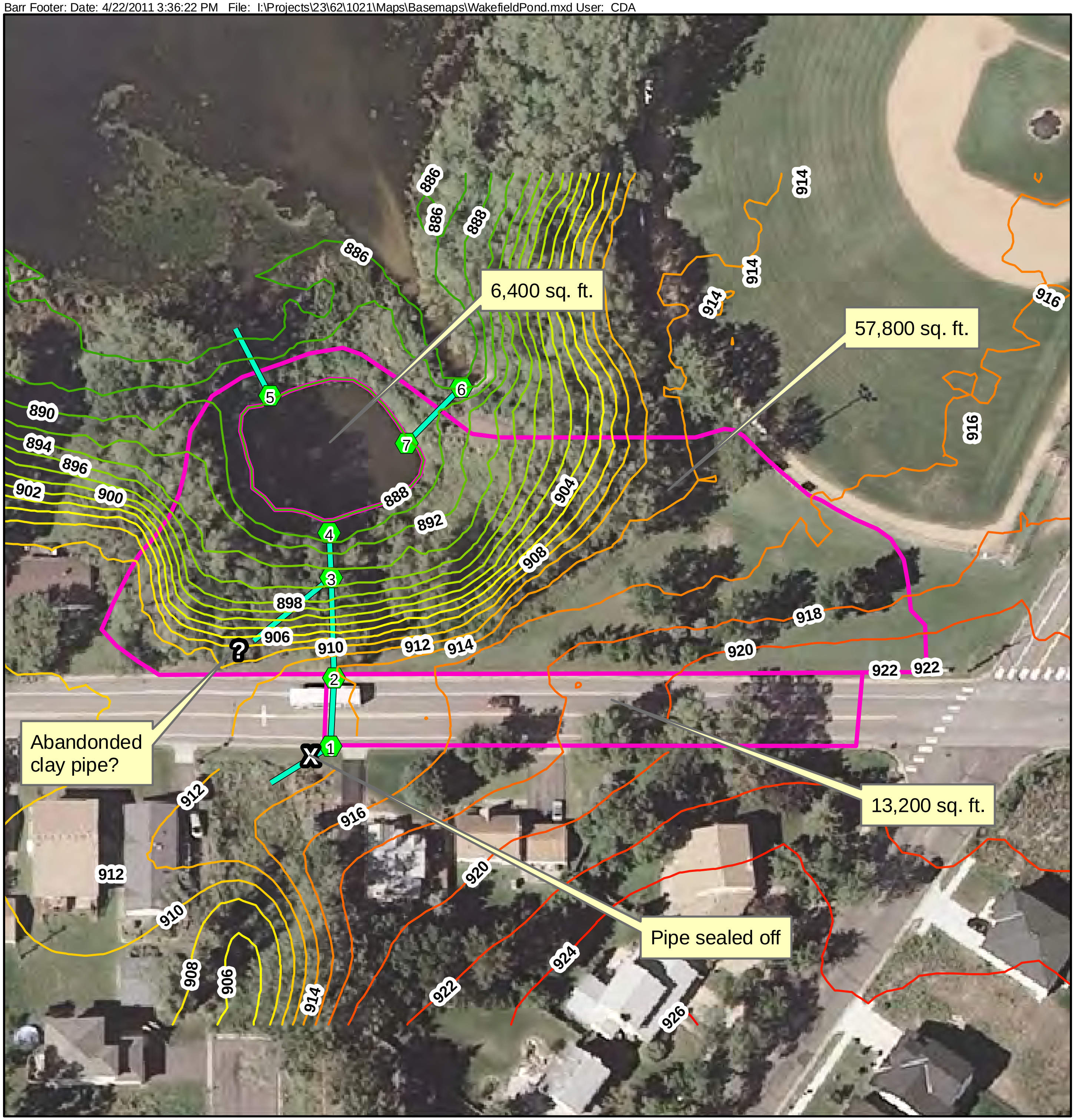
Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

H:RLG\STDFORMS\Chain Of Custody Form RLG Rev. 070105

Appendix B

Design drawings and supporting design drawings



Note:
See the following pages for pictures of the manholes/catchbasins

Figure 1

WAKEFIELD POND
WATERSHED AND TOPO
PRB DESIGN
RWMWD
St. Paul, MN

Node #1 of Figure 1. Catchbasin on the South side of Larpenteur Ave. Pipe to the South-West is plugged.

Node #2 of Figure 1. Catchbasin on the North side of Larpenteur Ave.

Node #3 of Figure 1. Manhole along the hill side South of Wakefield Pond.

Node #6 of Figure 1. Low Flow diversion inlets to Wakefield Pond from the East.

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NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION

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SIGNATURE ____________

PRINTED NAME ____________

DATE ________ REG. NO. ________

	A	B	C	0	1	2	3
CLIENT							
BID							
CONSTRUCTION							
RELEASED TO/FOR	DATE RELEASED						

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MINNEAPOLIS, MN.
55435-4803
Ph: 1-800-632-2277
Fax: (952) 832-2601
www.barr.com

Scale	AS SHOWN
Date	03-23-11
Drawn	CDA
Checked	KMP
Designed	CDA
Approved	KMP

RWMWD
ST. PAUL, MN

PERMEABLE REACTIVE BARRIER
ST. PAUL, MN

EXISTING CONDITIONS
FIELD STUDY

BARR PROJECT No.
23/62-1021.01

CLIENT PROJECT No.

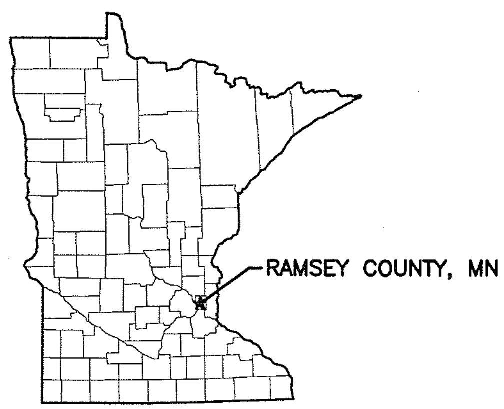
DWG. No.
C-01

REV. No.

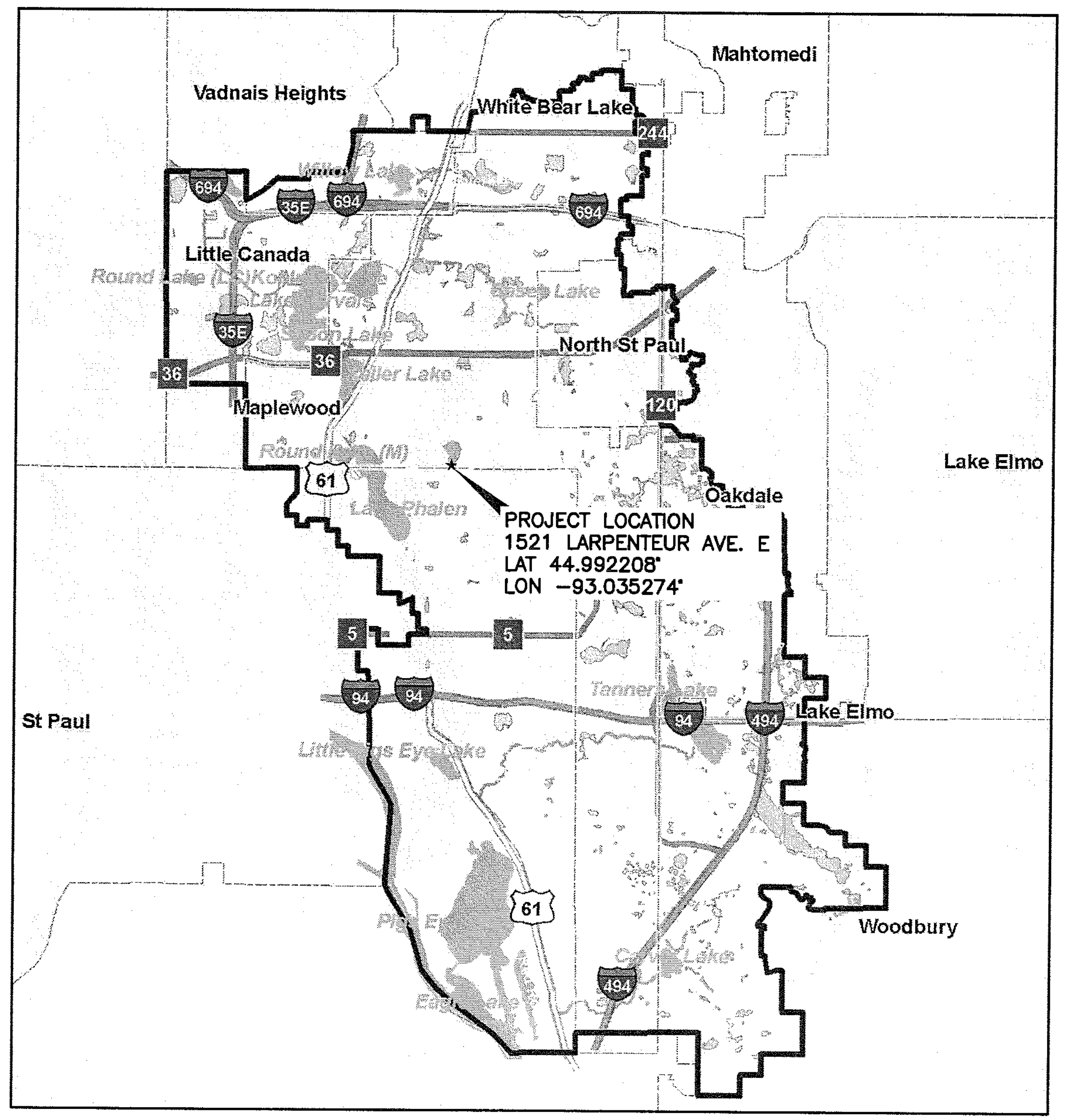
RAMSEY-WASHINGTON METRO WATERSHED DISTRICT

PERMEABLE REACTIVE BARRIER
WAKEFIELD PARK

MAPLEWOOD, MINNESOTA



STATE MAP



VICINITY MAP

SHEET INDEX
G-GENERAL
C-CIVIL

SHEET NO.	TITLE
G-01	SITE LOCATION AND SHEET INDEX
C-01	SITE PLAN AND EROSION CONTROL
C-02	GRADING AND STORM SEWER
C-03	SECTIONS AND DETAILS

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION

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SIGNATURE [signature]
PRINTED NAME NATHAN D. CAMPEAU
DATE 8/17/2011 REG. NO. 44917

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CLIENT							
BID			8/17				
CONSTRUCTION							

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Date	8/17/2011
Drawn	GGN
Checked	NDC
Designed	GGN
Approved	NDC

RAMSEY-WASHINGTON METRO WATERSHED DISTRICT
LITTLE CANADA, MINNESOTA

PERMEABLE REACTIVE BARRIER
MAPLEWOOD, MINNESOTA
SITE LOCATION AND SHEET INDEX

BARR PROJECT No. 23/62-1021
CLIENT PROJECT No.
DWG. No. G-01
REV. No. 0

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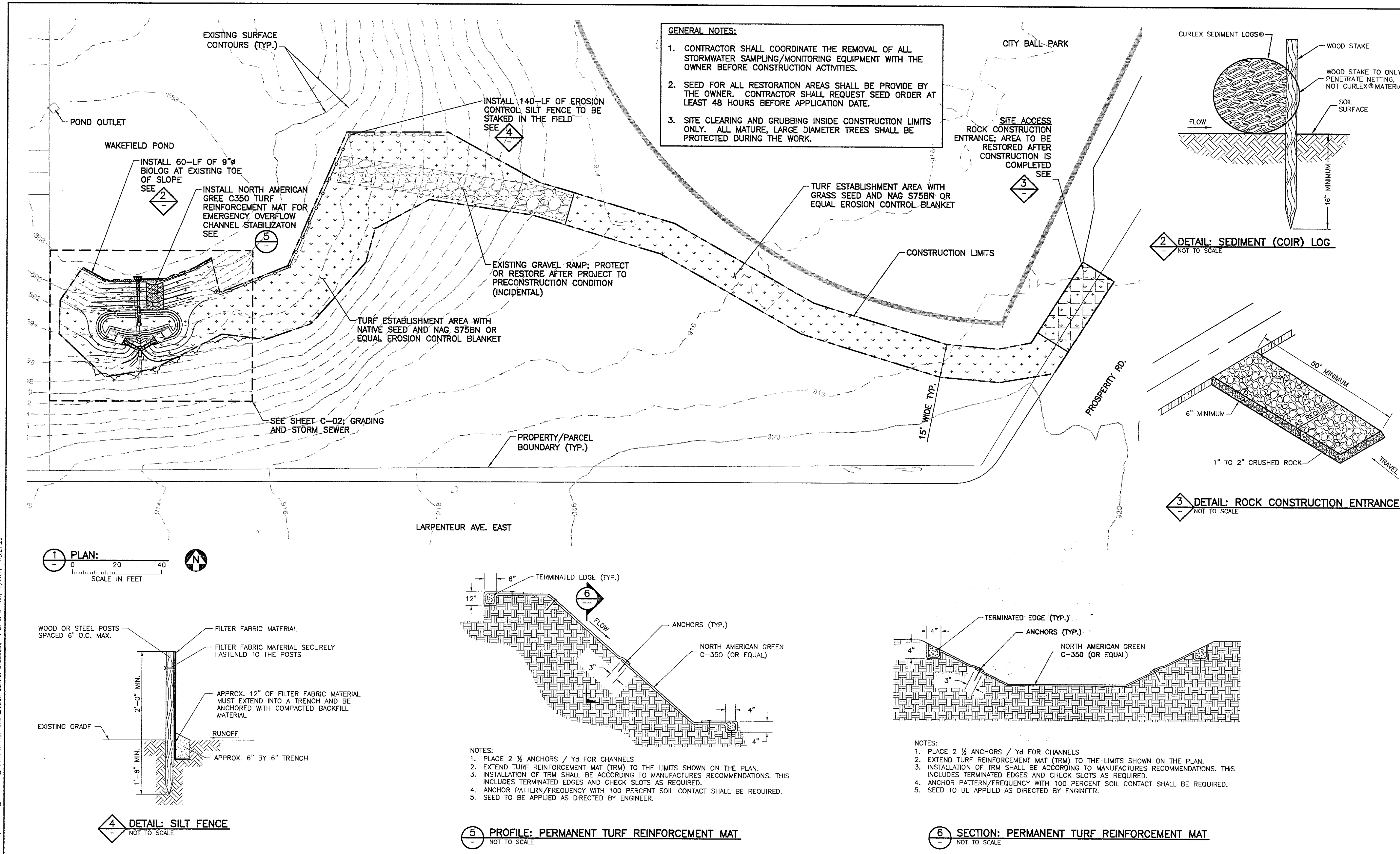

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Date	8/17/2011
Drawn	GGN
Checked	NDC
Designed	GGN
Approved	NDC

RAMSEY-WASHINGTON METRO WATERSHED DISTRICT

LITTLE CANADA, MINNESOTA

PERMEABLE REACTIVE BARRIER

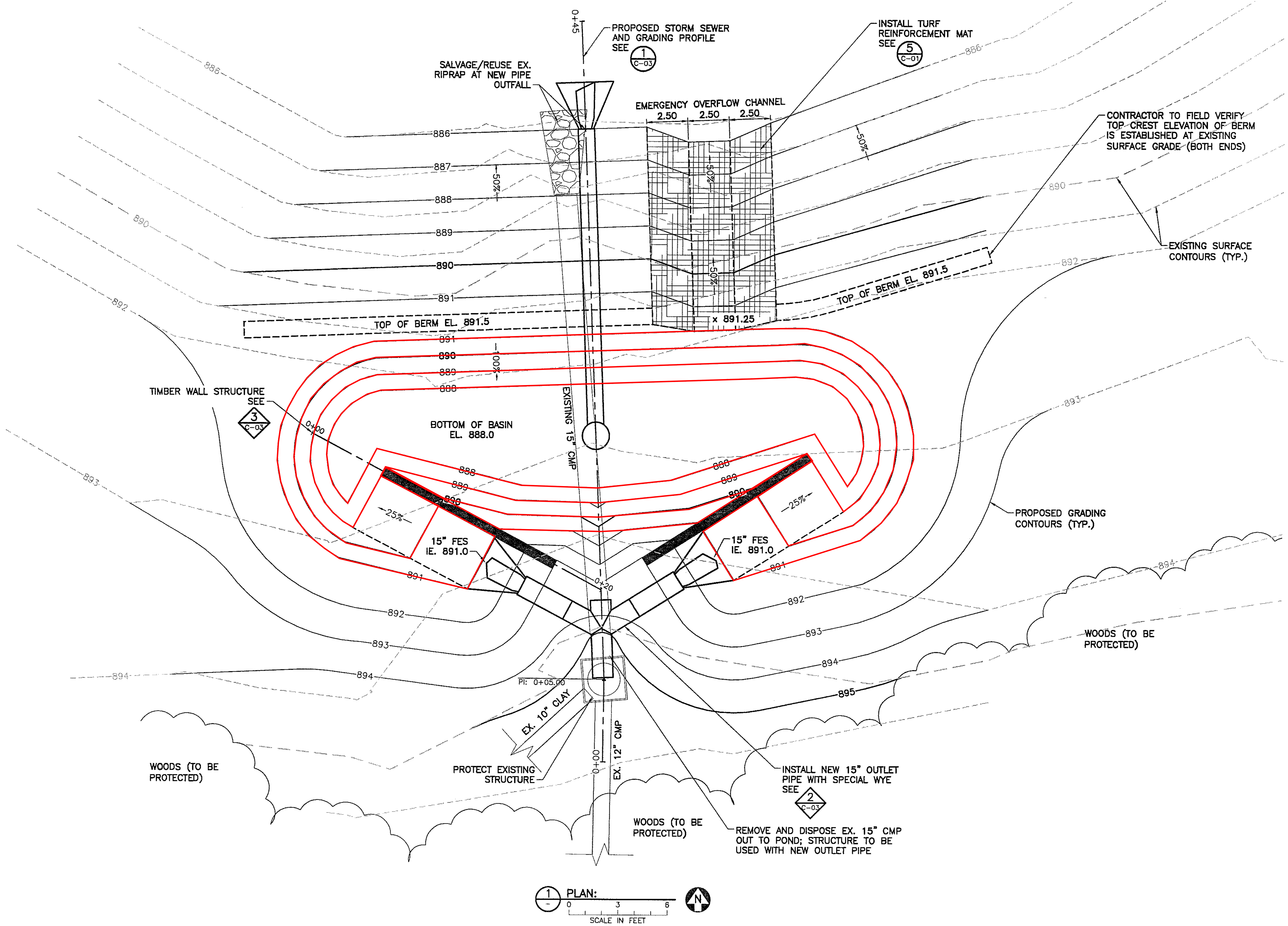
MAPLEWOOD, MINNESOTA

SITE PLAN AND EROSION CONTROL

BARR PROJECT No. 23/62-1021

CLIENT PROJECT No.

