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Laboratory Testing of Contaminant Attenuation in Rose Creek Aquifer Soils

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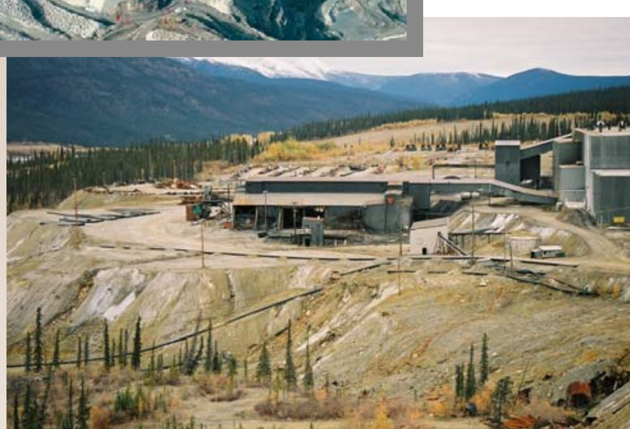
Prepared for:

DELOITTE & TOUCHE INC.
Interim Receiver of Anvil Range Mining Corporation
Suite 1900, 79 Wellington Street West
Toronto, ON M5K 1B9

Prepared by:

SRK Consulting
Engineers and Scientists



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Deloitte & Touche Inc.

Interim Receiver of Anvil Range Mining Corporation
Suite 1900, 79 Wellington Street West
Toronto, ON M5K 1B9
Canada

SRK Consulting (Canada) Inc.
Suite 800, 1066 West Hastings Street
Vancouver, B.C. V6E 3X2

Tel: 604.681.4196   Fax: 604.687.5532
E-mail: vancouver@srk.com   Web site: www.srk.com

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Authors
John Chapman, P.Eng

Reviewed by
Daryl Hockley, P.Eng

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1 Introduction

1.1 Terms of Reference

The tailings in the Rose Creek Tailings Facility are underlain by granular soil that behaves as an aquifer. The rate of transport of contaminants through the underlying aquifer to the downstream receiving environment will affect the selection of decommissioning options for the Rose Creek Tailings Facility. Experience elsewhere has shown that the rate of contaminant transport within an aquifer can be affected strongly by reactions between the contaminants and the aquifer soils. The reactions tend to slow the contaminant movement and this phenomenon is, therefore, commonly referred to as “attenuation”.

Preliminary testing carried out by Gartner Lee Ltd. suggested that some attenuation may be expected within the Rose Creek aquifer. A project to further assess metal attenuation within the aquifer soils was identified during the 2004/05 planning meetings (Deloitte & Touche Inc., 2004). A detailed scope of work for evaluating metal attenuation in the aquifer soils was discussed with a working group that included staff of the Type II Mines Office, Environment Canada, Gartner Lee Ltd. (GLL), and Deloitte & Touche Inc., during a series of conference calls. The agreed scope of work was presented in a memorandum from SRK to Deloitte & Touche Inc., dated March 21, 2004.

1.2 Background

Two separate testing programs had been undertaken to assess zinc attenuation on soil and gravel samples from under the tailings deposit.

In the first program, undertaken as part of the 2001 Rose Creek Tailings Facility Hydrological and Geochemical Investigation (GLL, 2002), a synthetic solution containing about 0.3 mg/L zinc was contacted with soil samples at various solution to solid ratios. The results for selected tests are summarized in Table 1.1. The results from these tests, showed significant attenuation potential with calculated distribution coefficients (K_d’s) ranging from 16 for a 4:1 liquid to solid ratio, to 538 for a 20:1 liquid to solid ratio.

Table 1.1: Summary of GLL 2001 Sorption Test Results

Parameters	Units	Test		
		1	2	3
Soil:Solution Ratio	(g:ml)	1:4	1:10	1:20
pH		8.26	8.45	8.55
Temperature	(^{o}C)	4 - 8	4 - 8	4 - 8
Zn (Initial)	(mg/L)	0.307	0.307	0.307
Zn (final)	(mg/L)	0.061	0.02	0.011
Calculated K_d	L/kg	16	144	538

These results further suggest that the natural soils could retain in excess of 150 mg of zinc per kg of soil (150 mg/kg), while maintaining an equilibrium zinc concentration of about 0.06 mg/L or less.

The second series of batch contact tests, completed on samples obtained during the 2003 drilling program (GLL, 2004), comprised contacting metal rich porewater samples, taken from the tailings, with soil samples. The pore water was diluted to yield varying initial zinc concentrations in contact with the solids, however the contact ratio was maintained at a constant value. The results from that testing program are summarised in Table 1.2. As shown, all the tests were conducted at an acidic pH.

The calculated K_d values obtained from these results suggest that little zinc attenuation would occur at acidic pH conditions. Nevertheless, it is noted that up to about 350 mg of zinc was retained per kg of soil.

Table 1.2: Summary of GLL 2003 Attenuation Test Results

Parameter	Units	Soil Sample P03-05-H-S3					Soil Sample P03-06-F-S2				
pH		3.5	3.8	3.9	3.7	3.8	3.9	3.9	4.1	4.4	3.7
Zn (Initial)	mg/L	666	444	333	222	111	222	166.5	111	55.5	22.2
Zn (Final)	mg/L	648	450	327	218.1	102.3	201	144	98.9	45.8	15.2
K_d	L/kg	0.15	-0.07	0.09	0.09	0.43	0.18	0.30	0.20	0.35	0.78

1.3 Program Objectives

The initial purpose of the additional testing was to provide a more definitive assessment of the attenuation properties of the aquifer. It was also recognized that attenuation of contaminants in the tailings, especially the neutral tailings, may be significant. The program was therefore expanded to include the attenuation capacity and sorption properties for the tailings deposit, i.e. the aquifer system as a whole. The specific objectives included assessment of:

- Neutralization of the acid front in the tailings and the concurrent contaminant release;
- Attenuation of metals in the tailings porewater; and,
- Attenuation of zinc in the aquifer soils.

2 Sampling and Testing Program

2.1 Sampling and Analysis

2.1.1 Tailings and Aquifer Soil Samples

In consultation with Gartner Lee Ltd., representative samples of the tailings and aquifer soils were selected from samples obtained by Gartner Lee Ltd. during the 2003 drilling program. The samples are listed in Table 2.1. The table also shows the analytical program that was undertaken to characterize the samples.

Table 2.1: Summary of Tailings and Soil Samples

Solids Samples ID	Type	Zone	Wt (g)	Org. Carbon	Inorg. Carbon	NP	ICP
P03-03-B-S1	Tailings	A-Dry	549.9	-	✓	✓	✓
P03-03-C-S4	Tailings	A-Dry	747.4	-	✓	✓	✓
P03-03-D-S1	Tailings	N-Dry	594.2	-	✓	✓	✓
P03-03-D-S3	Tailings	N-Sat	833.6	✓	✓	✓	✓
P03-03-E-S2	Tailings	N-Sat	486.2	✓	✓	✓	✓
P03-03-E-S3	Tailings	N-Sat	449.1	✓	✓	✓	✓
P03-04-G-S2	Soil	Sat	1227.3	✓	✓	✓	✓
P03-04-G-S3	Soil	Sat	1244.0	✓	✓	✓	✓
P03-04-J-S2	Soil	Sat	1482.7	✓	✓	✓	✓
P03-08-A-S1	Tailings	A-Dry	344.6	-	✓	✓	✓
P03-08-A-S3	Tailings	N-Dry	385.4	-	✓	✓	✓
P03-08-B-S3	Tailings	N-Dry	304.5	-	✓	✓	✓
P03-08-B-S4	Tailings	N-Dry	305.9	-	✓	✓	✓
P03-08-C-S2	Tailings	N-Dry	239.0	-	✓	✓	✓

Notes: N – neutral; A – acidic; Sat – Saturated (below the water table)

The tailings samples were obtained from Drill Hole P03-03, located in the Second Impoundment, and from Drill Hole P03-08, located in the Intermediate Impoundment. The tailings samples ranged from fine sand to sandy silt which was typically described as grey in colour, signifying little or no oxidation.

Soil samples P03-04-G-S2 and P03-04-G-S3 contained tan brown to grey, coarse, sandy, silty till, with some gravel and cobbles. These samples originated from within 1 meter of the base of the tailings. Soil sample P03-04-J-S2 is black-stained coarse sand with gravel and cobbles, containing trace amounts of silt. The latter sample originated some 10 meters below the base of the tailings deposit. These samples were all obtained from Drill Hole P03-04 located immediately adjacent and upstream of the approximate middle of the Second Impoundment dam, which corresponds approximately to the geometric centre of the entire tailings deposit.

2.1.2 Water Samples and Analysis

Tailings porewater samples were obtained from existing monitoring wells in the Rose Creek tailings deposit. The wells were selected to provide porewater containing a range of zinc concentrations. Porewater was pumped from Wells X21A-96 (2 samples), P01-06A (3 samples) and P01-09B (2 samples) using a peristaltic pump, and pumped directly into closed, expandable 10 L plastic containers to minimise headspace and limit exposure to oxygen during pumping. The containers were sealed once filled, placed in cooler boxes and shipped to CEMI for sub-sampling and analysis. The analytical program is shown in Table 2.2.

Table 2.2: Tailing Porewater Samples and Summary of Analytical Program

Sample ID	Vol. (L)	Category	ICP-OES	pH	Cond.	Alkalinity	Acidity	Redox
X21A-96-1	10	TYP III	✓	✓	✓	✓	✓	✓
X21A-96-2	10	TYP III	✓	✓	✓	✓	✓	✓
P106A1	10	TYP I	✓	✓	✓	✓	✓	✓
P106A2	10	TYP I	✓	✓	✓	✓	✓	✓
P106A3	10	TYP I	✓	✓	✓	✓	✓	✓
P0109B1	10	TYP II	✓	✓	✓	✓	✓	✓
P0109B2	10	TYP II	✓	✓	✓	✓	✓	✓

Note: ICP-OES refers to inductively coupled optical emission spectrophotometry; cond. refers to conductivity; and redox refers to measurements of oxidation-reduction potential.

2.2 Contact Testing

Contact tests were completed on each of the soil samples and a tailings composite sample. One contact test was completed for each type of tailings porewater, at the three dilution ratios shown in Table 2.3. The tailings composite was prepared from samples that originated from the saturated zone (below the water table) in the tailings deposit.

The contact tests were completed in a glove box with atmospheric oxygen excluded with a slight nitrogen overpressure. The “Timed Samples” column shown in Table 2.3 indicates the tests from which small aliquots of samples were extracted at 8, 24, 48 and 72 hours for analysis. The remainder of the tests were contacted for 72 hours and only the final solutions were analyzed.

Table 2.3: Contact Test Program

Solids Sample	Test	Timed Samples	Solids* (g)	Site Water (mL)			Distilled (mL)	Total (mL)
				Type I	Type II	Type III		
P03-04-G-S2	1	Yes	100	100	-	-	200	300
	2	No	75	-	150	-	75	225
	3	No	75	-	-	225	0	225
P03-04-G-S3	1	No	75	75	-	-	150	225
	2	Yes	100	-	200	-	100	300
	3	No	75	-	-	225	0	225
P03-04-J-S2	1	No	75	75	-	-	150	225
	2	No	75	-	150	-	75	225
	3	Yes	100	-	-	300	0	300
Tailings Composite 350g P03-03-E-S2 +	1	Yes	100	100	-	-	200	300
350g P03-03-E-S3 +	2	No	75	-	150	-	75	225
600g P03-03-D-S3	3	No	75	-	-	225	0	225

Note: * weight indicated is the 'as received' weight

2.3 Column Test Program

2.3.3 Acid Neutralization Column Tests

Two acid neutralization column tests were completed on the composite tailings sample. The following provides a brief description of the sample preparation, test set-up and column operation.

Sample Preparation

A composite was prepared from the tailings samples by blending the tailings samples listed in Table 2.4. A representative sub-sample was obtained from the composite sample and submitted for modified Sobek neutralization potential (NP) and inorganic carbon analyses, as well as trace element analysis by an inductively coupled plasma (ICP) scan.

Table 2.4: Composite Tailings Sample Make-up

Sample ID	'As Received' Wt (g)
P03-08-A-S1	232
P03-08-A-S3	275
P03-08-B-S3	192
P03-08-B-S4	187
P03-08-C-S2	125
Total	1011

Apparatus

Two columns (CT1 and CT2), 220 mm long with an internal diameter of 38 mm and removable head-plates, each of which was equipped with an inlet, were used for these tests. A fine mesh distribution 'plate' (3 to 4 nylon mesh disks) were placed at each end of the column as shown schematically in Figure 2.1. The internal volume of each column was about 250 mL and accommodated about 475 g of tailings. The pore volume of the contained tailings was estimated to be about 100 mL.

Procedure

The operational set-up of the column test is shown in Figure 2.2. The tests were carried out using tailings porewater sample P0109B-2. At the time of commencing the test, a sample of the water was submitted for analysis for ICP-OES, pH, conductivity, acidity and redox (oxidation-reduction reactions).