DWG. No. C-01 REV. No. 0



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RELEASED TO/FOR	A	B	C	0	1	2	3
CLIENT							
BID			8/17				
CONSTRUCTION							
	DATE RELEASED						

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Date	8/17/2011
Drawn	GGN
Checked	NDC
Designed	GGN
Approved	NDC

RAMSEY-WASHINGTON METRO WATERSHED DISTRICT

LITTLE CANADA, MINNESOTA

PERMEABLE REACTIVE BARRIER
MAPLEWOOD, MINNESOTA

GRADING AND STORM SEWER

BARR PROJECT No. 23/62-1021
CLIENT PROJECT No.
DWG. No. C-02
REV. No. 0

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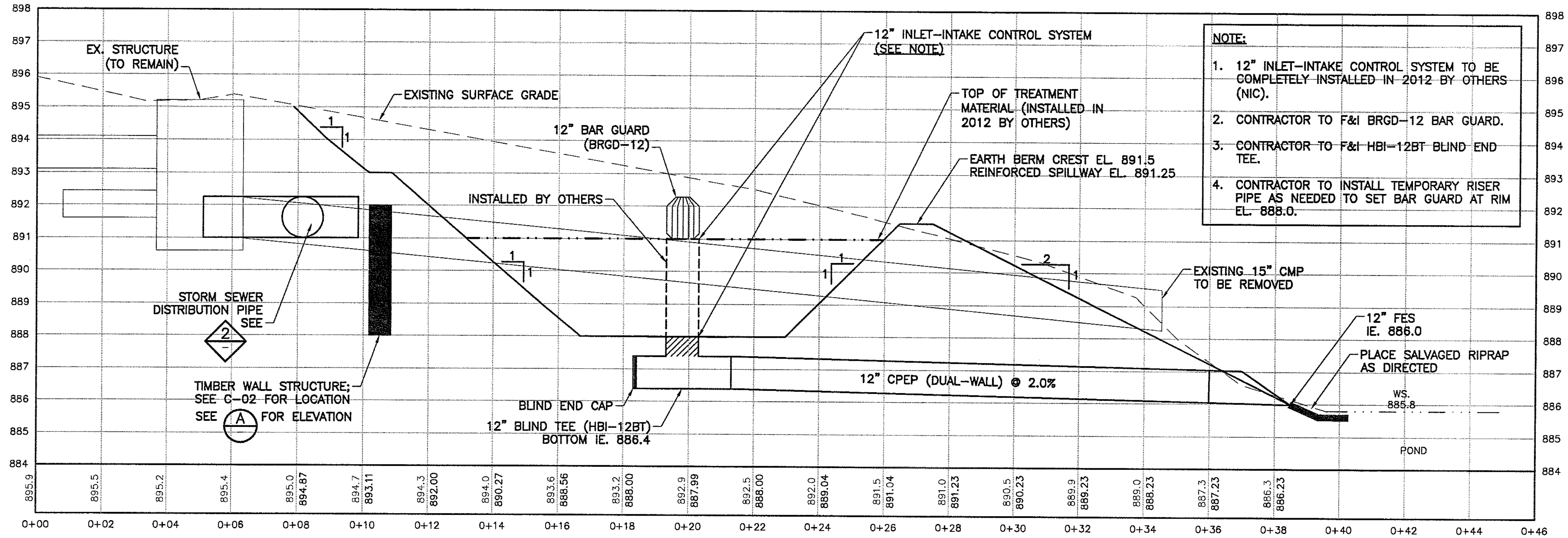
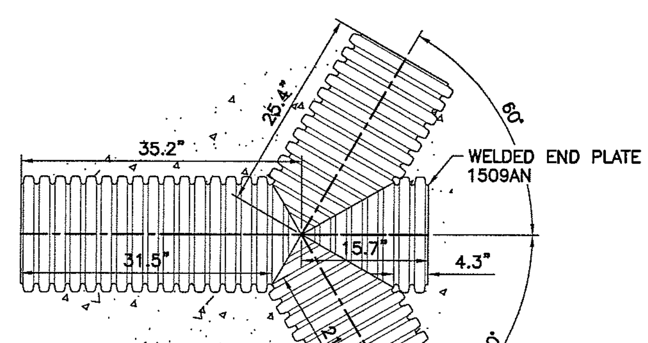


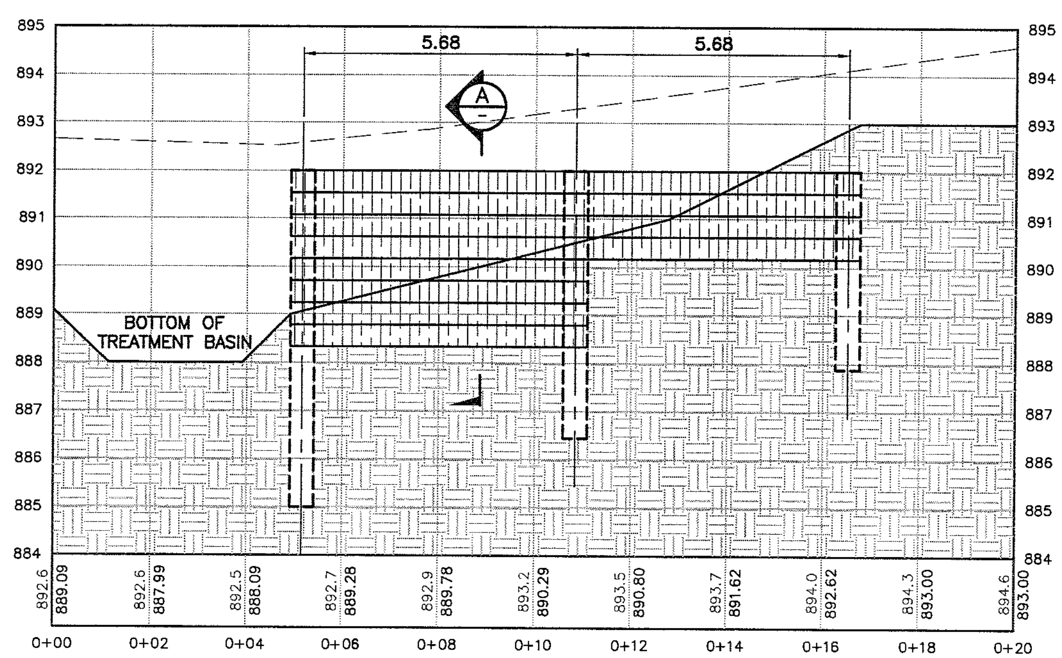
1 PROFILE: STORM SEWER AND GRADING

SCALE IN FEET



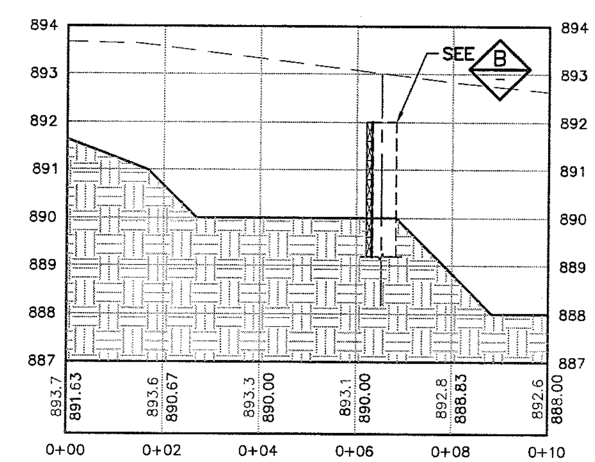
NOTE:
15" DOUBLE MITERED WYE W/WELDED END PLATE TO BE INSTALLED IN APPROX. 7-CF OF CONCRETE FILL (INCIDENTAL)

2 DETAIL: 15" SPECIAL WYE
NOT TO SCALE



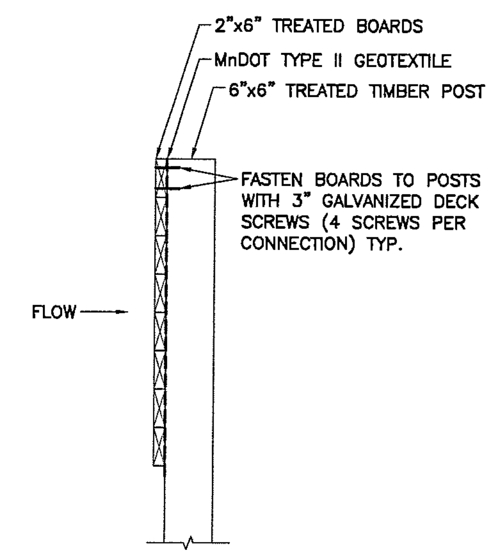
3 ELEVATON: TIMBER WALL STRUCTURE

SCALE IN FEET



A ELEVATON: TIMBER WALL STRUCTURE

SCALE IN FEET



B DETAIL: TIMBER WALL ASSEMBLY
NOT TO SCALE

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CLIENT							
BID			8/17				
CONSTRUCTION							
	DATE RELEASED						

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Scale	AS SHOWN
Date	8/17/2011
Drawn	GGN
Checked	NDC
Designed	GGN
Approved	NDC

RAMSEY-WASHINGTON METRO WATERSHED DISTRICT
LITTLE CANADA, MINNESOTA

PERMEABLE REACTIVE BARRIER
MAPLEWOOD, MINNESOTA
SECTIONS AND DETAILS

BARR PROJECT No. 23/62-1021
CLIENT PROJECT No.
DWG. No. C-03
REV. No. 0

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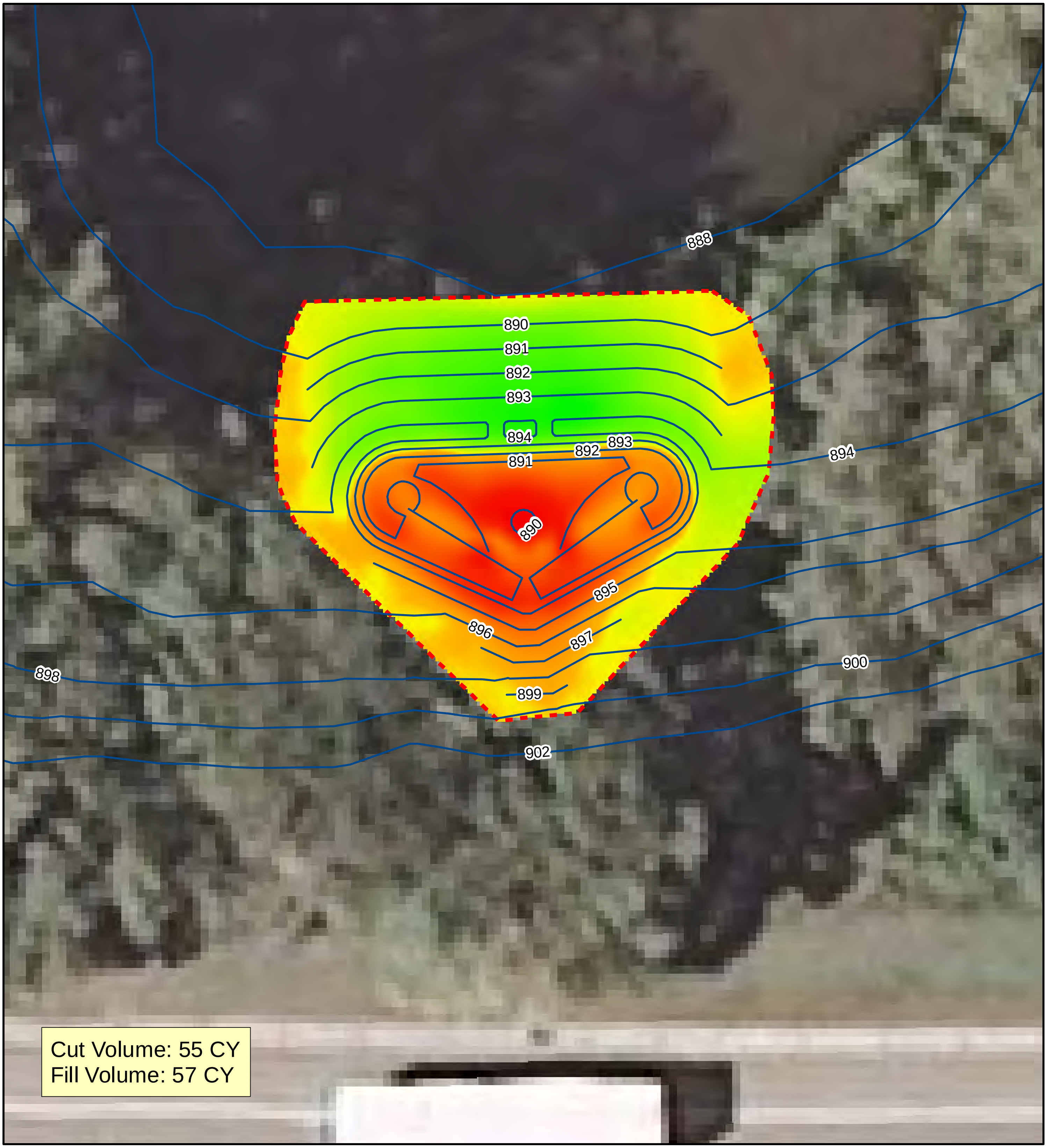


Design Contours

Cut Depth

4.1' Cut

3.5' Fill

N

Feet

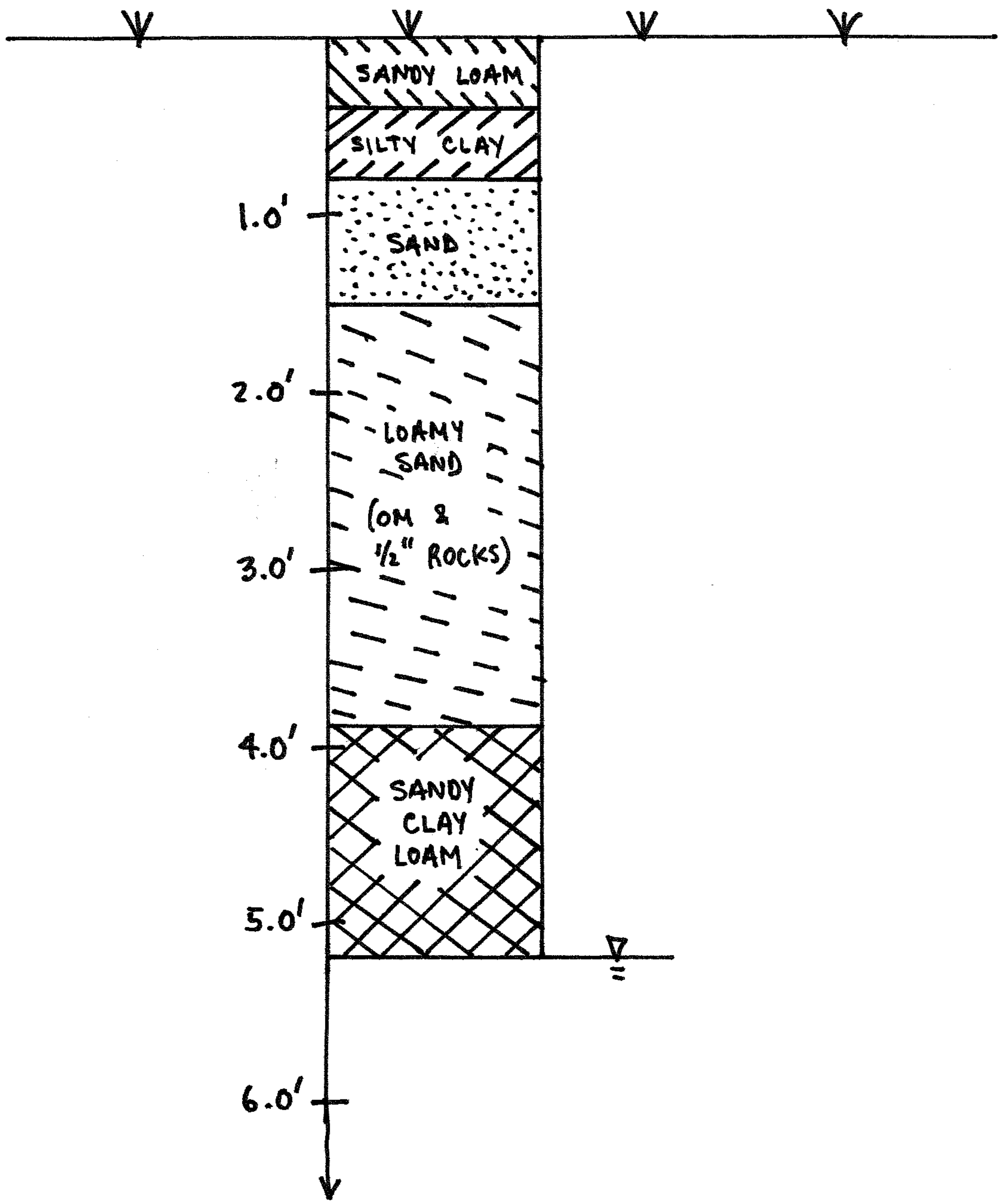
0 10 20 30 40 50

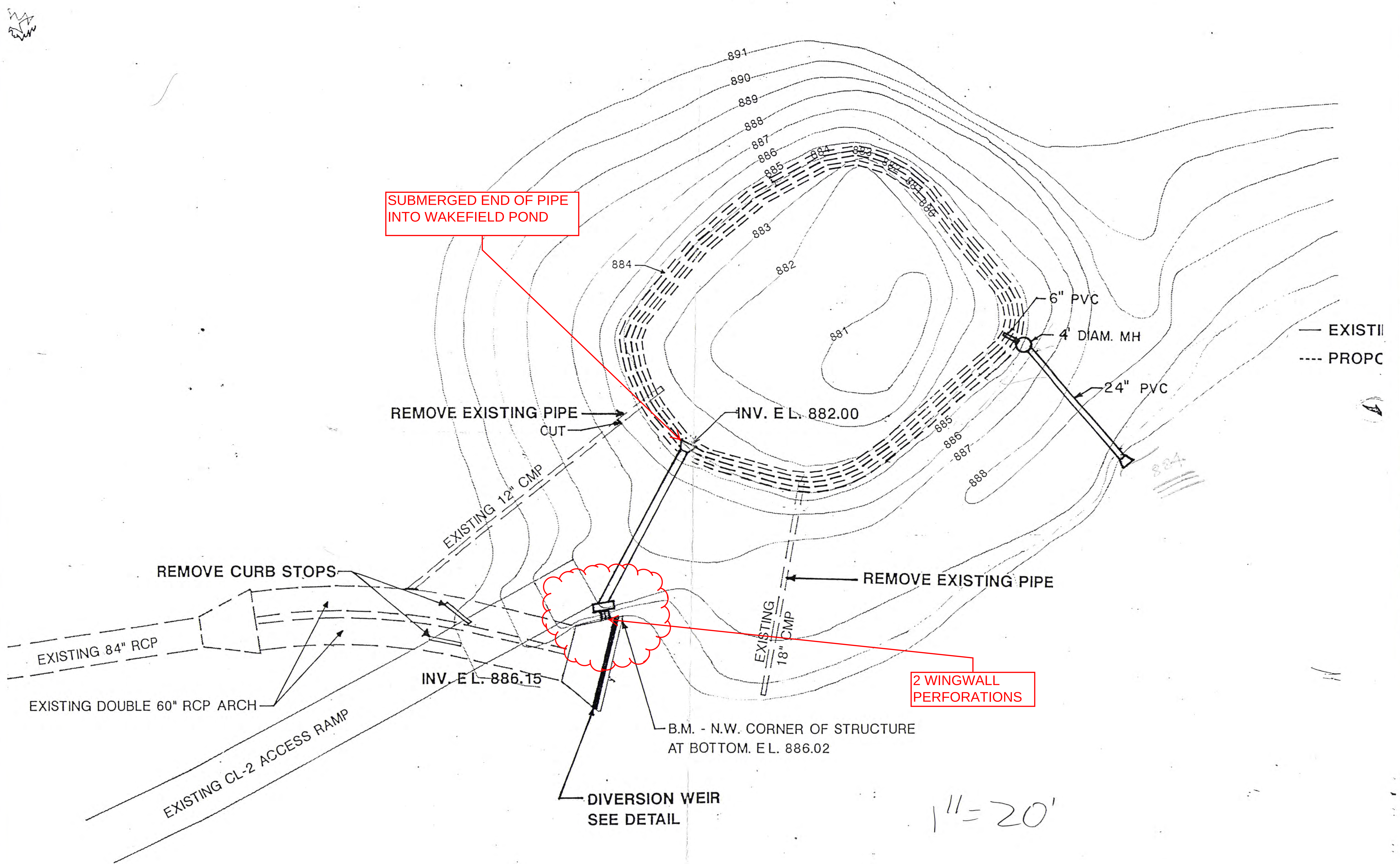
Cut & Fill
PRB Field Study Design
RWMWD
Maplewood, MN

HAND-AUGERED BORE HOLE NEAR WAKEFIELD POND.

DATE: 5/17/2011

LOCATION: WITHIN THE LIME TREATMENT BASIN





SUBMERGED END OF PIPE INTO WAKEFIELD POND
891
890
889
888
887
886
885
884
883
882
881
6" PVC
4' DIAM. MH
24" PVC
EXISTI
PROPC
REMOVE EXISTING PIPE
CUT
INV. E L. 882.00
EXISTING 12" CMP
REMOVE CURB STOPS
REMOVE EXISTING PIPE
EXISTING 18" CMP
EXISTING 84" RCP
INV. E L. 886.15
2 WINGWALL PERFORATIONS
EXISTING DOUBLE 60" RCP ARCH
B.M. - N.W. CORNER OF STRUCTURE AT BOTTOM. E L. 886.02
EXISTING CL-2 ACCESS RAMP
DIVERSION WEIR SEE DETAIL
1" = 20'

Appendix C

Monitoring data collected in 2012 and 2013 for the pilot system

Table C-1. Concentration of metals, nutrients, and other constituents in stormwater entering the treatment cell (In) and after treatment (Out).

Date	Aluminum (mg/L)		Calcium (mg/L)		Copper (ug/l)		Iron (mg/L)		Lead (ug/L)		Zinc (ug/L)	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
5/21/12	0.325	0.311	4.76	5.32	8.7	17.5	0.45	0.40	3.1	3.5	56.5	68.8
5/25/12	0.305	0.200	3.54	4.25	(1)	(1)	0.38	0.24	(1)	(1)	(1)	(1)
6/11/12	0.663	0.783	8.76	30.4	(1)	(1)	0.94	2.79	(1)	(1)	(1)	(1)
6/18/12	0.093	0.169	2.91	2.28	(1)	(1)	0.11	0.20	(1)	(1)	(1)	(1)
6/19/12	0.374	0.317	3.56	4.14	(1)	(1)	0.49	0.38	(1)	(1)	(1)	(1)

Date	Total Phosphorus (mg/L)		Total Dissolved Phosphorus (mg/L)		Ortho-Phosphorus (mg/L)		Total Suspended Solids (mg/L)		Chloride (mg/L)	
	In	Out	In	Out	In	Out	In	Out	In	Out
5/21/12	0.360	0.160	0.300	<0.100	0.210	<0.02	34.8	37.8	3.9	12.9
5/25/12	0.180	<0.100	0.110	<0.100	0.050	<0.02	31.2	12.3	<4.0	4.1
6/11/12	0.34	0.270	(1)	(1)	0.046	0.062	(1)	(1)	(1)	(1)
6/18/12	0.110	0.110	0.120	<0.100	0.035	<0.02	(1)	(1)	<4.0	<4.0
6/19/12	0.150	<0.100	(1)	(1)	0.038	<0.02	17.7	40.3	<4.0	<4.0

Table C-2. Concentration of metals, nutrients, and other constituents in stormwater entering the treatment cell (In) and after treatment (Out).

Date	Aluminum (mg/L)		Calcium (mg/L)		Copper (ug/l)		Iron (mg/L)		Lead (ug/L)		Zinc (ug/L)	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
5/20/2013	2.00	0.41	15.0	5.3	29	10	3	0.47	12	1.7	140	20
6/13/2013	1.20	0.11	10.0	3.7	20	2.5	1.7	0.12	8.8	0	110	6.6
6/17/2013	8.50	3.70	15.0	10.0	(1)	(1)	9.1	4	(1)	(1)	(1)	(1)
6/21/2013	4.00	2.00	12.0	10.0	21	24	4.5	2.1	9.3	3.8	82	35
6/24/2013	3.70	4.00	16.0	18.0	(1)	(1)	4.7	4.3	(1)	(1)	(1)	(1)
7/1/2013	1.10	1.10	6.5	7.3	(1)	(1)	1.2	1.1	(1)	(1)	(1)	(1)
7/15/2013	0.41	0.34	6.8	3.3	(1)	(1)	0.5	0.35	(1)	(1)	(1)	(1)
8/5/2013	0.98	0.16	10.0	11.0	(1)	(1)	1.4	0.2	(1)	(1)	(1)	(1)
10/3/2013	8.40	0.63	11.0	2.6	(1)	(1)	8.6	0.54	(1)	(1)	(1)	(1)

(1) Analyte not analyzed.

Date	Ortho-Phosphorus (mg/L)		Total Dissolved Phosphorus (mg/L)		Total Phosphorus (mg/L)		Total Suspended Solids (mg/L)		Chloride (mg/L)	
	In	Out	In	Out	In	Out	In	Out	In	Out
5/20/2013	0.26	0	0.34	0.015	0.98	0.081	160	21	6.3	9.6
6/13/2013	0.1	0.014	(1)	(1)	0.29	0.049	58	8.5	2.9	4.0
6/17/2013	0.061	0.034	0.082	0.049	0.49	0.21	350	150	1.1	2.1
6/21/2013	0.16	0.046	0.13	0.019	0.49	0.18	170	78	2.2	4.9
6/24/2013	0.048	0.09	0.086	0.091	0.38	0.31	200	180	2.8	2.2
7/1/2013	0.048	0.036	0.063	0.055	0.12	0.11	110	48	0.4	3.5
7/15/2013	0.073	0.024	0.085	0.034	0.16	0.056	18	16	3.3	3.5
8/5/2013	0.15	0.015	0.12	0.02	0.29	0.081	70	9.5	2.9	22.0
10/3/2013	0.34	0.032	0.22	0.015	0.68	0.063	190	4	3.0	3.0

(1) Analyte not analyzed.

Table C-3. Phosphorus fractions and metals in sediment collected from the bottom of a pond that received the lime-cell treated stormwater.

Average of Cores 2012

Bottom Depth (cm)	Mobile P (mg/cm3)	Al-P (mg/cm3)	Ca-P (mg/cm3)	Org-P (mg/cm3)	Aluminum (g/kg)	Calcium (g/kg)	Iron (g/kg)
0-1	0.045	0.017	0.041	0.044	15.0	27.5	31.5
1-2	0.069	0.039	0.081	0.059	16.0	29.5	32.0
2-3	0.074	0.045	0.092	0.067	16.5	28.5	32.0
3-4	0.058	0.040	0.085	0.079	14.5	30.0	29.0
4-5	0.056	0.037	0.080	0.074	15.0	30.0	28.0
5-7	0.062	0.061	0.121	0.059	14.5	29.5	26.5
7-9	0.074	0.083	0.172	0.051	15.0	30.0	26.5
9-11	0.094	0.085	0.216	0.028	13.5	23.0	26.5
11-13	0.112	0.101	0.265	0.060	13.0	22.5	25.5
13-15	0.109	0.100	0.281	0.057	15.5	24.0	27.0
15-17	0.137	0.115	0.315	0.059	15.5	23.5	27.5
17-19	0.105	0.130	0.285	0.0	14.0	26.0	27.0
19-21	0.115	0.112	0.240	0.088	14.0	26.5	27.0

Average of Cores 2014

Bottom Depth (cm)	Mobile P (mg/cm3)	Al-P (mg/cm3)	Ca-P (mg/cm3)	Org-P (mg/cm3)	Aluminum (g/kg)	Calcium (g/kg)	Iron (g/kg)
0-2	0.013	0.015	0.035	0.056	13.0	17.0	21.7
2-4	0.029	0.035	0.073	0.053	14.0	20.3	23.3
4-6	0.046	0.060	0.100	0.034	15.0	24.0	25.7
6-8	0.048	0.068	0.112	0.041	16.0	25.3	26.3
8-10	0.052	0.074	0.120	0.031	14.7	29.7	21.7
10-15	0.053	0.102	0.191	0.025	11.6	27.7	20.7

Attachment A

Pilot system laboratory data for sediment, spent lime, and toxicity

Pace Analytical Services, Inc.
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January 27, 2014

Mr. Jim Bode
St. Paul Regional Water Serv.
1900 Rice St.N
St. Paul, MN 55113

RE: Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Dear Mr. Bode:

Enclosed are the analytical results for sample(s) received by the laboratory on December 17, 2013. The results relate only to the samples included in this report. Results reported herein conform to the most current TNI standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Shawn Davis
shawn.davis@pacelabs.com
Project Manager

Enclosures

REPORT OF LABORATORY ANALYSIS

Pace Analytical Services, Inc.
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Minneapolis, MN 55414
(612)607-1700

CERTIFICATIONS

Project:	SPENT LIME-PRESS CAKE
Pace Project No.:	10252590

Minnesota Certification IDs

1700 Elm Street SE Suite 200, Minneapolis, MN 55414
A2LA Certification #: 2926.01
Alabama Dept of Environmental Management #40770
Alaska Certification #: UST-078
Alaska Certification #MN00064
Arizona Certification #: AZ-0014
Arkansas Certification #: 88-0680
California Certification #: 01155CA
Colorado Certification #Pace
Connecticut Certification #: PH-0256
EPA Region 8 Certification #: Pace
EPA Region 5 #WD-15J
Florida/NELAP Certification #: E87605
Georgia Certification #: 959
Hawaii Certification #Pace
Idaho Certification #: MN00064
Illinois Certification #: 200011
Indiana Certification#C-MN-01
Iowa Certification #: 368
Kansas Certification #: E-10167
Kentucky Dept of Envi. Protection - DW #90062
Louisiana Certification #: 03086
Louisiana Certification #: LA080009
Maine Certification #: 2007029
Maryland Certification #: 322
Michigan DEQ Certification #: 9909
Minnesota Certification #: 027-053-137
Mississippi Certification #: Pace
Montana Certification #: MT CERT0092
Nebraska Certification #: Pace
Nevada Certification #: MN_00064
New Jersey Certification #: MN-002
New York Certification #: 11647
North Carolina Certification #: 530
North Dakota Certification #: R-036
Ohio VAP Certification #: CL101
Oklahoma Certification #: 9507
Oregon Certification #: MN200001
Oregon Certification #: MN300001
Pennsylvania Certification #: 68-00563
Puerto Rico Certification
Tennessee Certification #: 02818
Texas Certification #: T104704192
Utah Certification #: MN00064
Virginia/DCLS Certification #: 002521
Virginia/VELAP Certification #: 460163
Washington Certification #: C754
West Virginia Certification #: 382
Wisconsin Certification #: 999407970