The following steps were taken to prepare and set-up the column tests:

- The base plate of the column was sealed in place.
- The nylon disks were placed at the bottom of the column, and the complete apparatus was weighed.
- Each column was then filled with tailings to the top of the column, ensuring that an even compact fill density was achieved. The apparatus was again weighed and the weight of the the column was subtracted to obtain the weight of tailings charge.
- The top of the column was sealed in place, and pressure tested.
- The top outlet of the column was then attached to an air trap and the pore gases were displaced with pressurized nitrogen.
- The column was then flooded with de-aerated distilled water to prime the column. The volume of water used to saturate the column was measured.
- Conditions were allowed to equilibrate for 24 hours before acidic water displacement commenced. The displacement rate was set at approximately 100 mL a 24 hour period.
- While maintaining anoxic conditions, the effluent pH and redox conditions were measured for each 100 mL displaced. Each 100 mL aliquot was then sealed and place in cold storage for analysis as required.
- Initially, the first and then every fifth displacement were submitted for ICP analysis and alkalinity and acidity testing, as appropriate. The column tests were intended to be operated for up to 30 pore volume displacements.

Once the tests were completed, the tailings residue was carefully extruded from each of the columns. The tailings charge from each column was then divided into quarters (from top to bottom as it was aligned in the column), and each quarter was submitted for modified Sobek NP, inorganic carbon and metals ICP analysis.

2.3.4 Metal Attenuation Column Tests

Testing Program

From the initial batch contact tests, two soil samples were selected for further testing. Altogether a series of four columns were completed as shown in Table 2.5. Since the mass of available soil samples was limited, and since some particles exceeded the diameter of the columns, the respective soil samples were screened to less than 25 mm. The oversize material was hand broken to less than 25 mm, recombined with the undersize material for testing.

Table 2.5: Summary of Column Attenuation Tests

Column #	Soils Sample	Water Source
CTS3	P03-04-G-S2	P106A3
CTS4	P03-04-G-S2	P0109B1
CTS5	P03-04-G-S3	P106A3
CTS6	P03-04-G-S3	P0109B1

Apparatus

Four columns, 220 mm long with an internal diameter of 38 mm, with removable head-plates each equipped with an inlet were prepared for testing. As described previously, a fine mesh distribution ‘plate’ comprising 3 to 4 nylon mesh disks, was placed at each end of the columns as shown schematically in Figure 2.1. The internal volume of each column was about 250 mL and accommodated about 425 g of soil sample. The pore volume of the contained soils was estimated to be about 120 mL.

Procedure

The operational set-up of the column test is shown in Figure 2.2. The tests were carried out using water samples indicated in Table 2.5 above. At the time of commencing the test, a sample from each of the water types was submitted for analysis including ICP-OES, pH conductivity, acidity and redox.

The experimental procedure adopted for the preparation and operation of the column tests was as follows:

- The base plate of the column was sealed in place.
- The nylon disks were placed at the bottom of the column, and the apparatus was weighed.
- The column was filled to the top with soil, ensuring that an even compact fill density was achieved. The filled column was weighed and the empty column weight was subtracted to obtain the soil charge weight.
- The top of the column was sealed in place, and pressure tested.

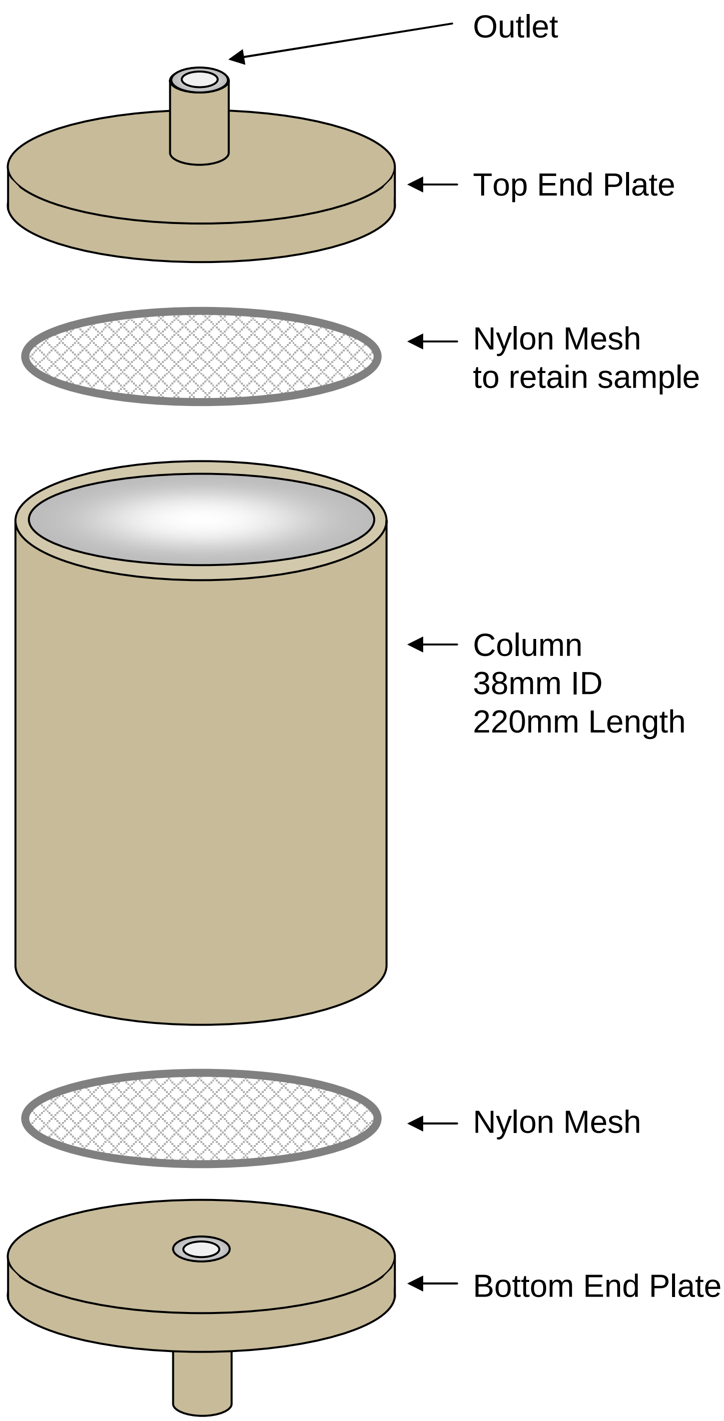
- The top outlet of the column was attached to an air trap and the pore gases were displaced with nitrogen.

- The column was flooded with de-aerated distilled water in preparation for testing. The volume of water used to saturate the column was measured.

- Conditions were allowed to equilibrate for 24 hours before testing commenced. The pore water was displaced at rate of about 60 mL over a 24 hour period, which equated to a retention time of about 48 hours. While maintaining anoxic conditions the pH and redox were measured for each 120 mL displaced, representing one displacement. Each complete pore volume displaced was then sealed and place in cold storage for analysis as required.

- Initially, the first and then every third displacement were submitted for ICP analysis, and alkalinity and acidity testing, as appropriate.

- The tests were intended to be continued for 20 days or until 10 pore volume displacements had been completed.



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Anvil Range Mining Complex
Attenuation Testing

Column Schematic

PROJECT:	DATE:	APPROVED:	FIGURE:
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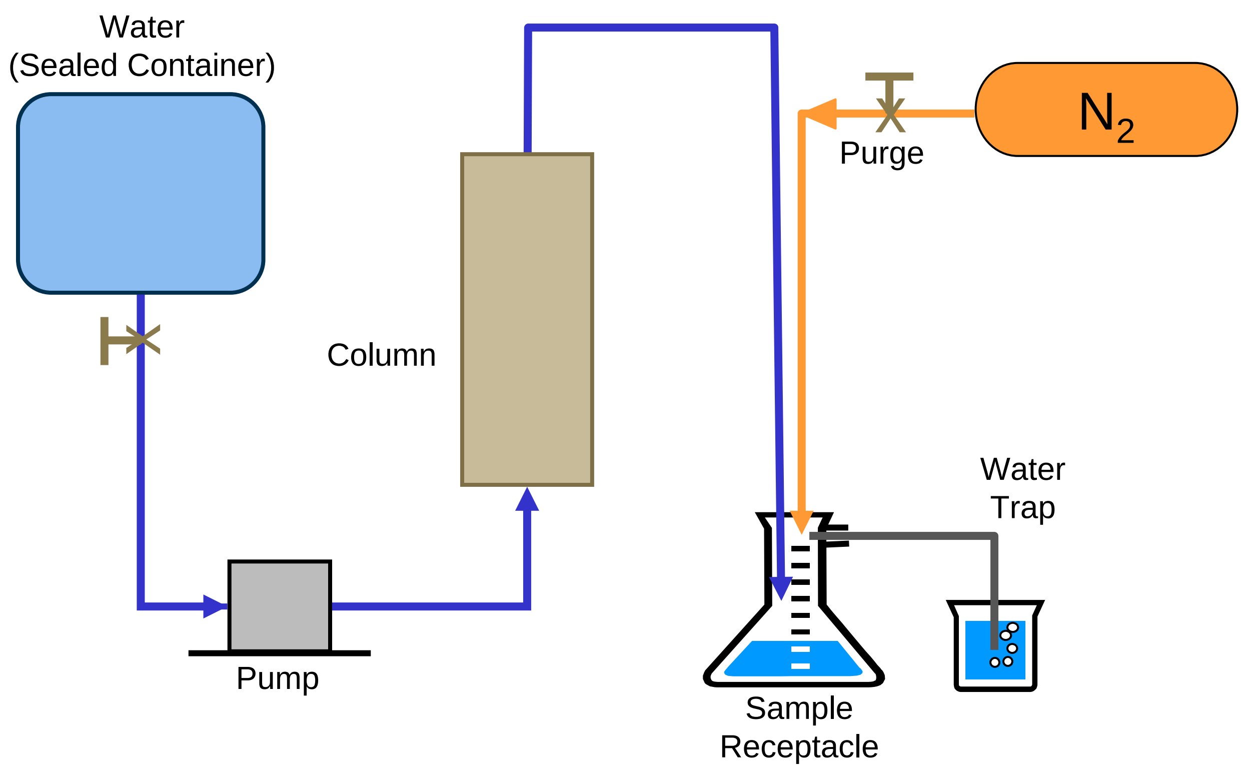


SRK Consulting Engineers and Scientists	Anvil Range Mining Complex Attenuation Testing
Deloitte & Touche	**Operational Column Set-Up**

PROJECT:	DATE:	APPROVED:	FIGURE:
1CD003.43	Nov. 2004		**2.2**

3 Results and Discussion

3.1 Solids Analysis

The detailed analytical results for the tailings and the subsoils are presented in Appendix A. The results indicate that the subsoils contain significantly less zinc than the tailings, with concentrations below about 600 ppm, compared to > 6,000 ppm for the tailings. Compared to the tailings, the subsoils are also characterized by comparatively low iron content, averaging about 3 %. The tailings contain in excess of 15 % iron.

The NP and organic and inorganic analyses are shown in Table 3.1. The table also shows the estimated carbonate equivalent NP (CO_3NP) calculated from the inorganic carbon content.

The results indicate a poor correlation between the NP and CO_3NP for the tailings samples; generally the carbonate NP is much higher than the NP indicated by the modified Sobek method. This is contrary to expectation and may indicate the presence of excess iron carbonates, which provide no net neutralizing capacity. A better correlation exists for the soil samples, with the carbonate NP marginally lower than the modified Sobek method NP.

The results for the tailings samples selected for the preparation of the composite for contact testing indicate that, even though the tailings originated from the saturated zone, the NP was essentially depleted. This was unexpected and may have had significant bearing on the contact test results, as discussed later.

Table 3.1: Summary of Neutralization Potential of Tailings and Subsoils

Sample	Description	Moisture Content (%)	Sample pH	NP	Organic Carbon (%)	Inorganic Carbon (%)	CO_3NP
P03-08-A-S1	Tailings	19.0	5.2	18.0	-	0.79	65.8
P03-08-A-S3	Tailings	15.7	6.4	16.3	-	0.87	72.5
P03-08-B-S3	Tailings	18.0	7.4	28.4	-	1.12	93.3
P03-08-B-S4	Tailings	15.5	7.4	12.3	-	0.83	69.2
P03-08-C-S2	Tailings	19.7	6.6	26.3	-	1.14	95.0
P03-03-B-S1	Tailings	6.3	4.1	1.0	-	0.56	46.7
P03-03-C-S4	Tailings	11.3	3.9	-8.5	-	0.25	20.8
P03-03-D-S1	Tailings	12.7	4.5	1.6	-	0.45	37.5
P03-03-D-S3*	Tailings	12.5	5.5	1.3	0.12	0.63	52.5
P03-03-E-S2*	Tailings	11.2	5.2	0.8	0.07	0.50	41.7
P03-03-E-S3*	Tailings	12.3	5.7	1.8	0.07	0.51	42.5
P03-04-J-S2	Subsoil	0.2	7.0	7.9	0.19	0.03	2.5
P03-04-G-S3	Subsoil	4.9	7.3	12.3	0.13	0.08	6.7
P03-04-G-S2	Subsoil	2.9	7.1	15.0	0.14	0.12	10.0

Note: NP and CO_3NP in units of kg $CaCO_3$eq/tonne;
* Samples composited for contact tests

3.2 Porewater Analyses

The detailed analyses and field parameters are provided in Appendix B. The results are summarised in Table 3.2. There was a decrease in pH from the initial field conditions to the time that the analyses were completed. This suggests that some air ingress had occurred during sampling and transportation and that ferrous iron oxidation resulted in the formation of some iron oxy-hydroxides. This likely also resulted in the sorption of some zinc.