Pennsylvania Certification IDs

1638 Roseytown Rd Suites 2,3&4 Greensburg, PA 15601
ACLASS DOD-ELAP Accreditation #: ADE-1544
Alabama Certification #: 41590
Arizona Certification #: AZ0734
Arkansas Certification
California/TNI Certification #: 04222CA
Colorado Certification
Connecticut Certification #: PH-0694
Delaware Certification
Florida/TNI Certification #: E87683
Guam/PADEP Certification
Hawaii/PADEP Certification
Idaho Certification
Illinois/PADEP Certification
Indiana/PADEP Certification
Iowa Certification #: 391
Kansas/TNI Certification #: E-10358
Kentucky Certification #: 90133
Louisiana/TNI Certification #: LA080002
Louisiana/TNI Certification #: 4086
Maine Certification #: PA0091
Maryland Certification #: 308
Massachusetts Certification #: M-PA1457
Michigan/PADEP Certification
Missouri Certification #: 235
Montana Certification #: Cert 0082
Nevada Certification
New Hampshire/TNI Certification #: 2976
New Jersey/TNI Certification #: PA 051
New Mexico Certification
New York/TNI Certification #: 10888
North Carolina Certification #: 42706
North Dakota Certification #: R-190
Oregon/TNI Certification #: PA200002
Pennsylvania/TNI Certification #: 65-00282
Puerto Rico Certification #: PA01457
South Dakota Certification
Tennessee Certification #: TN2867
Texas/TNI Certification #: T104704188
Utah/TNI Certification #: ANTE
Vermont Dept. of Health: ID# VT-0282
Virgin Island/PADEP Certification
Virginia/VELAP Certification #: 460198
Washington Certification #: C868
West Virginia Certification #: 143
Wisconsin/PADEP Certification
Wyoming Certification #: 8TMS-Q

Green Bay Certification IDs

1241 Bellevue Street, Green Bay, WI 54302
Florida/NELAP Certification #: E87948
Illinois Certification #: 200050
Kentucky Certification #: 82
Louisiana Certification #: 04168
Minnesota Certification #: 055-999-334
New York Certification #: 11888
North Dakota Certification #: R-150
South Carolina Certification #: 83006001
US Dept of Agriculture #: S-76505
Wisconsin Certification #: 405132750

Pace Analytical Services, Inc.
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SAMPLE SUMMARY

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Lab ID	Sample ID	Matrix	Date Collected	Date Received
10252590001	**WB SLURRY**	Solid	12/16/13 11:00	12/17/13 10:44
10252590002	**CAKE**	Solid	12/16/13 11:00	12/17/13 10:44

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SAMPLE ANALYTE COUNT

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
10252590001	**WB SLURRY**	EPA 6010	IP	19	PASI-M
		EPA 7471	WBS	1	PASI-M
		ASTM D2974	CMB	1	PASI-M
		EPA 901.1m	MAH	2	PASI-PA
		EPA 300.0	JCJ	1	PASI-G
		EPA 300.0	JCJ	2	PASI-G
		EPA 350.1	HMB	1	PASI-G
		EPA 351.2	HMB	1	PASI-G
		EPA 365.4	DAW	1	PASI-G
		EPA 9012	DAW	1	PASI-G
		EPA 9060 Modified	TJJ	4	PASI-G
10252590002	**CAKE**	EPA 6010	IP	19	PASI-M
		EPA 7471	WBS	1	PASI-M
		ASTM D2974	CMB	1	PASI-M
		EPA 901.1m	MAH	2	PASI-PA
		EPA 300.0	JCJ	1	PASI-G
		EPA 300.0	JCJ	2	PASI-G
		EPA 350.1	HMB	1	PASI-G
		EPA 351.2	HMB	1	PASI-G
		EPA 365.4	DAW	1	PASI-G
		EPA 9012	DAW	1	PASI-G
		EPA 9060 Modified	TJJ	4	PASI-G

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ANALYTICAL RESULTS

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Sample: WB SLURRY **Lab ID: 10252590001** Collected: 12/16/13 11:00 Received: 12/17/13 10:44 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050							
Aluminum	**725**	mg/kg	95.3	5	12/21/13 06:35	12/27/13 08:59	7429-90-5	
Arsenic	ND	mg/kg	9.5	5	12/21/13 06:35	12/27/13 08:59	7440-38-2	
Barium	**39.0**	mg/kg	4.8	5	12/21/13 06:35	12/27/13 08:59	7440-39-3	
Boron	ND	mg/kg	71.5	5	12/21/13 06:35	12/27/13 08:59	7440-42-8	
Cadmium	ND	mg/kg	1.4	5	12/21/13 06:35	12/27/13 08:59	7440-43-9	
Calcium	**353000**	mg/kg	238	5	12/21/13 06:35	12/27/13 08:59	7440-70-2	
Chromium	**217**	mg/kg	4.8	5	12/21/13 06:35	12/27/13 08:59	7440-47-3	
Copper	**9.6**	mg/kg	4.8	5	12/21/13 06:35	12/27/13 08:59	7440-50-8	
Iron	**1660**	mg/kg	23.8	5	12/21/13 06:35	12/27/13 08:59	7439-89-6	
Lead	ND	mg/kg	9.5	5	12/21/13 06:35	12/27/13 08:59	7439-92-1	
Magnesium	**26000**	mg/kg	238	5	12/21/13 06:35	12/27/13 08:59	7439-95-4	
Manganese	**198**	mg/kg	2.4	5	12/21/13 06:35	12/27/13 08:59	7439-96-5	
Molybdenum	ND	mg/kg	7.1	5	12/21/13 06:35	12/27/13 08:59	7439-98-7	
Nickel	**141**	mg/kg	9.5	5	12/21/13 06:35	12/27/13 08:59	7440-02-0	
Potassium	ND	mg/kg	1190	5	12/21/13 06:35	12/27/13 08:59	7440-09-7	
Selenium	ND	mg/kg	7.1	5	12/21/13 06:35	12/27/13 08:59	7782-49-2	
Silver	ND	mg/kg	4.8	5	12/21/13 06:35	12/27/13 08:59	7440-22-4	
Sodium	ND	mg/kg	477	5	12/21/13 06:35	12/27/13 08:59	7440-23-5	
Zinc	**13.8**	mg/kg	9.5	5	12/21/13 06:35	12/27/13 08:59	7440-66-6	
7471 Mercury	Analytical Method: EPA 7471 Preparation Method: EPA 7471							
Mercury	ND	mg/kg	0.041	1	12/24/13 13:57	12/26/13 12:43	7439-97-6	
Dry Weight	Analytical Method: ASTM D2974							
Percent Moisture	**55.9**	%	0.10	1		12/17/13 00:00		
300.0 IC Anions	Analytical Method: EPA 300.0 Preparation Method: EPA 300.0							
Nitrate as N	ND	mg/kg	6.8	1	12/23/13 09:56	12/24/13 10:03	14797-55-8	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0 Preparation Method: EPA 300.0							
Chloride	ND	mg/kg	91.1	1	12/23/13 09:56	12/24/13 10:03	16887-00-6	
Sulfate	ND	mg/kg	91.1	1	12/23/13 09:56	12/24/13 10:03	14808-79-8	
350.1 Ammonia	Analytical Method: EPA 350.1 Preparation Method: EPA 350.1							
Nitrogen, Ammonia	ND	mg/kg	27.2	1	12/30/13 19:45	12/30/13 21:37	7664-41-7	
351.2 Total Kjeldahl Nitrogen	Analytical Method: EPA 351.2 Preparation Method: EPA 351.2							
Nitrogen, Kjeldahl, Total	ND	mg/kg	181	1	12/26/13 14:00	12/26/13 17:36	7727-37-9	
365.4 Total Phosphorus	Analytical Method: EPA 365.4 Preparation Method: EPA 365.4							
Phosphorus	ND	mg/kg	62.6	1	01/03/14 08:40	01/03/14 12:39	7723-14-0	
9012 Cyanide, Total	Analytical Method: EPA 9012 Preparation Method: EPA 9012A							
Cyanide	ND	mg/kg	0.97	1	12/23/13 09:30	12/23/13 14:56	57-12-5	

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ANALYTICAL RESULTS

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Sample: WB SLURRY **Lab ID: 10252590001** Collected: 12/16/13 11:00 Received: 12/17/13 10:44 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
Total Organic Carbon	Analytical Method: EPA 9060 Modified							
Surrogates								
RPD%	**66.6**	%	0.10	1		12/30/13 10:13		
Total Organic Carbon	ND	mg/kg	250	1		12/30/13 10:03	7440-44-0	
Total Organic Carbon	ND	mg/kg	250	1		12/30/13 10:13	7440-44-0	
Mean Total Organic Carbon	ND	mg/kg	250	1		12/30/13 10:13	7440-44-0	1M

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ANALYTICAL RESULTS

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Sample: CAKE **Lab ID: 10252590002** Collected: 12/16/13 11:00 Received: 12/17/13 10:44 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
6010 MET ICP	Analytical Method: EPA 6010 Preparation Method: EPA 3050							
Aluminum	**5350**	mg/kg	109	5	12/21/13 06:35	12/27/13 09:06	7429-90-5	
Arsenic	ND	mg/kg	10.9	5	12/21/13 06:35	12/27/13 09:06	7440-38-2	
Barium	**122**	mg/kg	5.4	5	12/21/13 06:35	12/27/13 09:06	7440-39-3	
Boron	ND	mg/kg	81.6	5	12/21/13 06:35	12/27/13 09:06	7440-42-8	
Cadmium	ND	mg/kg	1.6	5	12/21/13 06:35	12/27/13 09:06	7440-43-9	
Calcium	**333000**	mg/kg	272	5	12/21/13 06:35	12/27/13 09:06	7440-70-2	
Chromium	**184**	mg/kg	5.4	5	12/21/13 06:35	12/27/13 09:06	7440-47-3	
Copper	**15.3**	mg/kg	5.4	5	12/21/13 06:35	12/27/13 09:06	7440-50-8	
Iron	**5080**	mg/kg	27.2	5	12/21/13 06:35	12/27/13 09:06	7439-89-6	
Lead	ND	mg/kg	10.9	5	12/21/13 06:35	12/27/13 09:06	7439-92-1	
Magnesium	**35700**	mg/kg	272	5	12/21/13 06:35	12/27/13 09:06	7439-95-4	
Manganese	**115**	mg/kg	2.7	5	12/21/13 06:35	12/27/13 09:06	7439-96-5	
Molybdenum	ND	mg/kg	8.2	5	12/21/13 06:35	12/27/13 09:06	7439-98-7	
Nickel	**116**	mg/kg	10.9	5	12/21/13 06:35	12/27/13 09:06	7440-02-0	
Potassium	ND	mg/kg	1360	5	12/21/13 06:35	12/27/13 09:06	7440-09-7	
Selenium	ND	mg/kg	8.2	5	12/21/13 06:35	12/27/13 09:06	7782-49-2	
Silver	ND	mg/kg	5.4	5	12/21/13 06:35	12/27/13 09:06	7440-22-4	
Sodium	ND	mg/kg	544	5	12/21/13 06:35	12/27/13 09:06	7440-23-5	
Zinc	ND	mg/kg	10.9	5	12/21/13 06:35	12/27/13 09:06	7440-66-6	
7471 Mercury	Analytical Method: EPA 7471 Preparation Method: EPA 7471							
Mercury	ND	mg/kg	0.046	1	12/24/13 13:57	12/26/13 12:49	7439-97-6	
Dry Weight	Analytical Method: ASTM D2974							
Percent Moisture	**59.3**	%	0.10	1		12/17/13 00:00		
300.0 IC Anions	Analytical Method: EPA 300.0 Preparation Method: EPA 300.0							
Nitrate as N	ND	mg/kg	7.4	1	12/23/13 09:56	12/24/13 10:14	14797-55-8	
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0 Preparation Method: EPA 300.0							
Chloride	**113**	mg/kg	98.9	1	12/23/13 09:56	12/24/13 10:14	16887-00-6	
Sulfate	ND	mg/kg	98.9	1	12/23/13 09:56	12/24/13 10:14	14808-79-8	
350.1 Ammonia	Analytical Method: EPA 350.1 Preparation Method: EPA 350.1							
Nitrogen, Ammonia	**74.4**	mg/kg	36.9	1	12/30/13 19:45	12/30/13 21:38	7664-41-7	
351.2 Total Kjeldahl Nitrogen	Analytical Method: EPA 351.2 Preparation Method: EPA 351.2							
Nitrogen, Kjeldahl, Total	**831**	mg/kg	223	1	12/26/13 14:00	12/26/13 17:36	7727-37-9	
365.4 Total Phosphorus	Analytical Method: EPA 365.4 Preparation Method: EPA 365.4							
Phosphorus	**117**	mg/kg	89.4	1	01/03/14 08:40	01/03/14 12:39	7723-14-0	
9012 Cyanide, Total	Analytical Method: EPA 9012 Preparation Method: EPA 9012A							
Cyanide	ND	mg/kg	1.3	1	12/23/13 09:30	12/23/13 14:56	57-12-5	M0,R1

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ANALYTICAL RESULTS

Project: SPENT LIME-PRESS CAKE

Pace Project No.: 10252590

Sample: CAKE **Lab ID: 10252590002** Collected: 12/16/13 11:00 Received: 12/17/13 10:44 Matrix: Solid

Results reported on a "dry-weight" basis

Parameters	Results	Units	Report Limit	DF	Prepared	Analyzed	CAS No.	Qual
Total Organic Carbon	Analytical Method: EPA 9060 Modified							
Surrogates								
RPD%	**28.4**	%	0.10	1		12/30/13 10:26		
Total Organic Carbon	**1800**	mg/kg	752	1		12/30/13 10:23	7440-44-0	
Total Organic Carbon	**1350**	mg/kg	735	1		12/30/13 10:26	7440-44-0	
Mean Total Organic Carbon	**1580**	mg/kg	744	1		12/30/13 10:26	7440-44-0	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: MERP/9868 | Analysis Method: EPA 7471
QC Batch Method: EPA 7471 | Analysis Description: 7471 Mercury
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 1599833 | Matrix: Solid
Associated Lab Samples: 10252590001, 10252590002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Mercury	mg/kg	ND	0.020	12/26/13 12:39	

LABORATORY CONTROL SAMPLE: 1599834

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Mercury	mg/kg	.43	0.45	106	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1599835 1599836

Parameter	Units	10252590001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Mercury	mg/kg	ND	.98	1	1.0	1.1	104	103	80-120	5	20	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: MPRP/43860 | Analysis Method: EPA 6010
QC Batch Method: EPA 3050 | Analysis Description: 6010 MET
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 1599829 | Matrix: Solid
Associated Lab Samples: 10252590001, 10252590002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Aluminum	mg/kg	ND	9.3	12/26/13 17:45	
Arsenic	mg/kg	ND	0.93	12/26/13 17:45	
Barium	mg/kg	ND	0.46	12/26/13 17:45	
Boron	mg/kg	ND	6.9	12/26/13 17:45	
Cadmium	mg/kg	ND	0.14	12/26/13 17:45	
Calcium	mg/kg	ND	23.1	12/26/13 17:45	
Chromium	mg/kg	ND	0.46	12/26/13 17:45	
Copper	mg/kg	ND	0.46	12/26/13 17:45	
Iron	mg/kg	ND	2.3	12/26/13 17:45	
Lead	mg/kg	ND	0.93	12/26/13 17:45	
Magnesium	mg/kg	ND	23.1	12/26/13 17:45	
Manganese	mg/kg	ND	0.23	12/26/13 17:45	
Molybdenum	mg/kg	ND	0.69	12/26/13 17:45	
Nickel	mg/kg	ND	0.93	12/26/13 17:45	
Potassium	mg/kg	ND	116	12/26/13 17:45	
Selenium	mg/kg	ND	0.69	12/26/13 17:45	
Silver	mg/kg	ND	0.46	12/26/13 17:45	
Sodium	mg/kg	ND	46.3	12/26/13 17:45	
Zinc	mg/kg	ND	0.93	12/26/13 17:45	

LABORATORY CONTROL SAMPLE: 1599830

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Aluminum	mg/kg	490	489	100	80-120	
Arsenic	mg/kg	49	48.0	98	80-120	
Barium	mg/kg	49	50.2	102	80-120	
Boron	mg/kg	49	46.9	96	80-120	
Cadmium	mg/kg	49	47.4	97	80-120	
Calcium	mg/kg	490	507	103	80-120	
Chromium	mg/kg	49	50.7	104	80-120	
Copper	mg/kg	49	49.7	101	80-120	
Iron	mg/kg	490	489	100	80-120	
Lead	mg/kg	49	49.1	100	80-120	
Magnesium	mg/kg	490	489	100	80-120	
Manganese	mg/kg	49	50.9	104	80-120	
Molybdenum	mg/kg	49	51.5	105	80-120	
Nickel	mg/kg	49	49.5	101	80-120	
Potassium	mg/kg	490	521	106	80-120	
Selenium	mg/kg	49	45.9	94	80-120	
Silver	mg/kg	24.5	23.2	95	80-120	
Sodium	mg/kg	490	488	100	80-120	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

LABORATORY CONTROL SAMPLE: 1599830

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Zinc	mg/kg	49	48.0	98	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 1599831 1599832

Parameter	Units	10252773001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Aluminum	mg/kg	2320	504	483	3500	3530	236	251	75-125	.8	30	M1
Arsenic	mg/kg	ND	50.4	48.3	50.6	49.6	100	102	75-125	2	30	
Barium	mg/kg	15.8	50.4	48.3	66.6	68.9	101	110	75-125	3	30	
Boron	mg/kg	ND	50.4	48.3	50.3	48.5	100	100	75-125	4	30	
Cadmium	mg/kg	ND	50.4	48.3	49.1	49.2	97	102	75-125	.05	30	
Calcium	mg/kg		504	483	9230	8760	40	-53	75-125	5	30	M1
Chromium	mg/kg	5.4	50.4	48.3	56.9	57.1	102	107	75-125	.4	30	
Copper	mg/kg	2.6	50.4	48.3	54.4	54.7	103	108	75-125	.6	30	
Iron	mg/kg	4680	504	483	5360	5480	135	165	75-125	2	30	M1
Lead	mg/kg	1.6	50.4	48.3	50.3	49.7	97	100	75-125	1	30	
Magnesium	mg/kg		504	483	2800	2740	46	34	75-125	2	30	M1
Manganese	mg/kg	110	50.4	48.3	160	176	100	136	75-125	9	30	M1
Molybdenum	mg/kg		50.4	48.3	51.5	51.0	102	105	75-125	1	30	
Nickel	mg/kg	5.1	50.4	48.3	52.7	52.8	95	99	75-125	.3	30	
Potassium	mg/kg	275	504	483	873	869	119	123	75-125	.4	30	
Selenium	mg/kg	0.73	50.4	48.3	49.2	48.5	96	99	75-125	2	30	
Silver	mg/kg	ND	25.2	24.1	24.2	24.1	96	100	75-125	.3	30	
Sodium	mg/kg	83.7	504	483	624	625	107	112	75-125	.1	30	
Zinc	mg/kg	8.4	50.4	48.3	56.0	55.9	94	98	75-125	.1	30	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: MPRP/43804 | Analysis Method: ASTM D2974
QC Batch Method: ASTM D2974 | Analysis Description: Dry Weight/Percent Moisture
Associated Lab Samples: 10252590001, 10252590002

SAMPLE DUPLICATE: 1596847

Parameter	Units	10252527003 Result	Dup Result	RPD	Max RPD	Qualifiers
Percent Moisture	%	6.0	5.7	6	30	

SAMPLE DUPLICATE: 1596848

Parameter	Units	10252520002 Result	Dup Result	RPD	Max RPD	Qualifiers
Percent Moisture	%	18.3	19.6	7	30	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: WETA/21299
Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0
Analysis Description: 300.0 IC Anions
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 916234 Matrix: Solid
Associated Lab Samples: 10252590001, 10252590002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Chloride	mg/kg	ND	40.0	12/24/13 11:42	
Nitrate as N	mg/kg	ND	3.0	12/24/13 11:42	
Sulfate	mg/kg	ND	40.0	12/24/13 11:42	

LABORATORY CONTROL SAMPLE: 916235

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Chloride	mg/kg	200	191	96	80-120	
Nitrate as N	mg/kg	20	19.5	97	80-120	
Sulfate	mg/kg	200	195	98	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 916236 916237

Parameter	Units	10252590001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/kg	ND	456	456	501	496	90	89	80-120	1	20	
Nitrate as N	mg/kg	ND	45.6	45.6	46.7	46.2	97	95	80-120	1	20	
Sulfate	mg/kg	ND	456	456	509	485	99	93	80-120	5	20	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: WETA/21286 Analysis Method: EPA 350.1
QC Batch Method: EPA 350.1 Analysis Description: 350.1 Ammonia
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 915790 Matrix: Solid
Associated Lab Samples: 10252590001, 10252590002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Nitrogen, Ammonia	mg/kg	ND	15.0	12/30/13 21:33	

LABORATORY CONTROL SAMPLE: 915791

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Nitrogen, Ammonia	mg/kg	300	300	100	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 915792 915793

Parameter	Units	10252590002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Nitrogen, Ammonia	mg/kg	74.4	737	737	799	768	98	94	80-120	4	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 917669 917670

Parameter	Units	10253352006 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Nitrogen, Ammonia	mg/kg	30.2	261	279	293	326	101	106	80-120	11	20	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: WETA/21310 | Analysis Method: EPA 351.2
QC Batch Method: EPA 351.2 | Analysis Description: 351.2 TKN
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 916427 | Matrix: Solid
Associated Lab Samples: 10252590001, 10252590002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Nitrogen, Kjeldahl, Total	mg/kg	ND	100	12/26/13 17:32	

LABORATORY CONTROL SAMPLE: 916428

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Nitrogen, Kjeldahl, Total	mg/kg	500	502	100	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 916429 916430

Parameter	Units	4090360001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Nitrogen, Kjeldahl, Total	mg/kg	37000	1640	1810	39100	39200	128	126	80-120	0	20	P6

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: WETA/21407
QC Batch Method: EPA 365.4
Analysis Method: EPA 365.4
Analysis Description: 365.4 Total Phosphorus
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 918414 Matrix: Solid
Associated Lab Samples: 10252590001, 10252590002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Phosphorus	mg/kg	ND	40.0	01/03/14 12:33	

LABORATORY CONTROL SAMPLE: 918415

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Phosphorus	mg/kg	500	511	102	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 918416 918417

Parameter	Units	10252590002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Phosphorus	mg/kg	117	1120	1120	1150	1180	93	95	80-120	3	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 918418 918419

Parameter	Units	4090425001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Phosphorus	mg/kg	2890	33400	33400	36300	34100	100	93	80-120	6	20	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: WETA/21295 | Analysis Method: EPA 9012
QC Batch Method: EPA 9012A | Analysis Description: 9012 Cyanide
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 916125 | Matrix: Solid
Associated Lab Samples: 10252590001, 10252590002

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Cyanide	mg/kg	ND	0.60	12/23/13 14:53	

LABORATORY CONTROL SAMPLE: 916126

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Cyanide	mg/kg	3	3.1	102	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 916127 916128

Parameter	Units	10252590002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Cyanide	mg/kg	ND	6.39	6.39	4.6	6.7	66	100	80-120	38	20	M0,R1

REPORT OF LABORATORY ANALYSIS

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: WETA/21368 | Analysis Method: EPA 9060 Modified
QC Batch Method: EPA 9060 Modified | Analysis Description: 9060 TOC Average
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 917729 | Matrix: Solid
Associated Lab Samples:

Parameter	Units	Blank Result	Reporting Limit	Analyzed	Qualifiers
Mean Total Organic Carbon	mg/kg	ND	250	12/30/13 09:53	

LABORATORY CONTROL SAMPLE: 917730

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Mean Total Organic Carbon	mg/kg	1000	946	95	80-120	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 917731 917732

Parameter	Units	201151338002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Mean Total Organic Carbon	mg/kg	12300	9110	10000	22500	23100	112	108	50-150	3	30	

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ANALYTICAL RESULTS

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Sample: WB SLURRY **Lab ID: 10252590001** Collected: 12/16/13 11:00 Received: 12/17/13 10:44 Matrix: Solid
PWS: Site ID: Sample Type:

Results reported on a "dry-weight" basis

Parameters	Method	Act ± Unc (MDC)	Units	Analyzed	CAS No.	Qual
Radium-226	EPA 901.1m	**0.650 ± 0.194 (0.343)**	pCi/g	01/16/14 10:40	13982-63-3	
Radium-228	EPA 901.1m	**0.348 ± 0.187 (0.576)**	pCi/g	01/16/14 10:40	15262-20-1	

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ANALYTICAL RESULTS

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Sample: CAKE **Lab ID: 10252590002** Collected: 12/16/13 11:00 Received: 12/17/13 10:44 Matrix: Solid
PWS: Site ID: Sample Type:

Results reported on a "dry-weight" basis

Parameters	Method	Act ± Unc (MDC)	Units	Analyzed	CAS No.	Qual
Radium-226	EPA 901.1m	**0.576 ± 0.200 (0.209)**	pCi/g	01/16/14 10:56	13982-63-3	
Radium-228	EPA 901.1m	**-0.060 ± 4.356 (0.590)**	pCi/g	01/16/14 10:56	15262-20-1	

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QUALITY CONTROL DATA

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

QC Batch: RADC/18222 | Analysis Method: EPA 901.1m
QC Batch Method: EPA 901.1m | Analysis Description: 901.1 Gamma Spec Ingrowth
Associated Lab Samples: 10252590001, 10252590002

METHOD BLANK: 675905 | Matrix: Solid
Associated Lab Samples:

Parameter	Act ± Unc (MDC)	Units	Analyzed	Qualifiers
Radium-226	-0.025 ± 0.989 (0.195)	pCi/g	01/16/14 08:46	
Radium-228	0.014 ± 0.118 (0.237)	pCi/g	01/16/14 08:46	

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QUALIFIERS

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to changes in sample preparation, dilution of the sample aliquot, or moisture content.

ND - Not Detected at or above adjusted reporting limit.

J - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

MDL - Adjusted Method Detection Limit.

PRL - Pace Reporting Limit.

RL - Reporting Limit.

S - Surrogate

1,2-Diphenylhydrazine (8270 listed analyte) decomposes to Azobenzene.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Act - Activity

Unc - Uncertainty

(MDC) - Minimum Detectable Concentration

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TNI - The NELAC Institute.

LABORATORIES

PASI-G	Pace Analytical Services - Green Bay
PASI-M	Pace Analytical Services - Minneapolis
PASI-PA	Pace Analytical Services - Greensburg

BATCH QUALIFIERS

Batch: WETA/21368

[WB] Results reported on dry weight basis per cited method.

Batch: WETA/21369

[WB] Results reported on dry weight basis per cited method.

ANALYTE QUALIFIERS

1M	Analysis conducted with full boat (0.04g), resulting in under range detection.
M0	Matrix spike recovery and/or matrix spike duplicate recovery was outside laboratory control limits.
M1	Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
P6	Matrix spike recovery was outside laboratory control limits due to a parent sample concentration notably higher than the spike level.
R1	RPD value was outside control limits.

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QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: SPENT LIME-PRESS CAKE
Pace Project No.: 10252590

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
10252590001	**WB SLURRY**	EPA 3050	MPRP/43860	EPA 6010	ICP/18457
10252590002	**CAKE**	EPA 3050	MPRP/43860	EPA 6010	ICP/18457
10252590001	**WB SLURRY**	EPA 7471	MERP/9868	EPA 7471	MERC/11342
10252590002	**CAKE**	EPA 7471	MERP/9868	EPA 7471	MERC/11342
10252590001	**WB SLURRY**	ASTM D2974	MPRP/43804		
10252590002	**CAKE**	ASTM D2974	MPRP/43804		
10252590001	**WB SLURRY**	EPA 901.1m	RADC/18169	EPA 901.1m	RADC/18222
10252590002	**CAKE**	EPA 901.1m	RADC/18169	EPA 901.1m	RADC/18222
10252590001	**WB SLURRY**	EPA 300.0	WETA/21299	EPA 300.0	WETA/21308
10252590002	**CAKE**	EPA 300.0	WETA/21299	EPA 300.0	WETA/21308
10252590001	**WB SLURRY**	EPA 300.0	WETA/21299	EPA 300.0	WETA/21308
10252590002	**CAKE**	EPA 300.0	WETA/21299	EPA 300.0	WETA/21308
10252590001	**WB SLURRY**	EPA 350.1	WETA/21286	EPA 350.1	WETA/21380
10252590002	**CAKE**	EPA 350.1	WETA/21286	EPA 350.1	WETA/21380
10252590001	**WB SLURRY**	EPA 351.2	WETA/21310	EPA 351.2	WETA/21336
10252590002	**CAKE**	EPA 351.2	WETA/21310	EPA 351.2	WETA/21336
10252590001	**WB SLURRY**	EPA 365.4	WETA/21407	EPA 365.4	WETA/21425
10252590002	**CAKE**	EPA 365.4	WETA/21407	EPA 365.4	WETA/21425
10252590001	**WB SLURRY**	EPA 9012A	WETA/21295	EPA 9012	WETA/21306
10252590002	**CAKE**	EPA 9012A	WETA/21295	EPA 9012	WETA/21306
10252590001	**WB SLURRY**	EPA 9060 Modified	WETA/21368		
10252590001	**WB SLURRY**	EPA 9060 Modified	WETA/21369		
10252590002	**CAKE**	EPA 9060 Modified	WETA/21368		
10252590002	**CAKE**	EPA 9060 Modified	WETA/21369		

Pace Analytical®
www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

1131
1025 2540

Page: of

1460318

Section A
Required Client Information:

- Company: SPRWS
- Address: 1900 Rice street, Saint Paul, MN
- Email To:
- Phone: 651-266-1631
- Fax: 651-266-1640
- Requested Due Date/TAT:

Section B
Required Project Information:

- Report To: JIM BODE
- Copy To: MARTHA BURCKHARDT
- Purchase Order No.: 31066
- Project Name: SPENT LIME-PRESS CAKE
- Project Number:

Section C
Invoice Information:

- Attention: JIM BODE
- Company Name: SPRWS
- Address:
- Pace Quote Reference:
- Pace Project Manager:
- Pace Profile #:

REGULATORY AGENCY

- ☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
- ☐ UST ☐ RCRA ☐ OTHER ______

Site Location
STATE: ______

Section D
Required Client Information

SAMPLE ID
(A-Z, 0-9 / ,-)
Sample IDs MUST BE UNIQUE

Matrix Codes MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Tissue	TS
Other	OT

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COMPOSITE START DATE	COMPOSITE START TIME	COMPOSITE END/GRAB DATE	COMPOSITE END/GRAB TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Analysis Test Y/N	metals by 6010/mercury	Radium 226	Radium 228	Anions/Amm/TP/TKN/[illegible]cyanide	Moisture by D2216								Residual Chlorine (Y/N)	Pace Project No./ Lab I.D.
1	WB SLURRY					12/16	11:00												✓	✓	✓	✓	✓									001
2	CAKE					12/16	11:00												✓	✓	✓	✓	✓									002
3																																
4																																
5																																
6																																
7																																
8																																
9																																
10																																
11																																
12																																

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	Temp in °C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)
	[signature]	12/17	10:45	[signature] Pace	12-17-13	10:44	6.3	Y	N	Y

SAMPLE CONDITIONS

ORIGINAL

SAMPLER NAME AND SIGNATURE

- PRINT Name of SAMPLER:
- SIGNATURE of SAMPLER:
- DATE Signed (MM/DD/YY):

*Important Note: By signing this form you are accepting Pace's NET 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

F-ALL-Q-020rev.07, 15-May-2007

Sample Condition Upon Receipt

Client Name: SPRWS

Project #: WO# : 10252590

10252590

Courier: ☐ Fed Ex ☐ UPS ☐ USPS ☑ Client ☐ Commercial ☐ Pace ☐ Other: ______

Tracking Number: ______

Custody Seal on Cooler/Box Present? ☐ Yes ☑ No **Seals Intact?** ☐ Yes ☑ No

Optional: Proj. Due Date: Proj. Name:

Packing Material: ☐ Bubble Wrap ☑ Bubble Bags ☐ None ☐ Other: ______ **Temp Blank?** ☑ Yes ☐ No

Thermom. Used: ☐ 80512447 ☐ 72337080 ☐ B88A912167504 ☑ B88A9132521491 **Type of Ice:** ☑ Wet (JP 12-17-13) ☑ Blue ☐ None ☐ Samples on ice, cooling process has begun

Cooler Temp Read (°C): 6.6 **Cooler Temp Corrected (°C):** 6.3 **Biological Tissue Frozen?** ☐ Yes ☐ No ☑ N/A

Temp should be above freezing to 6°C **Correction Factor:** -.3 **Date and Initials of Person Examining Contents:** JP 12-17-13

	Yes	No	N/A	Comments:
Chain of Custody Present?	☑	☐	☐	1.
Chain of Custody Filled Out?	☑	☐	☐	2.
Chain of Custody Relinquished?	☑	☐	☐	3.
Sampler Name and/or Signature on COC?	☑	☐	☐	4.
Samples Arrived within Hold Time?	☑	☐	☐	5.
Short Hold Time Analysis (<72 hr)?	☐	☑	☐	6.
Rush Turn Around Time Requested?	☐	☑	☐	7.
Sufficient Volume?	☑	☐	☐	8.
Correct Containers Used?	☑	☐	☐	9.
-Pace Containers Used?	☑	☐	☐	
Containers Intact?	☑	☐	☐	10.
Filtered Volume Received for Dissolved Tests?	☐	☐	☑	11.
Sample Labels Match COC? -Includes Date/Time/ID/Analysis Matrix: SL	☑	☐	☐	12.
All containers needing acid/base preservation have been checked? Noncompliances are noted in 13.	☐	☐	☑	13. ☐ HNO_3 ☐ H_2SO_4 ☐ NaOH ☐ HCl
All containers needing preservation are found to be in compliance with EPA recommendation? (HNO_3, H_2SO_4, HCl<2; NaOH>12)	☐	☐	☑	Sample #
Exceptions: VOA, Coliform, TOC, Oil and Grease, WI-DRO (water) DOC	☐	☑		Initial when completed: ______ Lot # of added preservative: ______
Headspace in VOA Vials (>6mm)?	☐	☐	☑	14.
Trip Blank Present?	☐	☐	☑	15.
Trip Blank Custody Seals Present?	☐	☐	☑	
Pace Trip Blank Lot # (if purchased): ______				

CLIENT NOTIFICATION/RESOLUTION **Field Data Required?** ☐ Yes ☐ No

Person Contacted: ______ Date/Time: ______

Comments/Resolution: ______

Project Manager Review: [signature] **Date:** 12-17-13

Note: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e out of hold, incorrect preservative, out of temp, incorrect containers)

BRAUN INTERTEC

Braun Intertec Corporation
11001 Hampshire Avenue S.
Minneapolis, MN 55438

Phone: 952.995.2000
Fax: 952.995.2020
Web: braunintertec.com

Mr. Keith Pilgrim
Barr Engineering Company
4700 West 77th Street
Minneapolis, MN 55435-4803

December 01, 2011

Report #: 1106761

RE: Permeable Reactive Barrier 23/62-1021

Dear Keith Pilgrim:

Braun Intertec Corporation received samples for the project identified above on November 23, 2011. Analytical results are summarized in the following report.