Table 3.2: Summary of Tailings Porewater Analysis

Parameter	Units	X21A-96-		P106A-			P0109B-	
		1	2	1	2	3	1	2
Field Tests								
pH		5.78	5.78	6.32	6.32	6.32	5.47	5.47
Conductivity	(uS/cm)	3180	3180	3106	3106	3106	1910	1910
Laboratory								
pH		3.65	3.79	6.0	5.85	6.11	3.41	3.21
Conductivity	(uS/cm)	2170	2080	1371	1286	1294	1615	1999
Redox	(mV)	291	284	-33	-17	-40	315	344
Acidity	(pH 4.5)	20	20	0	0	0	47	74
	(pH 8.3)	725	765	515	510	525	868	1515
Alkalinity	(mg CaCO3/L)	0	0	68	61	101	0	0
Sulphate	(mg/L)	2546	2246	2186	2126	2216	1163	1736
Dissolved Metals								
Calcium	(mg/L)	170	178	417	391	396	63.6	72.1
Iron	(mg/L)	328	360	220	205	229	381	673
Magnesium	(mg/L)	206	220	118	124	125	20.6	25.5
Manganese	(mg/L)	32.2	34.8	39.9	40.4	40.7	23.7	26.2
Sodium	(mg/L)	93.5	92.6	45.9	45.7	45.7	16.8	19
Zinc	(mg/L)	0.636	0.83	4.25	4.14	4.56	57.5	92.1

3.3 Contact Test Results

The initial conditions for all the contact tests are provided in Appendix C. The attachment also shows the volumes of water and water type, and weights of solids used in the tests. The results from the contact tests are discussed below.

3.3.1 Rate of Sorption

The results of the tests from which aliquots of the solution were extracted periodically are provided in Appendix C. As described above, small aliquots of solution sample were extracted from selected tests at 8, 24, 48 and 72 hours to assess the kinetics of sorption. The results for these tests are also provided in Appendix C. Changes in the solution pH, and iron and zinc concentrations are shown in Figure 3.1, Figure 3.2 and

Figure 3.3, respectively.

Two of the tests (samples P03-04-G-S2 and P03-04-G-S3) showed an increase in pH from initial conditions, whereas the pH decreased in the tests completed on the third soil sample (P03-04-J-S2) and the tailings composite. All tests showed a net removal of iron. However, zinc removal only occurred for the two samples that showed a net increase in pH. Considering that the redox potential increased in all cases (see Appendices C and E), it seems likely that some oxygen ingress may have occurred during the execution of the tests.

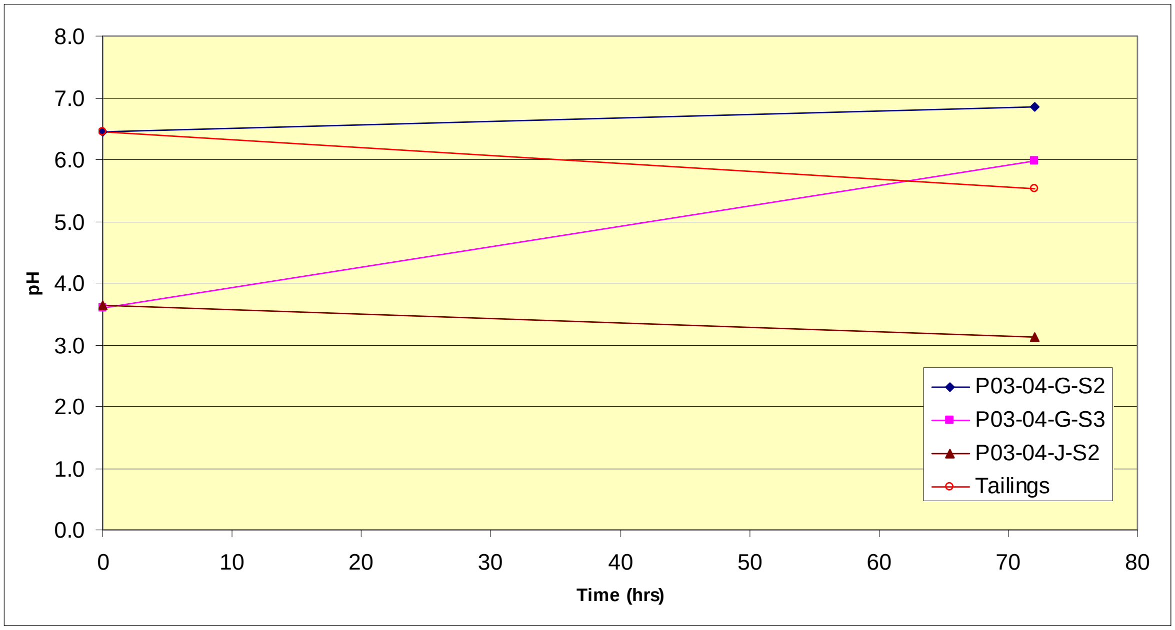


Figure 3.1 Contact Test pH Results

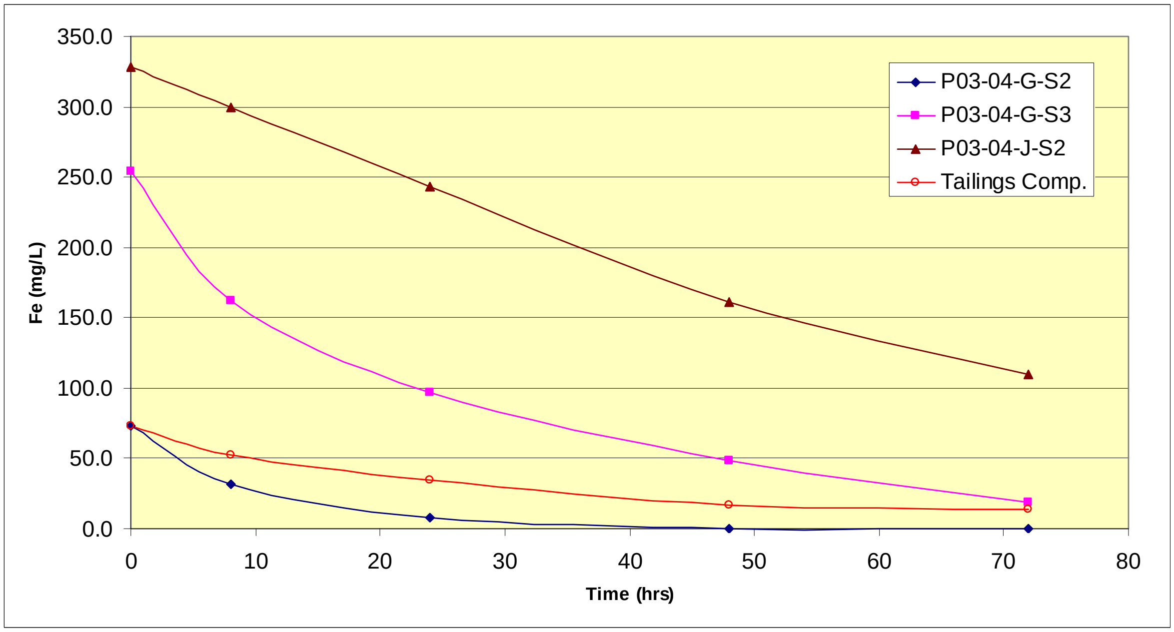


Figure 3.2. Changes in Iron Concentration with Time

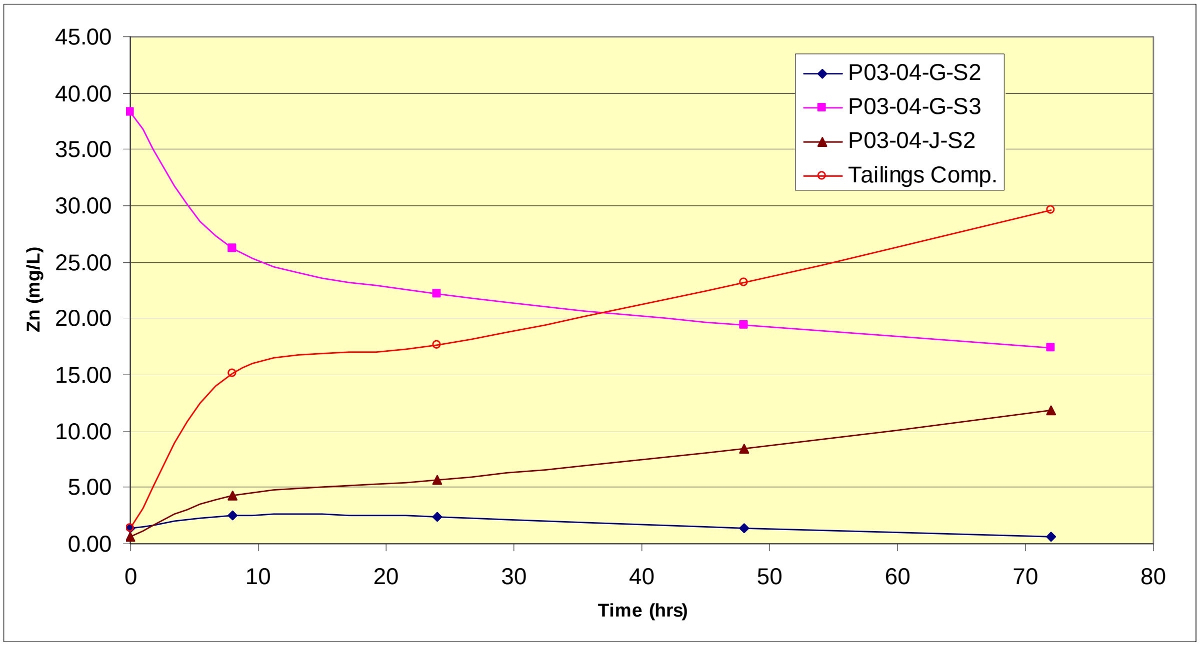


Figure 3.3. Changes in Zinc Concentrations with Time

It is further noted that for soil sample P03-04-G-S2, zinc was initially released and then removed. This may have been a result of the lower initial pH. Zinc concentrations increased over time for the two tests for which a net decrease in pH occurred. It is evident from these plots that zinc sorption does not occur readily at acidic pH conditions, but rather is leached from the solids.

Based on the zinc removal observed for sample P03-04-G-S3, a target residence time of about 48 was selected for the column testing.

3.3.2 Zinc Distribution Coefficients Estimated from Contact Tests

The results for all the 72 hour contact tests are provided in Appendix C. Based on these results, distribution coefficient (K_d) values for zinc were calculated as shown in Table 3.3. The table also summarises the initial and final conditions for each of the tests. Iron concentrations decreased for all tests, suggesting that oxygen ingress had occurred, that iron was oxidized to ferric and was precipitated as iron-oxy-hydroxides, which influenced the pH. This likely also influenced zinc sorption.

The results indicate that two of the three soil samples (P03-04-G-S2 and P03-04-G-S3) are likely to attenuate zinc. These two soil types also have excess neutralization capacity which is readily available. The third soil type (P03-04-J-S2) appears to have little neutralizing capacity and is not likely to attenuate zinc. The tailings composite sample, while exhibiting some residual neutralizing capacity, does not appear to attenuate zinc. The neutralizing capacity of the tailings, estimated from the iron removal (about 2 kg $CaCO_3$ eq/tonne), corresponds well with the modified Sobek NP measurements (see Table 3.1).

The calculated distribution coefficients for zinc are also shown in Figure 3.4. The results indicate that zinc attenuation is pH dependant and is not likely to occur at a pH below about 5.5.

Table 3.3: Summary of Estimated K_d Values for Zinc

Solids	Water	Ref. Test	pH		Redox (mV)		Iron (mg/L)			Zinc (mg/L)		K_d(Zn)
			Initial	Final	Initial	Final	Initial	Final	Change	Initial	Final	(L/kg)
P03-04-G-S2	P106A1	1	6.45	6.86	-11	264	73	0.12	73	1.4	0.67	3.33
P03-04-G-S3	P106A1	1	6.45	7.23	-11	137	73	0.03	73	1.4	0.42	7.14
P03-04-J-S2	P106A1	1	6.45	4.22	-11	301	73	0.19	73	1.4	5.2	-2.17
TAILINGS	P106A1	1	6.45	5.53	-11	293	73	13.8	60	1.4	29.6	-2.86
P03-04-G-S2	P0109B1	2	3.59	5.72	210	161	254	46.5	208	38	29	1.01
P03-04-G-S3	P0109B1	2	3.59	5.97	210	103	254	18.3	236	38	17	3.61
P03-04-J-S2	P0109B1	2	3.59	3.18	210	395	254	95.3	159	38	42	-0.26
TAILINGS	P0109B1	2	3.59	5.45	210	92	254	226	28	38	55	-0.90
P03-04-G-S2	X21A-96-1	3	3.65	5.73	291	71	328	110	218	0.64	7.6	-2.75
P03-04-G-S3	X21A-96-1	3	3.65	5.45	291	151	328	148	180	0.64	6.2	-2.69
P03-04-J-S2	X21A-96-1	3	3.65	3.13	291	388	328	110	218	0.64	11.8	-2.84
TAILINGS	X21A-96-1	3	3.65	5.21	291	180	328	263	65	0.64	26.1	-2.93

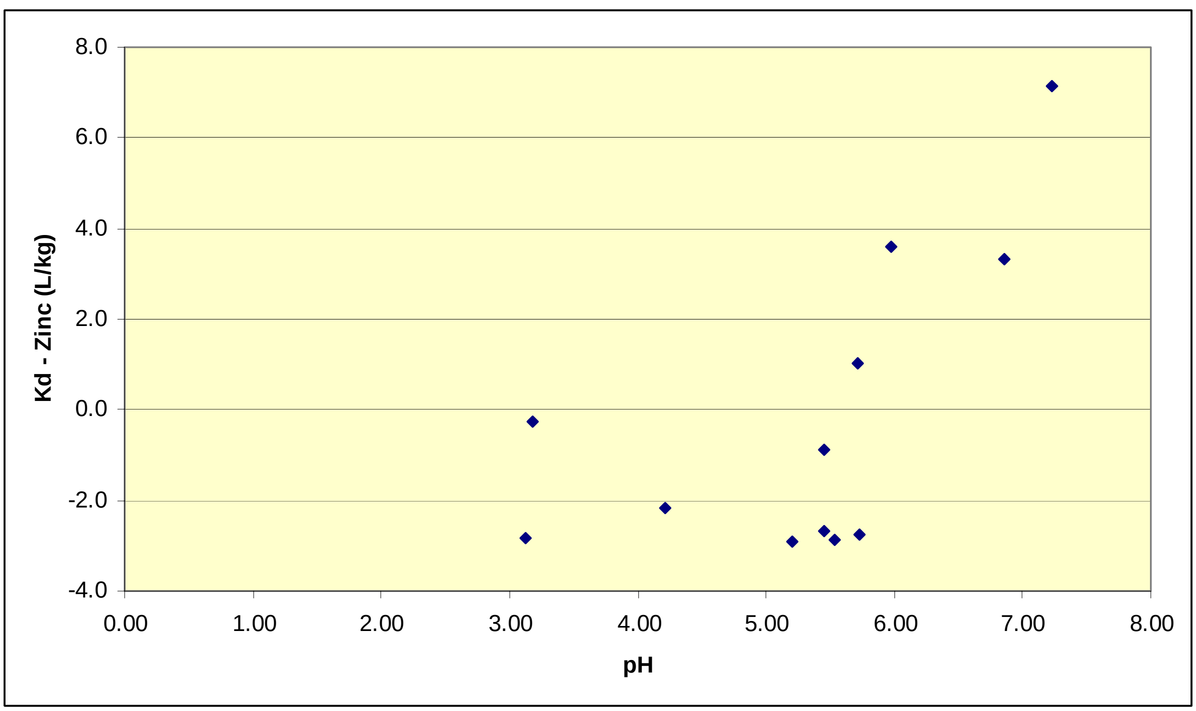


Figure 3.4. Effect of pH on Estimated Distribution Coefficient for Zinc

3.4 Column Test Results

A total of six column tests were carried out. The first two column tests were completed using a composite tailings sample to assess acid neutralization and the potential for metal attenuation within the tailings. The remainder of the columns were completed on aquifer soil samples. The results are presented and discussed below.

3.4.1 Acid Neutralization Tests

A brief memorandum that summarises the results for the acid neutralization column tests is provided in Appendix D. These tests were not successful due to the fact that the tailings samples had oxidized between the time that they were first analyzed and the time that they were used for testing. The acid base account results summarised in Table 3.4 demonstrated the extent of oxidation and NP consumption that occurred. As a result, the columns were acidic at the onset of the tests and remained acidic, even when the feed solution was changed to a less acidic solution.

However, some useful results were obtained as follows:

- Acidification of the tailings occurs at a residual NP of about 10 kg$CaCO_3$ eq/tonne;
- Below this, some neutralization of acidity does occur, albeit at a slow rate; and,
- Zinc attenuation does not appear to occur in the acidic tailings under anoxic conditions.

Table 3.4: Summary of Initial and Composite Tailings Properties

Sample	Weight (g)	Paste pH	NP (kg $CaCO_3$ eq/tonne)	TIC %	Carbonate NP (kg $CaCO_3$ eq/tonne)
P03-08-A-S1	232	5.2	18	0.79	65.8
P03-08-A-S3	275	6.4	16	0.87	72.5
P03-08-B-S3	192	7.4	28	1.12	93.3
P03-08-B-S4	187	7.4	12	0.83	69.2
P03-08-C-S2	125	6.6	26	1.14	95.0
Composite					
Calculated	1011	6.5	19	0.92	77
Measured	1011	4.7	10	0.67	56

Since part of the purpose of this component of the program was to establish the proportion of the NP that is available for acid neutralization, the data from the 2001 geochemical investigation conducted by Gartner Lee Limited was reviewed (GLL, 2002).

Figure 3.5 shows the correlation between rinse pH and neutralization potential from that program. As the figure indicates, acidification appears to occur at a residual NP between 5 and 10. In this regard, the results from the 2001 geochemical investigation and the current observations are in agreement.

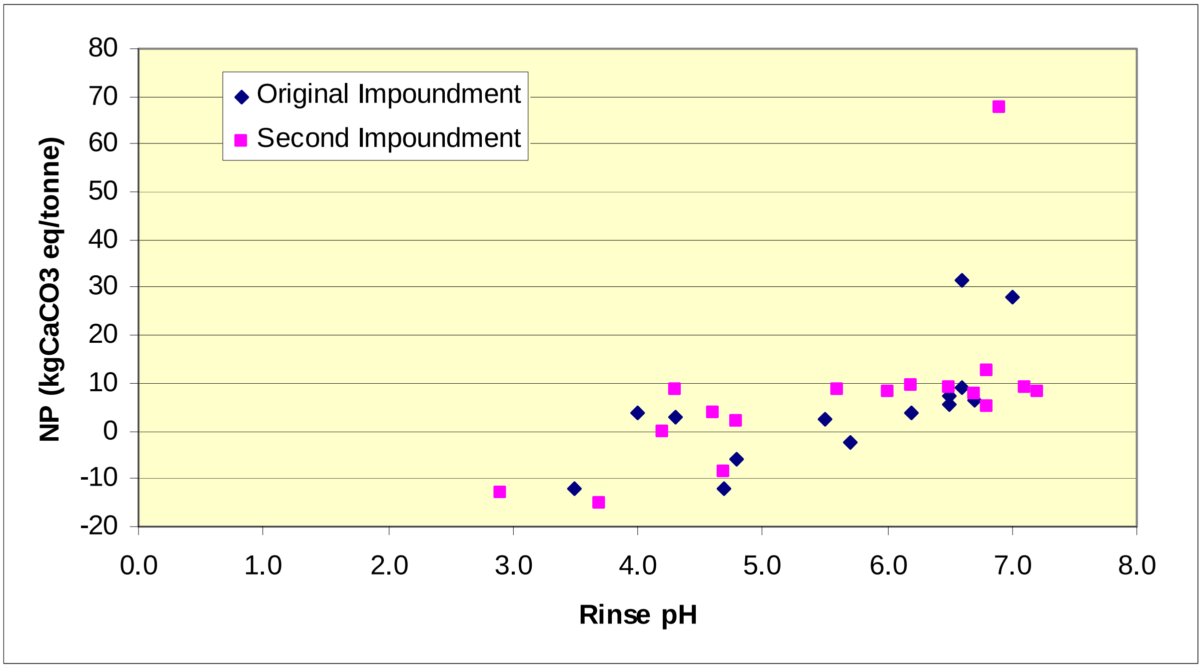


Figure 3.5 Correlation between Rinse pH and Residual NP (GLL, 2002)

3.4.2 Aquifer Soil Attenuation Tests

Complete results from the soil attenuation column testing are provided in Appendix E. The appendix also provides plots that compare column effluent parameters with the influent parameters. The results are summarised in Table 3.5. A series of plots have also been prepared to illustrate the results. The plots are shown on Figure 3.6 to Figure 3.11.

When the initial water analyses presented in Table 3.5 are compared to the original analyses shown in Table 3.2, it is apparent that even under sealed conditions oxygen entry to the water samples had occurred during storage. (The samples were stored during the period that the initial phase of batch testing was completed before being used in the column testing phase.) This led to a reduction in pH, but did not affect the zinc concentrations.

The results from the column tests can be summarised as follows:

- The influent was neutralized to a pH of about 6 for in excess of six pore volume displacements, as shown in Figure 3.6. The results indicate that the neutralization potential associated with the soils is reactive.
- The effluent redox remained below the influent redox (see Appendix E), but tended to increase as the pH decreased toward the end of testing, as shown in Figure 3.7. The initial results suggest that oxygen exclusion was likely achieved during the early stages of testing however, the tests may have been compromised toward the end.

- Zinc was removed from the high zinc solution by both soil samples, as shown for tests CT4 and CT6 in Figure 3.8. The gradual increase in the zinc concentration in the effluent may be indicative of a kinetic constraint on sorption reactions.

- In contrast to the high zinc influent tests, the tests conducted on the low zinc water samples (Tests CT3 and CT5) showed zinc removal only during the very early stages of testing. Overall mass balances further suggest a net release of zinc as the pH decreased toward the end of testing.

- All tests indicated a net removal of iron from solution. Iron concentrations in the column effluent tended to increase in the latter stages of testing as shown in Figure 3.9, which coincided with a decrease in pH.

- The cumulative mass of zinc adsorbed in the high zinc influent tests (CT4 and CT6) increased throughout the tests, even when the decrease in effluent pH occurred, as shown in Figure 3.10. These results suggest that the removal mechanism is less effective at lower pH but may not necessarily be reversible. Overall, up to 60 to 70 mg Zn /kg soil may be removed from solution. In contrast, the corresponding profiles for the low zinc influent tests indicated a net release toward the end the tests (negative values shown in the figure).

- As the results presented in Table 3.5 show, for a similar mass iron removed, the zinc removal is significantly different between the high and low influent zinc tests. The low influent tests showed continuous net removal of iron but a net release of zinc occurred, which would suggest that there is no connection between iron and zinc removal. However, there appears to be a correlation between the ratio of zinc to iron removed and pH as shown in Figure 3.11.

Table 3.5: Summary of Attenuation Column Test Results

Column	Parameter	Units	Test Results										
CT3			**P106A3**	**Effluent**									
Soil	Displacements	PV	0	1.3	2.6	3.9	5.3	6.6	7.7	9.1	10.3	11.4	12.7
P03-04-G-S2	pH		3.5	6.4	6.3	6.6	6.2	5.8	6.2	6.2	5.7	3.8	5.6
	Redox	mV	339	212	205	167	133	120	209	165	246	280	185
	Acidity	mgCaCO$_3$ eq/L	393	7	13	19	25	25	25	57	58	60	43
	Fe	mg/L	170	0.03	7.0	11.0	0.03	29.2	15.5	20.5	40.1	11.8	10.5
	Zn	mg/L	4.46	2	4.73	4.97	4.4	8.44	5.8	6.95	7.45	9.91	7.76
	Fe (Solids)	mg/kg	0	52	103	156	218	262	305	354	392	436	486
	Zn (Solids)	mg/kg	0	0.7	0.7	0.5	0.5	-0.7	-1.1	-1.9	-2.8	-4.3	-5.4
	Zn / Fe Removal	(mg Zn)/(mg Fe)	0	0.014	0.006	0.003	0.002	-0.003	-0.004	-0.005	-0.007	-0.010	-0.011
CT4			**P0109B1**	**Effluent**									
	Displacements	PV	0	1.3	2.7	4.0	5.2	6.5	7.9	9.1	10.4	11.5	12.9
P03-04-G-S2	pH		2.9	6.1	5.8	6.1	6.4	5.2	5.2	5.6	4.2	3.6	3.1
	Redox	mV	399	66	230	89	100	167	200	200	162	260	227
	Acidity	mgCaCO$_3$ eq/L	890	102	134	165	197	302	407	406	450	306	302
	Fe	mg/L	376	41	126	122	76	167	252	149	211	63.6	112
	Zn	mg/L	59.4	16	32.8	35.8	30.3	46.3	49.9	43	55.5	58.3	50.1
	Fe (Solids)	mg/kg	0	106	192	269	352	421	460	526	581	663	747
	Zn (Solids)	mg/kg	0	13.7	22.9	30.0	38.1	42.4	45.4	50.2	51.5	51.8	54.7
	Zn / Fe Removal	(mg Zn)/(mg Fe)	0	0.130	0.119	0.112	0.108	0.101	0.099	0.095	0.089	0.078	0.073
CT5			**P106A3**	**Effluent**									
	Displacements	PV	0	1.4	2.8	4.1	5.6	6.9	8.1	9.5	10.9	12.1	13.4
P03-04-G-S3	pH		3.5	6.4	6.0	6.4	6.3	3.7	5.6	5.9	4.3	3.6	4.9
	Redox	mV	339	45	210	200	115	180	231	237	195	260	167
	Acidity	mgCaCO$_3$ eq/L	393	10	17	23	30	32	34	67	71	62	29
	Fe	mg/L	170	4.54	40	37.1	1.06	33.6	16.6	22.7	32.1	11	13.7
	Zn	mg/L	4.46	2.17	3.3	3.07	2.88	6.18	4.76	5.12	6.44	6.67	5.38
	Fe (Solids)	mg/kg	0	49	89	125	179	217	257	302	343	382	428
	Zn (Solids)	mg/kg	0	0.7	1.0	1.4	1.9	1.4	1.3	1.1	0.6	0.0	-0.3
	Zn / Fe Removal	(mg Zn)/(mg Fe)	0	0.014	0.012	0.011	0.011	0.007	0.005	0.004	0.002	0.000	-0.001
CT6			**P0109B1**	**Effluent**									
	Displacements	PV	0	1.3	2.7	3.9	5.1	6.4	7.6	8.9	10.3	11.4	12.7
P03-04-G-S3	pH		2.9	6.2	5.9	6.3	6.4	5.1	5.1	5.4	4.3	3.6	3.1
	Redox	mV	399	35	240	194	110	182	240	245	195	265	244
	Acidity	mgCaCO$_3$ eq/L	890	70	155	240	324	348	372	381	411	324	339
	Fe	mg/L	376	25.4	47.2	60.7	120	125	169	146	166	134	116
	Zn	mg/L	59.4	11.6	16.5	19	36.2	35.5	41.3	41.2	48.7	49.8	51.9
	Fe (Solids)	mg/kg	0	99	200	277	343	414	470	535	597	656	730
	Zn (Solids)	mg/kg	0	13.5	26.7	36.6	42.6	49.3	54.2	59.3	62.5	64.8	66.9
	Zn / Fe Removal	(mg Zn)/(mg Fe)	0	0.136	0.133	0.132	0.124	0.119	0.115	0.111	0.105	0.099	0.092

Distribution coefficients, or K_d values, were estimated as the column tests progressed. A "breakthrough" K_d was also estimated at the point that zinc effluent concentrations reached 50 percent of the influent concentration in the high zinc tests. The results are summarised in Table 3.6, and indicate significantly lower K_d values than the batch tests.