All routine quality assurance procedures were followed, unless otherwise noted.

Analytical results are reported on an "as received" basis unless otherwise noted. Where possible, the samples will be retained by the laboratory for 14 days following issuance of the initial final report. The samples will be disposed of or returned at that time. Arrangements can be made for extended storage by contacting me at this time.

We appreciate your decision to use Braun Intertec Corporation for this project. We are committed to being your vendor of choice to meet your analytical chemistry needs.

If you have any questions please contact me at the above phone number.

Sincerely,

Steven J. Albrecht
Project Manager

Certification/Accreditation Number

Minnesota Department of Health #027-053-117

Providing engineering and environmental solutions since 1957

BRAUN INTERTEC

11001 Hampshire Ave. S.
Minneapolis, MN 55438
952.995.2000 Phone
952.995.2020 Fax

Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Qualifiers and Abbreviations

sd	See case narrative section for further information.
COC	Chain of Custody
dry	Sample results reported on a dry weight basis
MRL	Method Reporting Limit
NA	Not Applicable
ND	Analyte NOT DETECTED
NR	Not Reported
%Rec	Percent Recovery
RPD	Relative Percent Difference
VOC	Volatile Organic Compound

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4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Case Narrative

In the analysis of Aluminum, Calcium, and Iron in soil, the Matrix Spike (MS)/Matrix Spike Duplicate (MSD) results are not reported due to a high level of these analytes in the source sample. The amount of spike added to the MS/MSD samples was overwhelmed by the level of the analytes in the source sample, resulting in non-valid data for the MS/MSD.

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4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Sample Summary

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
WP1 (0-1 cm)	1106761-01	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (1-2 cm)	1106761-02	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (2-3 cm)	1106761-03	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (3-4 cm)	1106761-04	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (4-5 cm)	1106761-05	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (6-7 cm)	1106761-06	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (8-9 cm)	1106761-07	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (10-11 cm)	1106761-08	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (12-13 cm)	1106761-09	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (14-15 cm)	1106761-10	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (16-17 cm)	1106761-11	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (18-19 cm)	1106761-12	Soil	08/19/11 00:00	11/23/11 15:40
WP1 (20-21 cm)	1106761-13	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (0-1 cm)	1106761-14	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (1-2 cm)	1106761-15	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (2-3 cm)	1106761-16	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (3-4 cm)	1106761-17	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (4-5 cm)	1106761-18	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (6-7 cm)	1106761-19	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (8-9 cm)	1106761-20	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (10-11 cm)	1106761-21	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (12-13 cm)	1106761-22	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (14-15 cm)	1106761-23	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (16-17 cm)	1106761-24	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (18-19 cm)	1106761-25	Soil	08/19/11 00:00	11/23/11 15:40
WP2 (20-21 cm)	1106761-26	Soil	08/19/11 00:00	11/23/11 15:40

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Conditions Upon Receipt

Cooler: Cooler 1

Temperature:	18.8 °C	**COC Included:**	Yes	**Custody Seals Used:**	No
Temperature Blank:	No	**COC Complete:**	Yes	**Custody Seals Intact:**	NA
Received on Ice:	No	**COC & Labels Agree:**	Yes	**Hand Delivered by Client:**	Yes
Preservation Confirmed:	No	**Sufficient Sample Provided:**	Yes	**Headspace Present (VOC):**	No

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4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

	Analyte	Result	MRL	Units	Batch	Prepared	Analyzed	Method	Notes
1106761-01	**WP1 (0-1 cm)**								
	Aluminum	**14000**	50	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**29000**	200	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**33000**	100	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-02	**WP1 (1-2 cm)**								
	Aluminum	**16000**	48	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**30000**	190	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**31000**	96	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-03	**WP1 (2-3 cm)**								
	Aluminum	**17000**	47	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**28000**	190	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**34000**	95	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-04	**WP1 (3-4 cm)**								
	Aluminum	**14000**	45	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**29000**	180	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**28000**	90	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-05	**WP1 (4-5 cm)**								
	Aluminum	**15000**	45	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**28000**	180	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**29000**	90	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-06	**WP1 (6-7 cm)**								
	Aluminum	**15000**	45	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**30000**	180	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**27000**	89	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-07	**WP1 (8-9 cm)**								
	Aluminum	**15000**	43	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**31000**	170	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**27000**	86	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-08	**WP1 (10-11 cm)**								
	Aluminum	**14000**	48	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**21000**	190	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**25000**	97	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-09	**WP1 (12-13 cm)**								
	Aluminum	**12000**	43	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**15000**	170	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**25000**	85	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-10	**WP1 (14-15 cm)**								

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

	Analyte	Result	MRL	Units	Batch	Prepared	Analyzed	Method	Notes
1106761-10	**WP1 (14-15 cm)**								
	Aluminum	**16000**	43	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**18000**	170	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**27000**	85	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-11	**WP1 (16-17 cm)**								
	Aluminum	**15000**	45	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**17000**	180	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**27000**	90	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-12	**WP1 (18-19 cm)**								
	Aluminum	**16000**	47	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**26000**	190	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**32000**	94	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-13	**WP1 (20-21 cm)**								
	Aluminum	**14000**	47	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**23000**	190	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**28000**	94	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-14	**WP2 (0-1 cm)**								
	Aluminum	**13000**	42	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**26000**	170	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**30000**	84	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-15	**WP2 (1-2 cm)**								
	Aluminum	**16000**	45	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
	Calcium	**29000**	180	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	
	Iron	**33000**	90	mg/kg	B1K0540	11/25/11	11/28/11	EPA 6010B	sd
1106761-16	**WP2 (2-3 cm)**								
	Aluminum	**16000**	49	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	sd
	Calcium	**29000**	200	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	
	Iron	**30000**	98	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	sd
1106761-17	**WP2 (3-4 cm)**								
	Aluminum	**15000**	50	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	sd
	Calcium	**31000**	200	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	
	Iron	**30000**	100	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	sd
1106761-18	**WP2 (4-5 cm)**								
	Aluminum	**15000**	46	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	sd
	Calcium	**32000**	180	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	
	Iron	**27000**	92	mg/kg	B1K0540	11/25/11	11/29/11	EPA 6010B	sd
1106761-19	**WP2 (6-7 cm)**								

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

	Analyte	Result	MRL	Units	Batch	Prepared	Analyzed	Method	Notes
1106761-19	**WP2 (6-7 cm)**								
	Aluminum	**14000**	45	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**29000**	180	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**26000**	91	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
1106761-20	**WP2 (8-9 cm)**								
	Aluminum	**15000**	47	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**29000**	190	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**26000**	93	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
1106761-21	**WP2 (10-11 cm)**								
	Aluminum	**13000**	43	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**25000**	170	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**28000**	85	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
1106761-22	**WP2 (12-13 cm)**								
	Aluminum	**14000**	45	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**30000**	180	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**26000**	89	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
1106761-23	**WP2 (14-15 cm)**								
	Aluminum	**15000**	42	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**30000**	170	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**27000**	84	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
1106761-24	**WP2 (16-17 cm)**								
	Aluminum	**16000**	45	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**30000**	180	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**28000**	91	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
1106761-25	**WP2 (18-19 cm)**								
	Aluminum	**12000**	50	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**26000**	200	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**22000**	100	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
1106761-26	**WP2 (20-21 cm)**								
	Aluminum	**14000**	47	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Calcium	**30000**	190	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd
	Iron	**26000**	93	mg/kg	B1K0574	11/29/11	11/29/11	EPA 6010B	sd

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Metals - Quality Control

Batch B1K0540 - EPA 3050B

Method Blank (B1K0540-BLK1)

Prepared: 11/25/11 Analyzed: 11/28/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	< 5.0	5.0	mg/kg	NA	NA	NA	NA	NA	NA	
Calcium	< 20	20	mg/kg	NA	NA	NA	NA	NA	NA	
Iron	< 10	10	mg/kg	NA	NA	NA	NA	NA	NA	

Laboratory Control Sample (B1K0540-BS1)

Prepared: 11/25/11 Analyzed: 11/28/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	210	5.0	mg/kg	200	NA	105	80-120	NA	NA	
Calcium	5190	20	mg/kg	5000	NA	104	80-120	NA	NA	
Iron	202	10	mg/kg	200	NA	101	80-120	NA	NA	

Laboratory Control Sample Duplicate (B1K0540-BSD1)

Prepared: 11/25/11 Analyzed: 11/28/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	212	5.0	mg/kg	200	NA	106	80-120	0.946	20	
Calcium	5170	20	mg/kg	5000	NA	103	80-120	0.403	20	
Iron	204	10	mg/kg	200	NA	102	80-120	0.930	20	

Standard Reference Material (B1K0540-SRM1)

Prepared: 11/25/11 Analyzed: 11/28/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	10300	10	mg/kg	10100	NA	102	33.8-133	NA	NA	
Calcium	7400	41	mg/kg	7020	NA	105	70.8-120	NA	NA	
Iron	15600	20	mg/kg	15000	NA	104	25.1-139	NA	NA	

Batch B1K0574 - EPA 3050B

Method Blank (B1K0574-BLK1)

Prepared & Analyzed: 11/29/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	< 5.0	5.0	mg/kg	NA	NA	NA	NA	NA	NA	
Calcium	< 20	20	mg/kg	NA	NA	NA	NA	NA	NA	
Iron	< 10	10	mg/kg	NA	NA	NA	NA	NA	NA	

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Metals - Quality Control

Batch B1K0574 - EPA 3050B

Laboratory Control Sample (B1K0574-BS1)

Prepared & Analyzed: 11/29/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	215	5.0	mg/kg	200	NA	108	80-120	NA	NA	
Calcium	4990	20	mg/kg	5000	NA	99.9	80-120	NA	NA	
Iron	203	10	mg/kg	200	NA	101	80-120	NA	NA	

Laboratory Control Sample Duplicate (B1K0574-BSD1)

Prepared & Analyzed: 11/29/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	215	5.0	mg/kg	200	NA	107	80-120	0.352	20	
Calcium	4930	20	mg/kg	5000	NA	98.6	80-120	1.26	20	
Iron	201	10	mg/kg	200	NA	101	80-120	0.741	20	

Standard Reference Material (B1K0574-SRM1)

Prepared & Analyzed: 11/29/11

Analyte	Result	MRL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	10600	10	mg/kg	10100	NA	105	33.8-133	NA	NA	
Calcium	7430	40	mg/kg	7020	NA	106	70.8-120	NA	NA	
Iron	15700	20	mg/kg	15000	NA	104	25.1-139	NA	NA	

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

1106761

BARR *Chain of Custody*

4700 West 77th Street
Minneapolis, MN 55435-4803
(952) 832-2600

Project Number: 23/62-1021

Project Name: Permeable Reactive Barrier

Sample Origination State: MN (use two letter postal state abbreviation)

COC Number: № 33102

COC 1 of 3

Project Manager: K. Pilgrim

Project QC Contact:

Sampled by: K. Menken

Laboratory: Braun

Number of Containers/Preservative — Water: VOCs (HCl) #1; SVOCs (unpreserved) #2; Dissolved Metals (HNO3); Total Metals (HNO3); General (unpreserved) #3; Diesel Range Organics (HCl); Nutrients (H2SO4) #4; Aluminum, Calcium, Iron. Soil: VOCs (tared MeOH) #1; GRO, BTEX (tared MeOH) #1; DRO (tared unpreserved); Metals (unpreserved); SVOCs (unpreserved) #2; % Solids (plastic vial, unpres.). Total Number Of Containers.

Location	Start Depth	Stop Depth	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	Aluminum, Calcium, Iron (Water)	Total Number Of Containers
1. WP1 (0-1)			CM	08/19/2011			X				1	
2. WP1 (1-2)				↓			↓				1	
3. WP1 (2-3)				↓			↓				1	
4. WP1 (3-4)				↓			↓				1	
5. WP1 (4-5)				↓			↓				1	
6. WP1 (6-7)				↓			↓				1	
7. WP1 (8-9)				↓			↓				1	
8. WP1 (10-11)				↓			↓				1	
9. WP1 (12-13)				↓			↓				1	
10. WP1 (14-15)				V			V				1	

Common Parameter/Container - Preservation Key

#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Relinquished By:	On Ice?	Date	Time	Received by:	Date	Time
Kevin Menken	Y N	11/23/11	15:40	[signature]	11/23/11	1540
Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other: ______ Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

18.8°C (initials)

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

1106761

Chain of Custody

BARR
4700 West 77th Street
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(952) 832-2600

COC 2 of 3

Project Number: 23/62-1021

Project Name: Permeable Reactive Barrier

Sample Origination State MN (use two letter postal state abbreviation)

COC Number: № 33103

Project Manager:
Project QC Contact:
Sampled by:
Laboratory:

Location	Start Depth	Stop Depth	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	Water: VOCs (HCl) #1	Water: SVOCs (unpreserved) #2	Water: Dissolved Metals (HNO_3)	Water: Total Metals (HNO_3)	Water: General (unpreserved) #3	Water: Diesel Range Organics (HCl)	Water: Nutrients (H_2SO_4) #4	Water: Aluminum, Calcium, Iron	Soil: VOCs (tared MeOH) #1	Soil: GRO, BTEX (tared MeOH) #1	Soil: DRO (tared unpreserved)	Soil: Metals (unpreserved)	Soil: SVOCs (unpreserved) #2	Soil: % Solids (plastic vial, unpres.)	Total Number Of Containers
1. WP1 (16-17)				08/19/2011			X											1							
2. WP1 (18-19)																		1							
3. WP1 (20-21)																		1							
4. WP2 (0-1)																		1							
5. WP2 (1-2)																		1							
6. WP2 (2-3)																		1							
7. WP2 (3-4)																		1							
8. WP2 (4-5)																		1							
9. WP2 (6-7)																		1							
10. WP2 (8-9)																		1							

Common Parameter/Container - Preservation Key

#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time
				[signature]	8/21/11	1540
Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other: ______ Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

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Barr Engineering Company	Client Ref: Permeable Reactive Barrier 23/62-1021	Report #: 1106761
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

1106761

BARR Chain of Custody
4700 West 77th Street
Minneapolis, MN 55435-4803
(952) 832-2600

COC 3 of 3

Project Number: 23/62 - 1021
Project Name: Permeable Reactive Barrier
Sample Origination State: MN (use two letter postal state abbreviation)
COC Number: № 37052

Project Manager:
Project QC Contact:
Sampled by:
Laboratory:

Number of Containers/Preservative — Water: VOCs (HCl) #1; SVOCs (unpreserved) #2; Dissolved Metals (HNO3); Total Metals (HNO3); General (unpreserved) #3; Diesel Range Organics (HCl); Nutrients (H_2SO_4) #4; Aluminum, Calcium, Iron. Soil: VOCs (tared MeOH) #1; GRO, BTEX (tared MeOH) #1; DRO (tared unpreserved); Metals (unpreserved); SVOCs (unpreserved) #2; % Solids (plastic vial, unpres.). Total Number Of Containers.

Location	Start Depth	Stop Depth	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	Aluminum, Calcium, Iron
1. WPZ (10-11)				08/19/2011			X				1
2. WPZ (12-13)				↓			↓				1
3. WPZ (14-15)				↓			↓				1
4. WPZ (16-17)				↓			↓				1
5. WPZ (18-19)				↓			↓				1
6. WPZ (20-21)				↓			↓				1
7.											
8.											
9.											
10.											

Common Parameter/Container - Preservation Key
#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time
				[signature]	8/20/11	1540
Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other:
Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

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Braun Intertec Corporation
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Web: braunintertec.com

Mr. Keith Pilgrim
Barr Engineering Company
4700 West 77th Street
Minneapolis, MN 55435-4803

February 28, 2014

Report #: 1400783

RE: Spent Lime Pond 23621021.01 200 003

Dear Keith Pilgrim:

Braun Intertec Corporation received samples for the project identified above on February 19, 2014. Analytical results are summarized in the following report.

All routine quality assurance procedures were followed, unless otherwise noted.

Analytical results are reported on an "as received" basis unless otherwise noted. Where possible, the samples will be retained by the laboratory for 14 days following issuance of the initial final report. The samples will be disposed of or returned at that time. Arrangements can be made for extended storage by contacting me at this time.

We appreciate your decision to use Braun Intertec Corporation for this project. We are committed to being your vendor of choice to meet your analytical chemistry needs.

If you have any questions please contact me at the above phone number.

Sincerely,

Elizabeth Kadlec For Steven J. Albrecht
Project Manager

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Qualifiers and Abbreviations

sd	See case narrative section for further information.
qo	The relative percent difference (RPD) was outside of laboratory control limits for the matrix spike (MS) and matrix spike duplicate (MSD) samples.
qn	The spike recovery is outside of laboratory control limits for the matrix spike (MS) and/or the matrix spike duplicate (MSD).
J	Detected but below the Method Reporting Limit; therefore, result is an estimated concentration (CLP J-Flag).
COC	Chain of Custody
dry	Sample results reported on a dry weight basis
MDL	Method Detection Limit
MRL	Method Reporting Limit
NA	Not Applicable
ND	Analyte NOT DETECTED above the MDL value
NR	Not Reported
%Rec	Percent Recovery
RPD	Relative Percent Difference
VOC	Volatile Organic Compound

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Case Narrative

The sample containers in Cooler 1 were received at 19.4 °C. This exceeds the regulatory requirement of 6 °C.

In the analysis of Aluminum, Calcium, and Iron in Soil the Matrix Spike (MS)/Matrix Spike Duplicate (MSD) results from preparation batch B4B0335 are not reported due to high levels of target analyte in the source sample. The source sample was another sample from the same preparation batch. The amount of spike used in the MS/MSD was overwhelmed by the level of the analyte in the source sample, resulting in non-valid data for the MS/MSD.

In the analysis of Aluminum and Iron in Soil the Matrix Spike (MS)/Matrix Spike Duplicate (MSD) results from preparation batch B4B0360 are not reported due to high levels of target analyte in the source sample. The source sample was another sample from the same preparation batch. The amount of spike used in the MS/MSD was overwhelmed by the level of the analyte in the source sample, resulting in non-valid data for the MS/MSD.

In the analysis of Calcium in Soil, the Matrix Spike (MS)/Matrix Spike Duplicate (MSD) results from preparation batch B4B0360 are based on the results of a source sample from another project.

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Sample Summary

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Core 1 (0-2 cm)	1400783-01	Soil	01/10/14 13:00	02/19/14 13:18
Core 1 (2-4 cm)	1400783-02	Soil	01/10/14 13:01	02/19/14 13:18
Core 1 (4-6 cm)	1400783-03	Soil	01/10/14 13:02	02/19/14 13:18
Core 1 (6-8 cm)	1400783-04	Soil	01/10/14 13:03	02/19/14 13:18
Core 1 (8-10 cm)	1400783-05	Soil	01/10/14 13:04	02/19/14 13:18
Core 1 (10-15 cm)	1400783-06	Soil	01/10/14 13:05	02/19/14 13:18
Core 2 (0-2 cm)	1400783-07	Soil	01/10/14 13:15	02/19/14 13:18
Core 2 (2-4 cm)	1400783-08	Soil	01/10/14 13:16	02/19/14 13:18
Core 2 (4-6 cm)	1400783-09	Soil	01/10/14 13:17	02/19/14 13:18
Core 2 (6-8 cm)	1400783-10	Soil	01/10/14 13:18	02/19/14 13:18
Core 2 (8-10 cm)	1400783-11	Soil	01/10/14 13:19	02/19/14 13:18
Core 2 (10-15 cm)	1400783-12	Soil	01/10/14 13:20	02/19/14 13:18
Core 3 (0-2 cm)	1400783-13	Soil	01/10/14 13:30	02/19/14 13:18
Core 3 (2-4 cm)	1400783-14	Soil	01/10/14 13:31	02/19/14 13:18
Core 3 (4-6 cm)	1400783-15	Soil	01/10/14 13:32	02/19/14 13:18
Core 3 (6-8 cm)	1400783-16	Soil	01/10/14 13:33	02/19/14 13:18
Core 3 (8-10 cm)	1400783-17	Soil	01/10/14 13:34	02/19/14 13:18
Core 3 (10-15 cm)	1400783-18	Soil	01/10/14 13:35	02/19/14 13:18
Core 4 (0-2 cm)	1400783-19	Soil	01/10/14 13:45	02/19/14 13:18
Core 4 (2-4 cm)	1400783-20	Soil	01/10/14 13:46	02/19/14 13:18
Core 4 (4-6 cm)	1400783-21	Soil	01/10/14 13:47	02/19/14 13:18
Core 4 (6-8 cm)	1400783-22	Soil	01/10/14 13:48	02/19/14 13:18
Core 4 (8-10 cm)	1400783-23	Soil	01/10/14 13:49	02/19/14 13:18
Core 4 (10-15 cm)	1400783-24	Soil	01/10/14 13:50	02/19/14 13:18

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Conditions Upon Receipt

Cooler: Cooler 1

Temperature:	19.4 °C	**COC Included:**	Yes	**Custody Seals Used:**	No
Temperature Blank:	No	**COC Complete:**	Yes	**Custody Seals Intact:**	NA
Received on Ice:	No	**COC & Labels Agree:**	Yes	**Hand Delivered by Client:**	No
Preservation Confirmed:	No	**Sufficient Sample Provided:**	Yes	**Headspace Present (VOC):**	No

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Analyte	Result	MRL	MDL	Units	Batch	Prepared	Analyzed	Analyst	Method	Notes
1400783-01 Core 1 (0-2 cm)										
Aluminum	**13000**	5.0	0.075	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**17000**	20	1.7	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**20000**	10	0.34	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-02 Core 1 (2-4 cm)										
Aluminum	**15000**	9.5	0.14	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**20000**	38	3.3	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**25000**	19	0.65	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-03 Core 1 (4-6 cm)										
Aluminum	**16000**	10	0.15	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**23000**	40	3.5	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**26000**	20	0.68	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-04 Core 1 (6-8 cm)										
Aluminum	**17000**	9.4	0.14	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**25000**	38	3.3	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**27000**	19	0.64	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-05 Core 1 (8-10 cm)										
Aluminum	**15000**	8.8	0.13	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**25000**	35	3.0	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**24000**	18	0.60	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-06 Core 1 (10-15 cm)										
Aluminum	**15000**	9.0	0.13	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**25000**	36	3.1	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**24000**	18	0.62	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-07 Core 2 (0-2 cm)										
Aluminum	**11000**	4.8	0.072	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**14000**	19	1.7	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**18000**	9.6	0.33	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-08 Core 2 (2-4 cm)										
Aluminum	**12000**	8.9	0.13	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**19000**	36	3.1	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**19000**	18	0.61	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-09 Core 2 (4-6 cm)										
Aluminum	**15000**	10	0.15	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium	**25000**	40	3.5	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron	**25000**	20	0.68	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Analyte		Result	MRL	MDL	Units	Batch	Prepared	Analyzed/Analyst		Method	Notes
1400783-10	**Core 2 (6-8 cm)**										
Aluminum		**14000**	8.5	0.13	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**26000**	34	2.9	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron		**23000**	17	0.58	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-11	**Core 2 (8-10 cm)**										
Aluminum		**13000**	8.9	0.13	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**26000**	36	3.1	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron		**22000**	18	0.61	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-12	**Core 2 (10-15 cm)**										
Aluminum		**11000**	8.4	0.13	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**23000**	34	2.9	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron		**20000**	17	0.57	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-13	**Core 3 (0-2 cm)**										
Aluminum		**15000**	9.6	0.14	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**20000**	38	3.3	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron		**27000**	19	0.65	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-14	**Core 3 (2-4 cm)**										
Aluminum		**15000**	9.0	0.13	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**22000**	36	3.1	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron		**26000**	18	0.61	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-15	**Core 3 (4-6 cm)**										
Aluminum		**14000**	8.3	0.12	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**24000**	33	2.9	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
Iron		**26000**	17	0.57	mg/kg	B4B0335	2/20/14	2/25/14	DRM	EPA 6010C	sd
1400783-16	**Core 3 (6-8 cm)**										
Aluminum		**17000**	9.7	0.15	mg/kg	B4B0360	2/24/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**25000**	39	3.4	mg/kg	B4B0360	2/24/14	2/25/14	DRM	EPA 6010C	
Iron		**29000**	19	0.66	mg/kg	B4B0360	2/24/14	2/25/14	DRM	EPA 6010C	sd
1400783-17	**Core 3 (8-10 cm)**										
Aluminum		**16000**	9.4	0.14	mg/kg	B4B0360	2/24/14	2/25/14	DRM	EPA 6010C	sd
Calcium		**26000**	38	3.2	mg/kg	B4B0360	2/24/14	2/25/14	DRM	EPA 6010C	
Iron		**27000**	19	0.64	mg/kg	B4B0360	2/24/14	2/25/14	DRM	EPA 6010C	sd
1400783-18	**Core 3 (10-15 cm)**										
Aluminum		**15000**	8.8	0.13	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
Calcium		**26000**	35	3.1	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	
Iron		**25000**	18	0.61	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Analyte	Result	MRL	MDL	Units	Batch	Prepared	Analyzed	Analyst	Method	Notes
1400783-19 Core 4 (0-2 cm)										
Aluminum	**15000**	8.7	0.13	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
Calcium	**19000**	35	3.0	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	
Iron	**26000**	17	0.60	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
1400783-20 Core 4 (2-4 cm)										
Aluminum	**16000**	8.7	0.13	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
Calcium	**21000**	35	3.0	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	
Iron	**28000**	17	0.59	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
1400783-21 Core 4 (4-6 cm)										
Aluminum	**16000**	9.5	0.14	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
Calcium	**27000**	38	3.3	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	
Iron	**28000**	19	0.65	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
1400783-22 Core 4 (6-8 cm)										
Aluminum	**15000**	9.1	0.14	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
Calcium	**26000**	36	3.1	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	
Iron	**26000**	18	0.62	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
1400783-23 Core 4 (8-10 cm)										
Aluminum	**15000**	9.1	0.14	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
Calcium	**26000**	36	3.1	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	
Iron	**24000**	18	0.62	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
1400783-24 Core 4 (10-15 cm)										
Aluminum	**14000**	9.7	0.15	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd
Calcium	**26000**	39	3.4	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	
Iron	**25000**	19	0.67	mg/kg	B4B0360	2/24/14	2/26/14	DRM	EPA 6010C	sd

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4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Metals - Quality Control

Batch B4B0335 - EPA 3050B

Method Blank (B4B0335-BLK1) Prepared: 02/20/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	0.443 J	5.0	0.075	mg/kg	NA	NA	NA	NA	NA	NA	
Calcium	ND	20	1.7	mg/kg	NA	NA	NA	NA	NA	NA	
Iron	0.542 J	10	0.34	mg/kg	NA	NA	NA	NA	NA	NA	

Laboratory Control Sample (B4B0335-BS1) Prepared: 02/20/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	302	5.0	0.075	mg/kg	300	NA	101	80-120	NA	NA	
Calcium	4080	20	1.7	mg/kg	4000	NA	102	80-120	NA	NA	
Iron	311	10	0.34	mg/kg	300	NA	104	80-120	NA	NA	

Laboratory Control Sample Duplicate (B4B0335-BSD1) Prepared: 02/20/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	290	5.0	0.075	mg/kg	300	NA	96.6	80-120	4.35	20	
Calcium	3910	20	1.7	mg/kg	4000	NA	97.6	80-120	4.26	20	
Iron	296	10	0.34	mg/kg	300	NA	98.8	80-120	4.79	20	

Standard Reference Material (B4B0335-SRM1) Prepared: 02/20/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	10600	11	0.17	mg/kg	6130	NA	173	71.4-250	NA	NA	
Calcium	13400	44	3.8	mg/kg	11900	NA	113	85.7-139	NA	NA	
Iron	11400	22	0.76	mg/kg	9630	NA	118	26.8-193	NA	NA	

Batch B4B0360 - EPA 3050B

Method Blank (B4B0360-BLK1) Prepared: 02/24/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	0.580 J	5.0	0.075	mg/kg	NA	NA	NA	NA	NA	NA	
Calcium	ND	20	1.7	mg/kg	NA	NA	NA	NA	NA	NA	
Iron	0.882 J	10	0.34	mg/kg	NA	NA	NA	NA	NA	NA	

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4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

Metals - Quality Control

Batch B4B0360 - EPA 3050B

Laboratory Control Sample (B4B0360-BS1) Prepared: 02/24/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	300	5.0	0.075	mg/kg	300	NA	100	80-120	NA	NA	
Calcium	4020	20	1.7	mg/kg	4000	NA	100	80-120	NA	NA	
Iron	307	10	0.34	mg/kg	300	NA	103	80-120	NA	NA	

Laboratory Control Sample Duplicate (B4B0360-BSD1) Prepared: 02/24/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	297	5.0	0.075	mg/kg	300	NA	99.3	80-120	0.830	20	
Calcium	3980	20	1.7	mg/kg	4000	NA	99.4	80-120	0.939	20	
Iron	306	10	0.34	mg/kg	300	NA	102	80-120	0.316	20	

Matrix Spike (B4B0360-MS1) **Source: 1400812-01** Prepared: 02/24/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	7760	21	1.8	mg/kg dry	4140	1640	147	75-125	NA	NA	qn

Matrix Spike Duplicate (B4B0360-MSD1) **Source: 1400812-01** Prepared: 02/24/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	5670	20	1.7	mg/kg dry	4010	1640	100	75-125	31.1	20	qo

Standard Reference Material (B4B0360-SRM1) Prepared: 02/24/14 Analyzed: 02/25/14

Analyte	Result	MRL	MDL	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Aluminum	11200	12	0.18	mg/kg	6130	NA	183	71.4-250	NA	NA	
Calcium	13600	47	4.1	mg/kg	11900	NA	114	85.7-139	NA	NA	
Iron	11800	24	0.80	mg/kg	9630	NA	123	26.8-193	NA	NA	

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4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

1400783 Dynamx # 1114342

Chain of Custody

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COC 1 of 3

Project Number: 23621021.01 200 003

Project Name: Spent Lime Pond

Sample Origination State MN (use two letter postal state abbreviation)

COC Number: № 42650

Project Manager: Keith Pilgrim

Project QC Contact:

Sampled by: Kevin Menken 612-636-1907

Laboratory: Braun

Number of Containers/Preservative

Location	Start Depth (cm)	Stop Depth (cm)	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	Water: VOCs (HCl) #1	Water: SVOCs (unpreserved) #2	Water: Dissolved Metals (HNO_3)	Water: Total Metals (HNO_3)	Water: General (unpreserved) #3	Water: Diesel Range Organics (HCl)	Water: Nutrients (H_2SO_4) #4	Soil: VOCs (tared MeOH) #1	Soil: GRO, BTEX (tared MeOH) #1	Soil: DRO (tared unpreserved)	Soil: Metals (unpreserved) Al, Ca, Fe only	Soil: SVOCs (unpreserved) #2	Soil: % Solids (plastic vial, unpres.)	Total Number Of Containers
1. Core 1	0	2	cm	1/10/14	13:00		X	X	~~X~~												X			
2. Core 1	2	4	↓	↓	13:01		X	X													X			
3. Core 1	4	6			13:02		X	X													X			
4. Core 1	6	8			13:03		X	X													X			
5. Core 1	8	10			13:04		X	X													X			
6. Core 1	10	15			13:05		X	X													X			
7. Core 2	0	2			13:15		X	X													X			
8. Core 2	2	4			13:16		X	X													X			
9. Core 2	4	6			13:17		X	X													X			
10. Core 2	6	8	↓	↓	13:18		X	X													X			

Common Parameter/Container - Preservation Key

#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Relinquished By:	On Ice?	Date	Time	Received by:	Date	Time
Kevin Menken	(N)	2/19/14	10:20	[signature]	2/19/14	1313
Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other: ______

Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

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19.4°C

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Barr Engineering Company	Client Ref: Spent Lime Pond 23621021.01 200 003	Report #: 1400783
4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

1400783

Chain of Custody

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4700 West 77th Street
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COC 2 of 3

Project Number: 23621021.01
Project Name: Spent Lime Pond
Sample Origination State: MN (use two letter postal state abbreviation)
COC Number: № 42651

Number of Containers/Preservative — Water: VOCs (HCl) #1; SVOCs (unpreserved) #2; Dissolved Metals (HNO$_3$); Total Metals (HNO$_3$); General (unpreserved) #3; Diesel Range Organics (HCl); Nutrients (H$_2$SO$_4$) #4. Soil: VOCs (tared MeOH) #1; GRO, BTEX (tared MeOH) #1; DRO (tared unpreserved); Metals (unpreserved) Al, Ca, Fe only; SVOCs (unpreserved) #2; % Solids (plastic vial, unpres.). Total Number Of Containers.