Table 3.6: Summary of Estimated K_d Values Derived from Column Tests

Pore volumes Displaced	Estimated K_d (L/kg)			
	CT3	**CT4**	**CT5**	**CT6**
1.3	0.7	1.7	0.6	2.3
2.6	0.2	0.9	0.4	1.9
3.9	0.1	0.9	0.4	2.1
5.3	0.1	1.2	0.6	1.5
Breakthrough	n/a	0.7	n/a	1.1

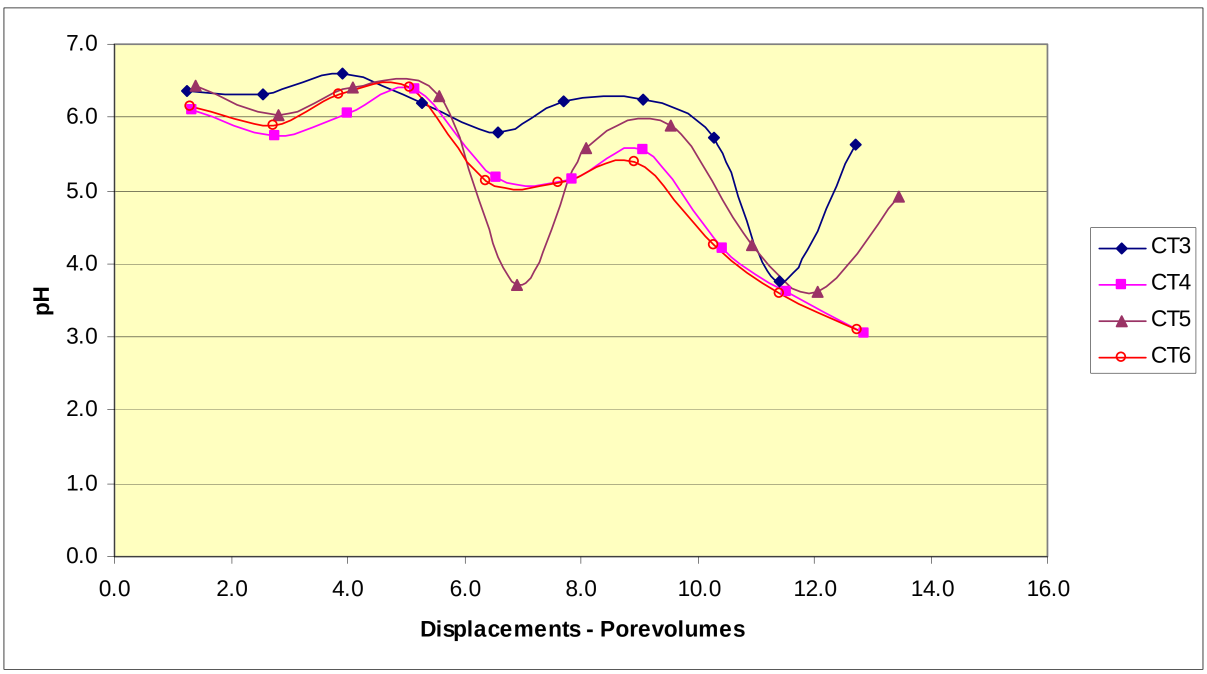


Figure 3.6 Column Test Effluent pH

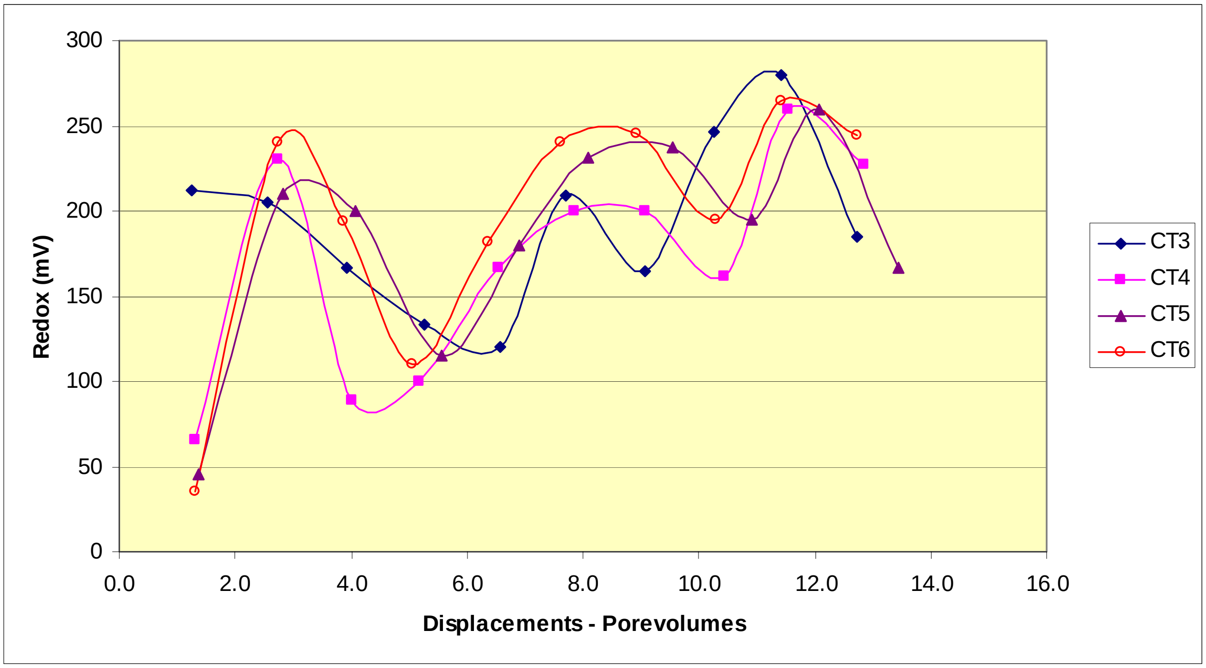


Figure 3.7 Column Test Effluent Redox Conditions

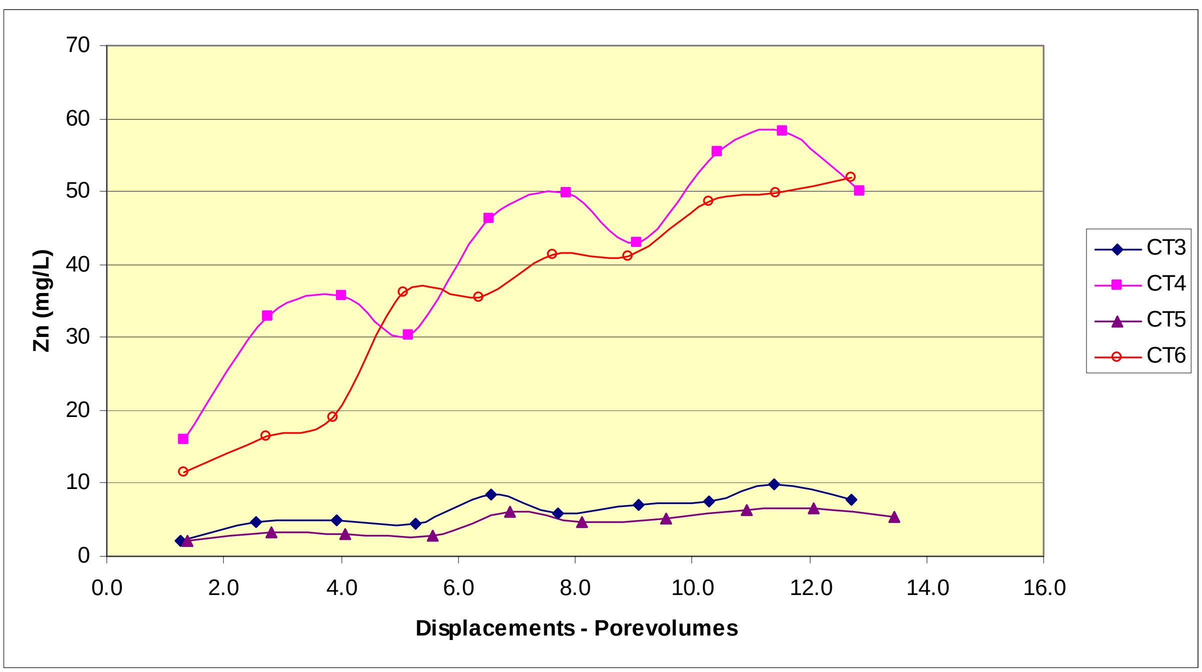


Figure 3.8 Zinc Concentrations in Column Effluents

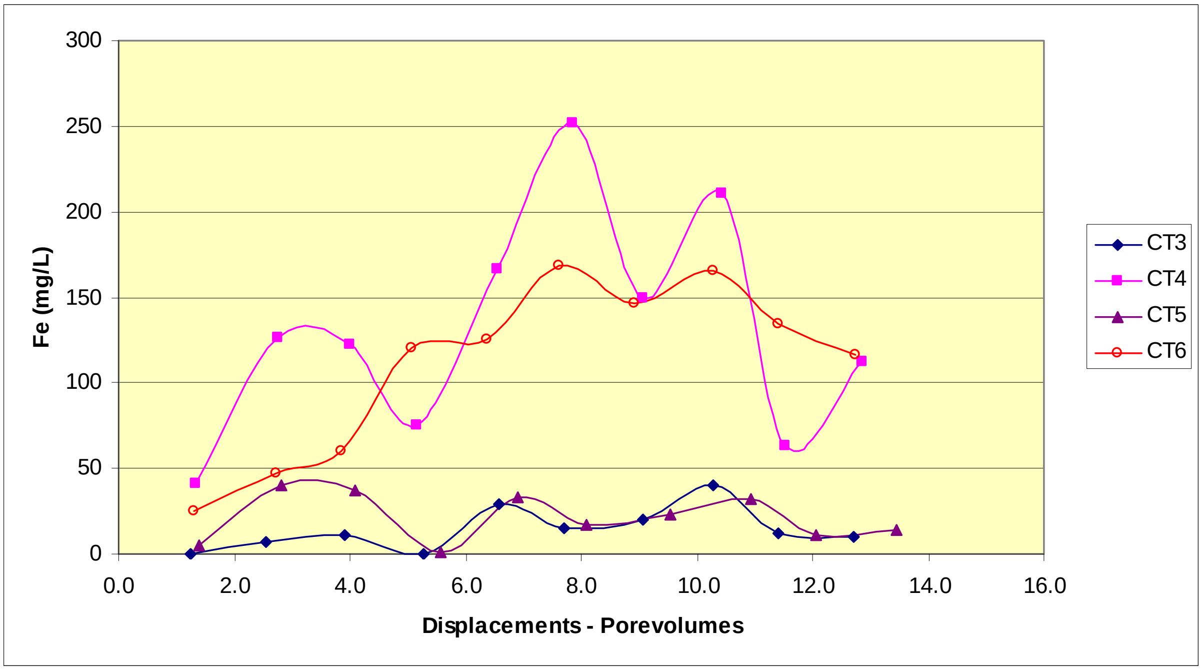


Figure 3.9 Iron Concentrations in Column Effluents

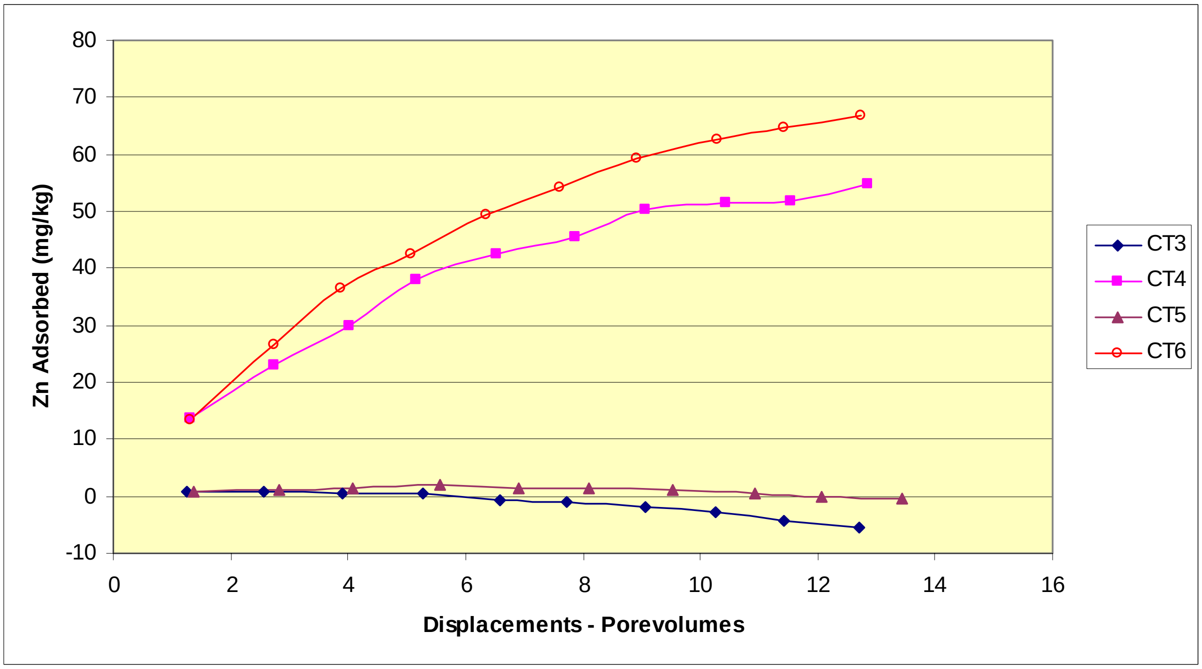


Figure 3.10 Cumulative Mass of Zinc Removed from Column Influent

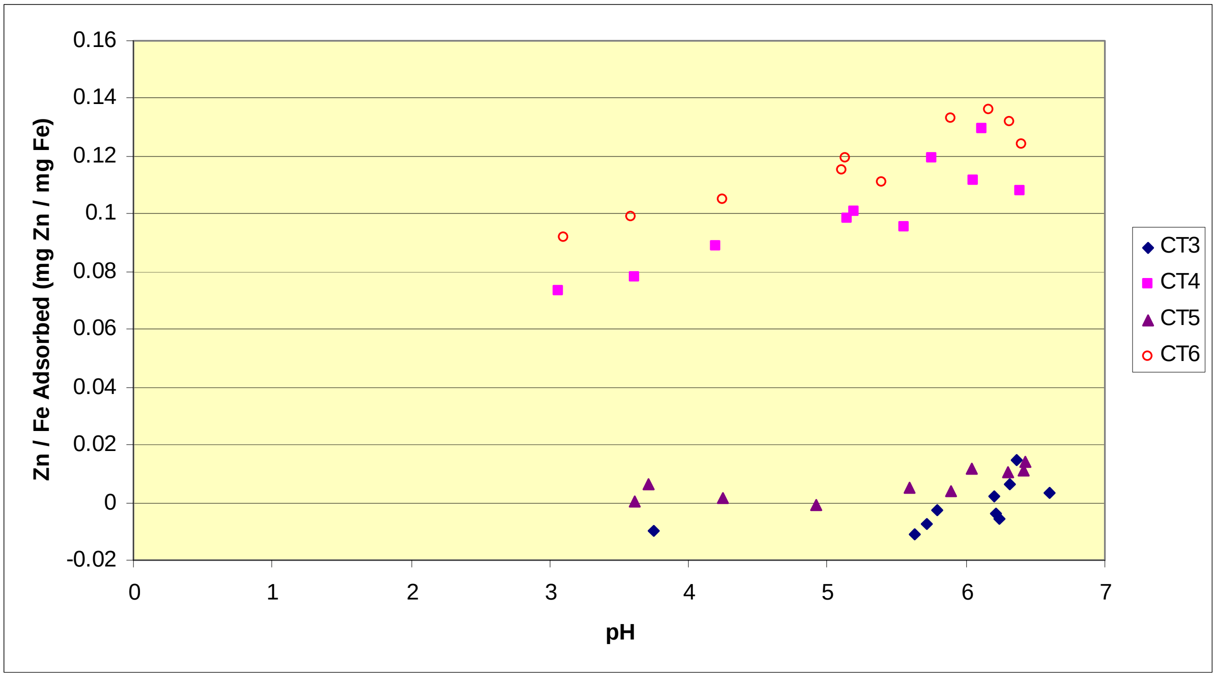


Figure 3.11 pH Dependency of the Ratio of Zinc to Iron Removed

4 Conclusions and Recommendations

4.1 Batch Test

A series of batch and column tests were completed to assess the potential of aquifer soils below the Rose Creek Tailings Facility to attenuate metals leached from the overlying tailings.

The testing generally indicated a potential for zinc attenuation and neutralization of acidity. In brief, the conclusions from the initial batch testing can be summarised as follows:

- The tailings composite sample used in the contact tests had little or no buffering capacity;
- Oxygen ingress during sample handling and testing affected the batch test results;
- Two of the three soil samples from the aquifer below the tailings likely have a capacity to attenuate zinc; and,
- Zinc attenuation appears to be strongly pH dependent with little or no attenuation expected once the porewater pH decreases below about 5.5.

4.2 Acid Neutralization

The acid neutralization column tests conducted on the tailings proved unsuccessful due to the fact that excessive oxidation of the tailings prior to testing consumed the readily available neutralization capacity. However, a comparison with field results confirmed that the availability of the neutralization potential below about 5 to 10 kg$CaCO_3$ eq/tonne is limited. Below this threshold a rapid decrease in pH can be expected. The column test results further indicated that no or little attenuation of zinc can be expected within the tailings under anoxic acidic conditions.

The conclusions from the attenuation column tests completed on the aquifer soil samples can be summarised as follows:

- The aquifer soils have a capacity to neutralize acidity released from tailings.
- Two soil samples from the aquifer immediately below the tailings deposit have a capacity to attenuate zinc, however, attenuation coefficients are significantly lower than those indicated by the batch test results.
- Contrary to the batch tests, the column tests suggest, in part, that zinc removal could continue even at low pH conditions, albeit at a significantly lower removal rate.
- The soils appear to have a capacity to remove zinc to in excess of 60 to 70 mg of zinc per kilogram of soil.

- While the mechanism is uncertain, it appears that the zinc removal is non-reversible within the range of pH decrease detected in the tests (below 5).

4.3 Column Test

The column test results further indicate that a K_d value of about 1 – 2 L/kg should provide a reasonable indication of the potential zinc attenuation that can be expected to occur within the aquifer. Evaluation of the effects on transport within the aquifer is not within the scope of this project, but will be addressed in Tasks 16 f and 16 g being undertaken by Robertson GeoConsultants Inc. The reader is referred to that report which was in progress at the time of writing. However, to demonstrate the significance of such attenuation, it is helpful to convert the K_d values to "retardation factors" as follows.