Project Manager:
Project QC Contact:
Sampled by:
Laboratory: Braun

	Location	Start Depth	Stop Depth	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Soil	Type: Grab	Soil: Metals (unpreserved) Al, Ca, Fe only
1.	Core 2	8	10	cm	1/10/14	13:19	X	X	X
2.	Core 2	10	15	↓	↓	13:20	X	X	X
3.	Core 3	0	2			13:30	X	X	X
4.	Core 3	2	4			13:31	X	X	X
5.	Core 3	4	6			13:32	X	X	X
6.	Core 3	6	8			13:33	X	X	X
7.	Core 3	8	10			13:34	X	X	X
8.	Core 3	10	15			13:35	X	X	X
9.	Core 4	0	2			13:45	X	X	X
10.	Core 4	2	4	↓	↓	13:46	X	X	X

Common Parameter/Container - Preservation Key
#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Relinquished By:	On Ice?	Date	Time	Received by:	Date	Time
[signature]	Y (N)	2/19/14	10:20	[signature]	2/19/14	1318
Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other: ______ Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

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4700 West 77th Street	Client Contact: Mr. Keith Pilgrim	Project Mgr: Steven J. Albrecht
Minneapolis, MN 55435-4803	PO Number:	Account ID: B01058

1400783

Chain of Custody

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COC 3 of 3

Project Number: 23621021.01

Project Name: Spent Lime Pond

Sample Origination State: MN (use two letter postal state abbreviation)

COC Number: № 42652

Project Manager:

Project QC Contact:

Sampled by:

Laboratory: Braun

Number of Containers/Preservative — Water: VOCs (HCl) #1; SVOCs (unpreserved) #2; Dissolved Metals (HNO_3); Total Metals (HNO_3); General (unpreserved) #3; Diesel Range Organics (HCl); Nutrients (H_2SO_4) #4. Soil: VOCs (tared MeOH) #1; GRO, BTEX (tared MeOH) #1; DRO (tared unpreserved); Metals (unpreserved) Al, Ca, Fe only; SVOCs (unpreserved) #2; % Solids (plastic vial, unpres.). Total Number Of Containers.

	Location	Start Depth	Stop Depth	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Water	Matrix: Soil	Type: Grab	Type: Comp.	Type: QC	Soil: Metals (unpreserved) Al, Ca, Fe only	Total Number Of Containers
1.	Core 4	4	6	Cm	1/10/14	13:47		X	X			X	
2.	Core 4	6	8	↓	↓	13:48		X	X			X	
3.	Core 4	8	10	↓	↓	13:49		X	X			X	
4.	Core 4	10	15	↓	↓	13:50		X	X			X	
5.													
6.													
7.													
8.													
9.													
10.													

Common Parameter/Container - Preservation Key

#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Relinquished By:	On Ice?	Date	Time	Received by:	Date	Time
Kevin Menke	Y (N)	2/19/14	10:20	[signature]	2/19/14	1313
Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other: ______ Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

H:\RLG\S\DFORMS\Chain Of Custody Form 2009 RLG Rev. 09/01/09

EPA Lab ID: MN00063

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

TOXICITY TEST RESULTS

WAKEFIELD STORM WATER POND

Report Date: May 31, 2012

Project No. 12-120

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

PROJECT: WHOLE EFFLUENT TOXICITY TESTING
WAKEFIELD STORM WATER POND

PROJECT NUMBER: 12-120

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on two water samples received by Environmental Toxicity Control (ETC) on May 22, 2012. The sample identified as outlet water and inlet water was from the Wakefield Storm Water Pond and was collected by employees from the Ramsey Washington Metro Watershed District on May 21, 2012. Mr. Keith Pilgrim of Barr Engineering requested that we conduct chronic toxicity testing on the water samples. The scope of our services was limited to conducting a chronic toxicity screen test on the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition, EPA-821-R-02-013.

Control water used for testing consisted of moderately hard laboratory water.

Testing was started on 5/22/12, approximately 24 hours after sample collection.

Testing was conducted under a 2% CO_2 head space.

RESULTS:

Toxicity test results are summarized in Tables 1, test conditions are summarized in Table 2.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference test is shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.910 g/l NaCl	05/11/12

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst

Walter Koenst
Bioassay Manager

Table 1. ***Ceriodaphnia dubia*** **Survival and Reproduction Results of Pit Water**

Screen Test: Ceriodaphnia dubia		
Sample ID	**% Survival**	**Mean # of Young Produced**
Lab Water	90	18.7
Outlet Water	100	25.9
Inlet Water	100	20.3

Table 2. Summary of Chemical and Physical Data of Toxicity Tests

Sample ID	pH	Dissolved Oxygen (mg/L)	Temp (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Lab Water	6.64 - 8.20	7.7 - 8.4	25	104	88	227
Outlet Water	6.66 - 8.02	7.5 - 8.5	25	128	92	576
Inlet Water	6.14 - 7.41	7.5 - 8.6	25	20	8	95

EPA Methods:

Parameter	EPA Method Number
Dissolved Oxygen (mg/L)	360.1
pH	150.1
Total Hardness (as mg/$CaCO_3$/L)	130.2
Total Alkalinity (as mg/$CaCO_3$/L)	310.2
Specific Conductivity (µmhos/cm)	120.1

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: RWMWD Project No.: 12-120

Test Dates/Time • Initiation: 1110 5/22/12 Termination: 1100 5/29/12

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
Lab H2O	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	4	2	4	5	4	4	3	4	2	4	
	5	7	6	0	0	8	0	0	7	5	0	
	6	0	0	7	5	0	7	6	0	X	3	
	7	11	8	11	11	8	11	9	9		12	
Total		22	16	22	21	20	22	18	20	7	19	x̄ = 18.7
Outlet	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	4	3	5	5	4	4	4	4	4	4	
	5	8	8	0	0	4	0	9	6	7	0	
	6	0	0	7	8	4	7	0	0	0	6	
	7	14	14	16	14	13	18	14	16	14	11	
Total		26	25	28	27	25	29	27	26	25	21	x̄ = 25.9
Inlet	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	4	3	1	4	2	2	3	2	3	
	5	3	0	0	5	0	4	0	0	7	0	
	6	0	7	5	0	7	0	6	6	0	7	
	7	11	14	12	9	13	11	10	13	15	12	
Total		16	25	20	15	24	17	18	22	24	22	x̄ = 20.3

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: Km /JS Reviewed By: WK

Toxicity Test
Daily Chemistries

Client: RWMWD	Project Number: 12-120
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Sample ID			Remarks
		Lab H20	Outlet	Inlet	
Day: 0	pH	8.19	7.94	7.14	2% CO2
	Dissolved Oxygen (mg/l)	8.3	8.4	8.3	
Date: 5/22/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (μmhos)	227	576	95	
Analyst: KM	Total Alkalinity (mg/l)	88	92	8	
	Total Hardness (mg/l)	104	128	20	
	Total Ammonia (mg/l)				
Day: 1 Old	pH	7.13	7.20	6.69	
	Dissolved Oxygen (mg/l)	8.0	7.9	7.9	
Date: 5/23/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (μmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 1 New	pH	8.19	7.85	7.13	2% CO2
	Dissolved Oxygen (mg/l)	8.2	8.3	8.3	
Date: 5/23/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (μmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 Old	pH	6.64	6.66	6.14	
	Dissolved Oxygen (mg/l)	7.9	8.0	8.0	
Date: 5/24/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (μmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 New	pH	7.98	7.50	6.59	2% CO2
	Dissolved Oxygen (mg/l)	7.9	8.3	8.3	
Date: 5/24/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (μmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Koenig (signature)   Date: 5/30/12

Toxicity Test
Daily Chemistries

Client: RW MWD	Project Number: 12-120
Test Type: Chronic	Species: C-dubia

Day/Date/Analyst	Parameter	Sample ID			Remarks
		Lab H20	Outlet	Inlet	
Day: 3 old	pH	7.14	7.16	6.64	
	Dissolved Oxygen (mg/l)	8.0	8.0	8.1	
Date: 5/25/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 3 New	pH	8.20	7.73	6.93	2% CO2
	Dissolved Oxygen (mg/l)	8.1	8.4	8.4	
Date: 5/25/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 old	pH	6.97	7.02	6.47	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.2	
Date: 5/26/12	Temperature (°C)	25.1	25.1	25.1	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 New	pH	8.15	8.02	7.41	2% CO2
	Dissolved Oxygen (mg/l)	8.4	8.5	8.4	
Date: 5/26/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 5 Old	pH	7.07	7.15	6.74	
	Dissolved Oxygen (mg/l)	8.3	8.3	8.3	
Date: 5/27/12	Temperature (°C)	25.2	25.2	25.2	
	Conductivity (µmhos)				
Analyst: JS	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter [signature]　　Date: 5/30/12

Toxicity Test
Daily Chemistries

Client: RWMWD	Project Number: 12-120
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID			Remarks
		Lab H20	Outlet	Inlet	
Day: 5 New	pH	8.03	7.71	6.82	2% CO_2
	Dissolved Oxygen (mg/l)	8.3	8.4	8.6	
Date: 5/27/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: JS	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 6 Old	pH	6.89	6.96	6.42	
	Dissolved Oxygen (mg/l)	7.7	7.5	7.5	
Date: 5/28/12	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: JS	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 6 New	pH	8.20	7.92	7.13	2% CO_2
	Dissolved Oxygen (mg/l)	8.0	7.9	7.9	
Date: 5/28/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: JS	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 7 Final	pH	7.19	7.22	6.92	
	Dissolved Oxygen (mg/l)	7.8	7.8	7.8	
Date: 5/29/12	Temperature (°C)	25.4	25.4	25.4	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day:	pH				
	Dissolved Oxygen (mg/l)				
Date:	Temperature (°C)				
/ /	Conductivity (µmhos)				
Analyst:	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: [signature] Date: 5/30/12

TOXICITY TEST RESULTS

WAKEFIELD STORM WATER POND

Report Date: June 27, 2012

Project No. 12-148

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

PROJECT: WHOLE EFFLUENT TOXICITY TESTING WAKEFIELD STORM WATER POND

PROJECT NUMBER: 12-148

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on two water samples received by Environmental Toxicity Control (ETC) on June 19, 2012. The samples identified as outlet water and inlet water were from the Wakefield Storm Water Pond and were collected by employees from the Ramsey Washington Metro Watershed District on June 19, 2012. Mr. Keith Pilgrim of Barr Engineering requested that we conduct chronic toxicity testing on the water samples. The scope of our services was limited to conducting a chronic toxicity screen test on the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition, EPA-821-R-02-013.

Control water used for testing consisted of moderately hard laboratory water.

Testing was started on 6/19/12, approximately 24 hours after sample collection.

Testing was conducted under a 2% CO_2 head space.

RESULTS:

Toxicity test results are summarized in Tables 1, test conditions are summarized in Table 2.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference test is shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.733 g/l NaCl	06/26/12

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst
Bioassay Manager

Table 1. ***Ceriodaphnia dubia* Survival and Reproduction Results of Pit Water**

Screen Test: Ceriodaphnia dubia		
Sample ID	**% Survival**	**Mean # of Young Produced**
Lab Water	100	17.7
Inlet Water	100	26.9
Outlet Water	90	24.8

Table 2. Summary of Chemical and Physical Data of Toxicity Tests

Sample ID	pH	Dissolved Oxygen (mg/L)	Temp (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (μmhos/cm)
Lab Water	6.92 - 8.26	7.7 - 8.6	25	112	84	222
Inlet Water	6.37 - 7.45	7.8 - 9.4	25	8	24	42
Outlet Water	6.97 - 7.87	7.8 - 9.6	25	116	108	469

EPA Methods:

Parameter	EPA Method Number
Dissolved Oxygen (mg/L)	360.1
pH	150.1
Total Hardness (as mg/$CaCO_3$/L)	130.2
Total Alkalinity (as mg/$CaCO_3$/L)	310.2
Specific Conductivity (μmhos/cm)	120.1

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: RWMWD Project No.: 12-148

Test Dates/Time ● Initiation: 1130 6/19/12 Termination: 1000 6/26/12

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
Lab H2O	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	4	0	0	0	0	0	0	0	0	
	4	4	0	6	4	4	4	4	4	4	4	
	5	8	1	9	0	0	5	0	3	10	6	
	6	10	11	12	0	0	0	2	0	0	0	
	7	0	0	0	10	3	10	10	3	11	11	
Total		22	16	27	14	7	19	16	10	25	21	x̄ = 17.7
Inlet	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	2	0	0	
	4	3	4	4	4	4	4	5	0	5	4	
	5	6	9	8	9	10	7	7	6	10	6	
	6	0	16	0	15	14	15	15	15	14	18	
	7	13	0	17	0	0	0	0	0	0	0	
Total		22	29	29	28	28	26	27	23	29	28	x̄ = 26.9
Outlet	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	0	5	0	0	0	0	3	4	0	
	4	0	4	0	5	5	4	4	1	0	0	
	5	10	8	8	8	12	9	9	10	11	8	
	6	12	12	X	0	13	0	0	13	15	0	
	7	0	0		14	0	15	11	0	0	11	
Total		26	24	13	27	30	28	24	27	30	19	x̄ = 24.8

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM Reviewed By: WK

Toxicity Test
Daily Chemistries

Client: RWMWD	Project Number: 12-148
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	Inlet	Outlet	Remarks
Day: 0	pH	8.12	7.31	7.51	2% CO2
	Dissolved Oxygen (mg/l)	7.7	7.8	7.8	
Date:	Temperature (°C)	25.0	25.0	25.0	
6/19/12	Conductivity (µmhos)	222	42	469	
Analyst:	Total Alkalinity (mg/l)	84	24	108	
Km	Total Hardness (mg/l)	112	8	116	
	Total Ammonia (mg/l)				
Day: 1 Old	pH	7.07	6.38	7.06	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.4	
Date:	Temperature (°C)	25.3	25.3	25.3	
6/20/12	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 1 New	pH	8.24	~~8~~ 7.39	7.83	2% CO2
	Dissolved Oxygen (mg/l)	8.3	8.4	8.4	
Date:	Temperature (°C)	25.0	25.0	25.0	
6/20/12	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 Old	pH	6.92	6.37	6.97	
	Dissolved Oxygen (mg/l)	8.4	8.4	8.5	
Date:	Temperature (°C)	25.2	25.2	25.2	
6/21/12	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 New	pH	8.19	7.41	7.56	2% CO2
	Dissolved Oxygen (mg/l)	8.3	8.3	8.2	
Date:	Temperature (°C)	25.0	25.0	25.0	
6/21/12	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Koenig (signature)

Date: 6/27/12

Toxicity Test
Daily Chemistries

Client: RWMWD	Project Number: 12-148
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	Inlet	Outlet	Remarks
Day: 3 old	pH	7.27	6.70	7.35	
	Dissolved Oxygen (mg/l)	8.1	8.2	8.3	
Date: 6/22/12	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 3 New	pH	8.22	7.45	7.87	2% CO_2
	Dissolved Oxygen (mg/l)	8.1	8.7	8.6	
Date: 6/22/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 old	pH	7.19	6.58	7.22	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.1	
Date: 6/23/12	Temperature (°C)	25.4	25.4	25.4	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 New	pH	8.26	7.27	7.86	2% CO_2
	Dissolved Oxygen (mg/l)	8.1	9.4	9.1	
Date: 6/23/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 5 old	pH	7.22	6.62	7.28	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.2	
Date: 6/24/12	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter [signature]   Date: 6/27/12

Toxicity Test
Daily Chemistries

Client: RWMWD	Project Number: 12-148
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	Inlet	Outlet	Remarks
Day: 5 New	pH	8.14	7.29	7.84	2% CO2
	Dissolved Oxygen (mg/l)	8.1	9.1	9.3	
Date: 6/24/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 6 Old	pH	7.32	6.69	7.36	
	Dissolved Oxygen (mg/l)	8.6	8.4	8.4	
Date: 6/25/12	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 6 New	pH	8.10	6.87	7.73	2% CO2
	Dissolved Oxygen (mg/l)	8.2	9.3	9.6	
Date: 6/25/12	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 7 Final	pH	7.26	6.69	7.28	
	Dissolved Oxygen (mg/l)	8.0	8.0	8.0	
Date: 6/26/12	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day:	pH				
	Dissolved Oxygen (mg/l)				
Date:	Temperature (°C)				
/ /	Conductivity (µmhos)				
Analyst:	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Kount

Date: 6/27/12