Assuming that the aquifer soils have a dry bulk density of 1.8 kg/L and a porosity of 0.3, the K_d value of 1 L/kg would correspond to a retardation factor of about 7 ($R = 1 + \rho K_d/\theta$), implying that a front of zinc contamination would move through the aquifer about seven times more slowly than the groundwater. The K_d value of 2 L/kg would correspond to a retardation factor of 13. Recent estimates of the groundwater velocity below the Rose Creek Tailings are in the range of 1.5×10^{-6} m/s. At that rate it will take water from the base of the Secondary Impoundment about 60 years to reach Station X14, which is about 2800 m downstream. The zinc front would take between 7 and 13 times that long, or from 420 to 780 years to reach the same point.

This report, **1CD003.043 - Laboratory Testing of Contaminant Attenuation in Rose Creek Aquifer Soils**, was prepared by SRK Consulting (Canada) Inc.

Prepared by

John Chapman, P.Eng.

Reviewed by

Daryl Hockley, P.Eng.
Principal

Appendix A
Solids Analyses

Table A-1. Solids Neutralization Potential and Carbon Contents

Sample	Description	Moisture Content (%)	Sample pH*	NP	Organic Carbon	Inorganic Carbon	CO3NP
P03-08-A-S1	Tailings	19.0	5.2	18.0	-	0.79	65.8
P03-08-A-S3	Tailings	15.7	6.4	16.3	-	0.87	72.5
P03-08-B-S3	Tailings	18.0	7.4	28.4	-	1.12	93.3
P03-08-B-S4	Tailings	15.5	7.4	12.3	-	0.83	69.2
P03-08-C-S2	Tailings	19.7	6.6	26.3	-	1.14	95.0
P03-03-B-S1	Tailings	6.3	4.1	1.0	-	0.56	46.7
P03-03-C-S4	Tailings	11.3	3.9	-8.5	-	0.25	20.8
P03-03-D-S1	Tailings	12.7	4.5	1.6	-	0.45	37.5
P03-03-D-S3	Tailings	12.5	5.5	1.3	0.12	0.63	52.5
P03-03-E-S2	Tailings	11.2	5.2	0.8	0.07	0.5	41.7
P03-03-E-S3	Tailings	12.3	5.7	1.8	0.07	0.51	42.5
P03-04-J-S2	Subsoil	0.2	7.0	7.9	0.19	0.03	2.5
P03-04-G-S3	Subsoil	4.9	7.3	12.3	0.13	0.08	6.7
P03-04-G-S2	Subsoil	2.9	7.1	15.0	0.14	0.12	10.0
RE P03-08-A-S1	Tailings	-	-	21.3		0.81	67.5

* Sample pHs were done on the as wet samples, as received. Insufficient pulverized sample to conduct paste pH.

AP = Acid potential in tonnes CaCO3 equivalent per 1000 tonnes of material. AP is determined from calculated sulphide sulphur content: S(T) - S(SO4), assuming total conversion of sulphide to sulphate.

NP = Neutralization potential in tonnes CaCO3 equivalent per 1000 tonnes of material.

NET NP = Net neutralization potential = Tonnes CaCO3 equivalent per 1000 tonnes of material.

Table A-2. Trace Element Analyses

	DH Sample	P03-08 A-S1	P03-08 A-S3	P03-08 B-S3	P03-08 B-S4	P03-08 C-S2	P03-03 B-S1	P03-03 C-S4	P03-03 D-S1	P03-03 D-S3	P03-03 E-S2	P03-03 E-S3	P03-04 J-S2	P03-04 G-S3	P03-04 G-S2
Ag	ppm	21.0	13.6	25.5	14.1	22.9	17.3	5.7	5.4	12.4	7.9	11.0	<0.2	<0.2	<0.2
Al	%	0.72	0.27	0.40	0.22	0.38	0.40	0.03	0.06	0.10	0.08	0.11	1.48	1.84	1.54
As	ppm	1000	1020	913	837	974	438	334	493	404	462	451	18	7	<5
Ba	ppm	52	34	37	34	37	38	24	19	43	39	27	237	279	285
Be	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	0.8	0.7
Bi	ppm	8	9	<5	9	5	7	12	14	10	13	13	<5	<5	<5
Ca	%	1.12	0.58	0.92	0.52	0.86	0.25	0.06	0.09	0.25	0.12	0.15	0.59	1.00	0.91
Cd	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Co	ppm	107	136	83	151	77	99	229	184	143	158	132	16	13	10
Cr	ppm	83	91	89	114	72	138	109	118	92	103	151	231	183	180
Cu	ppm	1572	1255	1782	963	1737	532	1317	816	741	858	836	45	35	28
Fe	%	>15.00	>15.00	>15.00	>15.00	>15.00	>15.00	>15.00	>15.00	>15.00	>15.00	>15.00	2.78	3.44	3.12
K	%	0.10	0.05	0.06	0.03	0.07	0.05	0.01	0.02	0.03	0.02	0.03	0.26	0.33	0.25
Mg	%	0.66	0.32	0.52	0.29	0.46	0.17	0.09	0.12	0.19	0.14	0.15	0.69	0.79	0.76
Mn	ppm	4771	2613	5259	2522	4301	845	615	676	1105	746	801	330	314	347
Mo	ppm	4	2	3	<2	3	5	<2	<2	<2	<2	<2	6	2	3
Na	%	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.04	0.02	0.05	0.06	0.05
Ni	ppm	40	36	43	32	39	56	14	22	31	26	31	45	38	32
P	ppm	491	544	476	477	461	628	319	335	547	370	448	584	658	661
Pb	ppm	7714	5029	9164	5152	7552	5434	3410	2925	2567	2985	4147	81	40	24
Sb	ppm	40	30	41	23	38	36	11	22	31	20	29	<5	<5	<5
Sc	ppm	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	3	5	4
Sn	ppm	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Sr	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	44	90	49
Ti	%	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.06	0.04
V	ppm	52	48	48	49	43	50	37	41	42	41	43	39	44	39
W	ppm	205	139	218	142	204	214	141	212	99	150	157	<10	<10	<10
Y	ppm	5	3	4	2	4	4	<1	<1	3	<1	2	6	7	7
Zn	ppm	>10000	9212	>10000	9657	>10000	>10000	9570	>10000	6807	9980	>10000	256	536	565
Zr	ppm	17	17	16	19	15	14	16	18	18	18	18	5	6	6

Appendix B
Porewater Analyses

Table B-1. Tailings Porewater Analysis

Parameter	Units	X21A-96-1	X21A-96-2	P106A-1	P106A-2	P106A-3	P0109B-1	P0109B-2
Field Tests								
pH		5.78	5.78	6.32	6.32	6.32	5.47	5.47
CONDUCTIVITY	(uS/cm)	3180	3180	3106	3106	3106	1910	1910
Laboratory								
pH		3.65	3.79	6.0	5.85	6.11	3.41	3.21
CONDUCTIVITY	(uS/cm)	2170	2080	1371	1286	1294	1615	1999
Redox	(mV)	291	284	-33	-17	-40	315	344
ACIDITY	(pH 4.5)	20	20	0	0	0	47	74
	(pH 8.3)	725	765	515	510	525	868	1515
ALKALINITY	(mg CaCO3/L)	0	0	68	61	101	0	0
SULPHATE	(mg/L)	2546	2246	2186	2126	2216	1163	1736
Dissolved Metals								
Aluminum	(mg/L)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	(mg/L)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	(mg/L)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	(mg/L)	<0.010	<0.010	0.026	0.032	0.029	0.017	0.019
Beryllium	(mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	(mg/L)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	(mg/L)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	(mg/L)	<0.010	<0.010	<0.010	<0.010	<0.020	<0.010	0.013
Calcium	(mg/L)	170	178	417	391	396	63.6	72.1
Chromium	(mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	(mg/L)	<0.010	<0.010	0.179	0.156	0.173	0.136	0.123
Copper	(mg/L)	<0.010	<0.010	<0.010	<0.010	<0.020	<0.010	<0.010
Iron	(mg/L)	328	360	220	205	229	381	673
Lead	(mg/L)	<0.050	0.121	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	(mg/L)	0.033	0.039	<0.020	<0.010	<0.010	0.038	0.038
	(mg/L)							
Magnesium	(mg/L)	206	220	118	124	125	20.6	25.5
Manganese	(mg/L)	32.2	34.8	39.9	40.4	40.7	23.7	26.2
Molybdenum	(mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	(mg/L)	<0.050	<0.050	0.128	0.075	0.101	0.169	0.147
Phosphorus	(mg/L)	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	(mg/L)	11.1	12.1	9.4	8.9	8.3	3.7	3.3
Selenium	(mg/L)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	(mg/L)	6.16	6.28	6.22	6.29	6.76	10.9	11
Silver	(mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	(mg/L)	93.5	92.6	45.9	45.7	45.7	16.8	19
Strontium	(mg/L)	0.42	0.434	1.33	1.33	1.37	0.203	0.223
Thallium	(mg/L)	<0.20	<0.30	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	(mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.050
Titanium	(mg/L)	<0.010	<0.010	<0.020	<0.010	<0.010	<0.010	<0.010
Vanadium	(mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	(mg/L)	0.636	0.83	4.25	4.14	4.56	57.5	92.1

Appendix C
Batch Contact Test Results

Table C-1.
Calculated Initial Solution Analyses

SAMPLE			P03-04-G-S2			P03-04-G-S3		
Extractions			Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Solids	Wet	g	100	75	75	75	100	75
TPYE I	P106A1	(mL)	100	0	0	75	0	0
TYPE II	P0109B1	(mL)	0	150	0	0	200	0
TYPE III	X21A-96-1	(mL)	0	0	225	0	0	225
Dist. Water		(mL)	200	75	0	150	100	0
Parameter								
pH			6.4	3.6	3.7	6.4	3.6	3.7
CONDUCTIVITY		(uS/cm)	457	1077	2170	457	1077	2170
Redox		(mV)	-11	210	291	-11	210	291
ACIDITY		(pH 4.5)	0	31	20	0	31	20
		(pH 8.3)	172	579	725	172	579	725
ALKALINITY		(mg CaCO	23	0	0	23	0	0
SULPHATE		(mg/L)	729	775	2546	729	775	2546
Dissolved Metals								
Aluminum		mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony		mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic		mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium		mg/L	0.0087	0.0113	<0.010	0.0087	0.0113	<0.010
Beryllium		mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth		mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron		mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium		mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium		mg/L	139	42.4	170	139	42.4	170
Chromium		mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt		mg/L	0.060	0.091	<0.010	0.060	0.091	<0.010
Copper		mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron		mg/L	73.3	254.0	328.0	73.3	254.0	328.0
Lead		mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium		mg/L	<0.010	0.025	0.033	<0.010	0.025	0.033
Magnesium		mg/L	39	14	206	39	14	206
Manganese		mg/L	13.3	15.8	32.2	13.3	15.8	32.2
Molybdenum		mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel		mg/L	0.043	0.113	<0.050	0.043	0.113	<0.050
Phosphorus		mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium		mg/L	3.1	2.5	11.1	3.1	2.5	11.1
Selenium		mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon		mg/L	2.1	7.3	6.2	2.1	7.3	6.2
Silver		mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium		mg/L	15.3	11.2	93.5	15.3	11.2	93.5
Strontium		mg/L	0.44	0.14	0.42	0.44	0.14	0.42
Thallium		mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin		mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Titanium		mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium		mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc		mg/L	**1.42**	**38.33**	0.64	**1.42**	**38.33**	0.64

Table C-1.
Calculated Initial Solution
Analyses

SAMPLE			PO3-04-J-S2			Talings Composite		
Extractions			Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Solids	Wet	g	75	75	100	100	75	75
TPYE I	P106A1	(mL)	75	0	0	100	0	0
TYPE II	P0109B1	(mL)	0	150	0	0	150	0
TYPE III	X21A-96-1	(mL)	0	0	300	0	0	225
Dist. Water		(mL)	150	75	0	200	75	0
Parameter								
pH			6.4	3.6	3.7	6.4	3.6	3.7
CONDUCTIVITY	(uS/cm)		457	1077	2170	457	1077	2170
Redox	(mV)		-11	210	291	-11	210	291
ACIDITY	(pH 4.5)		0	31	20	0	31	20
	(pH 8.3)		172	579	725	172	579	725
ALKALINITY	(mg CaCO		23	0	0	23	0	0
SULPHATE	(mg/L)		729	775	2546	729	775	2546
Dissolved Metals								
Aluminum	mg/L		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	mg/L		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	mg/L		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	mg/L		0.0087	0.0113	<0.010	0.0087	0.0113	<0.010
Beryllium	mg/L		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	mg/L		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	mg/L		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	mg/L		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	mg/L		139	42.4	170	139	42.4	170
Chromium	mg/L		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	mg/L		0.060	0.091	<0.010	0.060	0.091	<0.010
Copper	mg/L		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron	mg/L		73.3	254.0	328.0	73.3	254.0	328.0
Lead	mg/L		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	mg/L		<0.010	0.025	0.033	<0.010	0.025	0.033
Magnesium	mg/L		39	14	206	39	14	206
Manganese	mg/L		13.3	15.8	32.2	13.3	15.8	32.2
Molybdenum	mg/L		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	mg/L		0.043	0.113	<0.050	0.043	0.113	<0.050
Phosphorus	mg/L		<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	mg/L		3.1	2.5	11.1	3.1	2.5	11.1
Selenium	mg/L		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	mg/L		2.1	7.3	6.2	2.1	7.3	6.2
Silver	mg/L		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	mg/L		15.3	11.2	93.5	15.3	11.2	93.5
Strontium	mg/L		0.44	0.14	0.42	0.44	0.14	0.42
Thallium	mg/L		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	mg/L		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Titanium	mg/L		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	mg/L		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	mg/L		1.42	38.33	0.64	1.42	38.33	0.64

Table C2. Contact Test Results

Solids Sample		P03-04-G-S2			P03-04-G-S3			P03-04-J-S2			TAILINGS COMPOSITE		
Test	**Units**	**Test 1** 72Hr	**Test 2** 72 hr	**Test 3** 72 Hr	**Test 1** 72 Hr	**Test 2** 72 hr	**Test 3** 72 hr	**Test 1** 72 hr	**Test 2** 72 hr	**Test 3** 72 hr	**Test 1** 72 hr	**Test 2** 72 hr	**Test 3** 72 hr
Initial													
Solids	Wet (g)	100	75	75	75	100	75	75	75	100	100	75	75
Solution	mL	300	225	225	225	300	225	225	225	300	300	225	225
pH		6.45	3.59	3.65	6.45	3.59	3.65	6.45	3.59	3.65	6.45	3.59	3.65
CONDUCTIVITY	(uS/cm)	457	1077	2170	457	1077	2170	457	1077	2170	457	1077	2170
Redox	(mV)	-11	210	291	-11	210	291	-11	210	291	-11	210	291
ACIDITY		0	31	20	0	31	20	0	31	20	0	31	20
	(pH 8.3)	172	579	725	172	579	725	172	579	725	172	579	725
ALKALINITY	(mg CaCO3/L)	23	0	0	23	0	0	23	0	0	23	0	0
SULPHATE	(mg/L)	729	775	2546	729	775	2546	729	775	2546	729	775	2546
Final													
pH		6.86	5.72	5.73	7.23	5.97	5.45	4.22	3.18	3.13	5.53	5.45	5.21
CONDUCTIVITY	(uS/cm)	1023	994	1446	1190	1073	1416	1080	1501	2250	1250	1124	1541
Redox	(mV)	264	161	71	137	103	151	301	395	388	293	92	180
ACIDITY (pH 4.5)	(pH 4.5)	0	0	0	0	0	0	2.5	70	90	0	0	0
(pH 8.3)		10	135	264	14	70	827	36.25	340	410	89	525	560
ALKALINITY	(mg CaCO3/L)	19	9	17	106	6	6	0	0	0	3	9	7
SULPHATE	(mg/L)	1007	1031	2397	1173	1197	2301	815	983	2130	1053	1053	2397
Total Metals													
Aluminum	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	0.26	0.73	3.08	5.80	<0.20	<0.20	<0.20
Antimony	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	mg/L	0.021	0.023	0.019	0.022	0.028	0.023	0.044	0.037	0.029	<0.010	<0.010	<0.010
Beryllium	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	mg/L	<0.010	0.015	<0.010	<0.010	<0.010	<0.010	0.015	0.016	0.016	0.018	0.016	0.025
Calcium	mg/L	266	284	352	347	372	379	217	179	306	283	169	280
Chromium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	mg/L	0.028	0.099	0.035	0.017	0.077	0.053	0.380	0.822	0.808	0.081	0.103	0.047
Copper	mg/L	0.012	0.027	0.016	<0.010	0.028	0.033	0.077	0.218	0.367	0.035	<0.010	<0.010
Iron	mg/L	**0.118**	**46.5**	**110**	**0.03**	**18.3**	**148**	**0.193**	**95.3**	**110**	**13.8**	**226**	**263**
Lead	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.128	2.84	3.27	2.57
Lithium	mg/L	0.018	0.055	0.050	0.021	0.042	0.032	0.015	0.074	0.063	<0.010	0.059	0.033
Magnesium	mg/L	41.6	25.0	184	44.3	26.6	206	51.3	31.2	209	74.1	44.3	219
Manganese	mg/L	10.6	17.7	29.8	9.71	15.5	32.2	20.8	28.9	44.3	28.2	29.3	44.6
Molybdenum	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	mg/L	<0.050	0.089	<0.050	<0.050	0.072	0.092	0.654	1.44	1.46	0.241	0.299	0.185
Phosphorus	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	mg/L	7.5	10.9	15.3	10.0	12.3	17.1	5.4	8.7	15.9	5.9	8.0	12.8
Selenium	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	mg/L	2.66	7.83	7.06	4.11	6.90	8.68	5.82	15.6	14.5	5.29	8.47	8.36
Silver	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	mg/L	20.7	17.8	86.4	19.5	18.1	93.5	19.7	17.1	91.4	34.6	30.9	102
Strontium	mg/L	0.761	0.857	1.02	1.04	1.12	1.16	0.616	0.494	0.768	0.4	0.174	0.286
Thallium	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.22	<0.20
Tin	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	mg/L	<0.010	<0.010	<0.010	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	<0.010	0.011
Vanadium	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	mg/L	0.671	28.7	7.59	0.419	17.4	6.18	5.15	42.0	11.8	29.6	54.8	26.1

Table C3.
Batch Contact Timed
Sample Test Results

Sample ID	**P03-04-G-S2**					**P03-04-G-S3**				
Test	**Contact Test 1**					**Contact Test 2**				
Time (hrs)	0	8	24	48	72	0	8	24	48	72
pH	6.4	-	-	-	6.86	3.59	-	-	-	5.97
Aluminum	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	0.009	0.043	0.035	0.023	0.021	0.0113333	0.031	0.031	0.031	0.028
Beryllium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050 0	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	139	214	228	228	266	42.4	211	253	311	372
Chromium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	0.060	0.048	0.044	0.027	0.028	0.091	0.075	0.073	0.083	0.077
Copper	<0.010	0.021	0.027	0.031	0.012	<0.010	0.028	0.037	0.097	0.028
Iron	73.3	31.7	7.87	<0.030	0.118	254	162	96.7	48.1	18.3
Lead	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	<0.010	<0.010	0.030	0.016	0.018	0.025	0.030	0.040	0.037	0.042
Magnesium	39.3	41.6	41.8	39.8	41.6	13.7	19.5	20.9	23.2	26.6
Manganese	13.3	12.6	12.1	10.6	10.6	15.8	14.4	14.0	14.5	15.5
Molybdenum	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	0.043	<0.050	<0.050	<0.050	<0.050	0.11	0.090	0.122	0.101	0.072
Phosphorus	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	3.1	7.4	7.5	8.9	7.5	2.467	7.5	8.8	11	12.3
Selenium	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	2.1	2.89	2.89	2.57	2.66	7.27	7.43	7.17	6.97	6.90
Silver	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	15.3	18.5	18.3	18.1	20.7	11.2	15.5	15.4	16.7	18.1
Strontium	0.4	0.648	0.688	0.679	0.761	0.135	0.638	0.776	0.947	1.12
Thallium	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	<0.050	<0.030	<0.030	<0.030	<0.030	<0.050	<0.030	<0.030	<0.030	<0.030
Titanium D-Ti	<0.010	0.011	0.012	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc D-Zn	1.42	2.55	2.45	1.35	0.671	38.3	26.2	22.2	19.4	17.4

Table C3.
Batch Contact Timed
Sample Test Results

Sample ID	**P03-04-J-S2**					**TAILINGS COMPOSITE**				
Test	**Contact Test 3**					**Contact Test 1**				
Time (hrs)	0	8	24	48	72	0	8	24	48	72
pH	3.65				3.13	6.45				5.53
Aluminum	<0.20	0.26	0.71	2.85	5.80	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	<0.010	0.038	0.035	0.031	0.029	0	0.011	<0.010	<0.010	<0.010
Beryllium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.16	<0.10
Cadmium	<0.010	<0.010	<0.010	<0.010	0.016	<0.010	0.015	0.014	0.025	0.018
Calcium	170	218	214	238	306	139	188	201	221	283
Chromium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	<0.010	0.268	0.382	0.564	0.808	0.060	0.086	0.086	0.081	0.081
Copper	<0.010	0.024	0.088	0.317	0.367	<0.010	0.028	0.041	0.109	0.035
Iron	328	300	243	161	110	73	52.3	35.0	17.1	13.8
Lead	<0.050	<0.050	<0.050	0.089	0.128	<0.050	2.42	2.93	2.67	2.84
Lithium	0.033	0.031	0.040	0.061	0.063	<0.010	0.016	0.025	0.022	<0.010
Magnesium	206	193	176	181	209	39.3	58.0	57.4	61.2	74.1
Manganese	32.2	35.9	34.8	37.4	44.3	13	20.4	20.7	22.8	28.2
Molybdenum	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	<0.050	0.460	0.623	0.914	1.46	0.043	0.165	0.179	0.177	0.241
Phosphorus	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	11.1	12.5	12.5	11.2	15.9	3.1	6.2	6.0	6.7	5.9
Selenium	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	6.16	6.58	7.03	9.61	14.5	2.1	2.84	3.53	4.38	5.29
Silver	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	93.5	90.6	81.8	80.9	91.4	15	30.1	29.9	30.5	34.6
Strontium	0.42	0.523	0.525	0.607	0.768	0.44	0.424	0.374	0.329	0.4
Thallium	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.30	<0.20
Tin	<0.050	<0.030	<0.030	<0.030	<0.030	<0.050	<0.030	<0.030	<0.030	<0.030
Titanium D-Ti	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.012	0.011
Vanadium	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc D-Zn	0.636	4.33	5.64	8.46	11.8	1.42	15.1	17.7	23.2	29.6

Table C4
Estimated Kd Values

Parameter	Units	P03-04-G-S2			P03-04-G-S3			P03-04-J-S2			TAILINGS COMPOSITE		
Contact Time **Water Sample**		**Test 1** 72Hr P106A1	**Test 2** 72 hr P0109B1	**Test 3** 72 Hr X21A-96-1	**Test 1** 72 Hr P106A1	**Test 2** 72 hr P0109B1	**Test 3** 72 hr X21A-96-1	**Test 1** 72 hr P106A1	**Test 2** 72 hr P0109B1	**Test 3** 72 hr X21A-96-1	**Test 1** 72 hr P106A1	**Test 2** 72 hr P0109B1	**Test 3** 72 hr X21A-96-1
Aluminum	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Antimony	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Arsenic	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Barium	L/kg	-1.76	-1.52	na	-1.82	-1.79	na	-2.41	-2.08	na	na	na	na
Beryllium	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Bismuth	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Boron	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Cadmium	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Calcium	L/kg	-1.43	-2.55	-1.55	-1.80	-2.66	-1.65	-1.08	-2.29	-1.33	-1.53	-2.25	-1.18
Chromium	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Cobalt	L/kg	3.39	-0.25	na	7.53	0.53	na	-2.53	-2.67	na	-0.79	-0.36	na
Copper	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Iron	L/kg	1861	13	6	7330	39	4	1137	5	6	13	0	1
Lead	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Lithium	L/kg	na	-1.62	-1.02	na	-1.19	0.09	na	-1.97	-1.43	na	-1.71	0.00
Magnesium	L/kg	-0.16	-1.35	0.36	-0.34	-1.45	0.00	-0.70	-1.68	-0.04	-1.41	-2.07	-0.18
Manganese	L/kg	0.76	-0.32	0.24	1.11	0.06	0.00	-1.08	-1.36	-0.82	-1.59	-1.38	-0.83
Molybdenum	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Nickel	L/kg	na	0.80	na	na	1.69	na	-2.80	-2.77	na	-2.47	-1.87	na
Phosphorus	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Potassium	L/kg	-1.75	-2.32	-0.82	-2.06	-2.40	-1.05	-1.26	-2.15	-0.91	-1.41	-2.08	-0.40
Selenium	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Silicon	L/kg	-0.66	-0.22	-0.38	-1.49	0.16	-0.87	-1.93	-1.60	-1.73	-1.82	-0.43	-0.79
Silver	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Sodium	L/kg	-0.78	-1.11	0.25	-0.65	-1.14	0.00	-0.67	-1.04	0.07	-1.67	-1.91	-0.25
Strontium	L/kg	-1.25	-2.53	-1.76	-1.72	-2.64	-1.91	-0.84	-2.18	-1.36	0.33	-0.67	1.41
Thallium	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Tin	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Titanium	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Vanadium	L/kg	na	na	na	na	na	na	na	na	na	na	na	na
Zinc	L/kg	3.33	1.01	-2.75	7.14	3.61	-2.69	-2.17	-0.26	-2.84	-2.86	-0.90	-2.93

Appendix D
Tailings Neutralization Column Test Results

SRK Consulting
Engineers and Scientists

Steffen, Robertson and Kirsten (Canada) Inc.
Suite 800 – 1066 West Hastings Street
Vancouver, B.C. V6E 3X2
Canada

vancouver@srk.com
www.srk.com

Tel: 604.681.4196
Fax: 604.687.5532

Memorandum

To:	File	**Date:**	October 26, 2004
cc:		**From:**	John Chapman
Subject:	**Acid Neutralization Column Tests**	**Project #:**	1CD003.043

1 Introduction

As part of the attenuation testing program to assess metal attenuation in the Rose Creek Tailings Facility, two column tests were performed on tailings composite samples to assess their acid neutralization potential and metal attenuation properties. The results from these tests are summarised herein.

2 Tailings Sample Preparation and Properties

The samples tested in the column tests were selected based on their initial acid base account properties to yield a composite that is neutral and would have available neutralization potential. It was anticipated that the composite sample would exhibit the weighted average properties of the samples from which it was prepared. In the interest of time constraints, the column tests were initiated concurrently with submitting the composite sample for analysis. Hence, the initial column test results were generated before the solids analyses were complete.

The samples selected for the composite are shown in Table 1. The table also shows the weighted average calculation of the composite sample and the corresponding analytical results.

Table 1
Summary of Tailings Composite Calculated and Analytical Acid Base Account Properties

Sample	Dry Weight g	Paste pH	NP	TIC %	Carbonate NP
P03-08-A-S1*	188	5.2	18	0.79	65.8
P03-08-A-S3*	232	6.4	16	0.87	72.5
P03-08-B-S3*	157	7.4	28	1.12	93.3
P03-08-B-S4*	158	7.4	12	0.83	69.2
P03-08-C-S2*	100	6.6	26	1.14	95.0
Calc. Ave.	**836**	**6.5**	**19**	**0.92**	**77**
Composite	**836**	**4.7**	**10**	**0.67**	**56**

* Initial Analysis
NP and Carbonate NP in units of kg$CaCO_3$eq/tonne

It is clear from the paste pH and the decrease in the neutralization potential that the samples had undergone significant oxidation and NP consumption during storage at the laboratory. These results also explain the problems encountered in the column tests discussed below.

3 Column Test Results

The column test effluent pH was acidic from the onset. At first, without the prior knowledge of the oxidation of the tailings during storage, it was believed that the elevated acidity in the influent had ‘overwhelmed’ the reactivity of the NP of the tailings. The influent was switched to a lower acidity water from Sample P109B-2 to X21A-96-2, and the rate of displacement was lowered. Neither changes resulted in neutralization of the acidic influent. The tests were continued until 14 pore volume displacements had been completed without any significant changes in the rate of neutralization and were then terminated.

The effluent parameters indicated the following:

- The effluent pH typically was between 0.5 and 1.0 units below the influent pH, which suggests that some neutralization continued to occur, despite the acidification of the samples prior to testing;
- Effluent redox was consistently below influent redox, indicating that anoxic conditions had been achieved in the column tests;
- Iron was removed from solution in both tests, and,
- Effluent zinc concentrations were above influent zinc concentrations indicating net zinc release from the tailings.

Acidity and mass balance calculations indicated that acid neutralization by the tailings was minimal (0.2 and 0.4 kg $CaCO_3$ eq/tonne in Columns CT1 and CT2 respectively).

4 Conclusions

The column tests unfortunately did not meet their intended purpose because the tailings samples had oxidized prior to testing to the extent that they were acidic at the onset of the column tests. The tests did indicate some ongoing acid neutralization is occurring suggesting that some proportion of the residual neutralization potential remains reactive, however, the rate of neutralization is limited possibly due to blinding and/or surface area exposure limitations. The results indicate that zinc attenuation is unlikely within acidic tailings under anoxic conditions.

Appendix E
Attenuation Column Test Results

Table E1. Composite Tailings Sample Analysis

Sample	Weight g	Mositure %	Dry Weight g	Paste pH	NP	TIC %	Carbonate NP
P03-08-A-S1*	232	19.0	188	5.2	18	0.79	65.8
P03-08-A-S3*	275	15.7	232	6.4	16	0.87	72.5
P03-08-B-S3*	192	18.0	157	7.4	28	1.12	93.3
P03-08-B-S4*	187	15.5	158	7.4	12	0.83	69.2
P03-08-C-S2*	125	19.7	100	6.6	26	1.14	95.0
Calculated Average	**1011**	**17.3**	**836**	**6.5**	**19**	**0.92**	**77**
Tailings Composite	**1011**	**17.3**	**836**	**4.7**	**10**	**0.67**	**56**

* Initial Analysis

AP = Acid potential in tonnes CaCO3 equivalent per 1000 tonnes of material. AP is determined from calculated sulphide sulphur content: S(T) - S(SO4), assuming total conversion of sulphide to sulphate.
NP = Neutralization potential in tonnes CaCO3 equivalent per 1000 tonnes of material.
NET NP = Net neutralization potential = Tonnes CaCO3 equivalent per 1000 tonnes of material.
NOTE: Where S(T) is reported as <0.01%, a S(T) value of 0.01% is used for the AP calculation.
Where S(SO4) is reported as <0.01%, it is assumed to be zero for the AP calculation. (ie. if S(SO4) is less than 0.01% or is not analyzed, AP is calculated from S(T) only)
TIC = Total Inorganic Carbon as %C.
Carbonate NP calculated from total inorganic carbon (TIC) assay. TIC value of 0.01 is used in calculation if TIC <0.01%.

Table E2. Columns Sample Weights

Test	Sample	Sample Wt (g)	Water Source	Pore Volume (mL)
CT1	Tailings Comp	432	P109B2/X21A962	83
CT2	Tailings Comp	432	P109B2/X21A962	86
CT3	P03-04-GS2*	379	P10-6A3	92
CT4	P03-04-GS2*	379	P01-09B1	91
CT5	P03-04-GS3*	407.1	P10-6A3	87
CT6	P03-04-GS3*	407.4	P01-09B1	88

*A portion of the sample was crushed to fit the column - see below

	+25 mm	-25 mm	Weight after combining*
PO3-04-GS2	495.1	357.9	772.8
P03-04-GS3	472.6	395.4	840.1

The +25 mm samples was crushed. The crushed samples were combined with -25 mm.
Some sample was lost during curshing.

Table E3. Column Feed Solution Analyses

Parameter	P0109 B2	P106 A3	P0109 B1	X21A 962
pH	2.81	3.50	2.90	2.58
CONDUCTIVITY	2590	2160	1984	3230
Redox	389	339	399	374
ACIDITY (pH 4.5)	195.0	35.0	147.5	310.0
(pH 8.3)	1452.5	392.5	890.0	722.5
ALKALINITY	0.0	0.0	0.0	0.0
Dissolved Metals				
Aluminum	<0.20	<0.20	<0.20	<0.20
Antimony	<0.20	<0.20	<0.20	<0.20
Arsenic	<0.20	<0.20	<0.20	<0.20
Barium	0.016	0.030	0.018	0.013
Beryllium	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	<0.20	<0.20	<0.20	<0.20
Boron	<0.10	<0.10	<0.10	<0.10
Cadmium	<0.010	<0.010	<0.010	<0.010
Calcium	78.7	446	72.5	178.0
Chromium	<0.010	<0.010	<0.010	<0.010
Cobalt	0.150	0.182	0.146	0.011
Copper	0.036	<0.010	0.082	<0.010
Iron	666	170	376	234
Lead	<0.050	<0.050	<0.050	0.13
Lithium	0.041	<0.010	0.044	0.019
Magnesium	25.0	128	21.0	203
Manganese	27.0	42.0	24.7	32.6
Molybdenum	<0.030	<0.030	<0.030	<0.030
Nickel	0.181	0.073	0.218	<0.050
Phosphorus	<0.30	<0.30	<0.30	<0.30
Potassium	3.4	9.3	3.3	10.7
Selenium	<0.20	<0.20	<0.20	<0.20
Silicon	11.0	6.74	11.1	6.1
Silver	<0.010	<0.010	<0.010	<0.010
Sodium	19.7	49.3	18.2	92.4
Strontium	0.226	1.41	0.218	0.41
Thallium	<0.30	<0.20	<0.30	<0.20
Tin	<0.030	<0.030	<0.030	<0.030
Titanium	<0.010	<0.010	<0.010	<0.010
Vanadium	<0.030	<0.030	<0.030	<0.030
Zinc	94.0	4.46	59.4	0.902

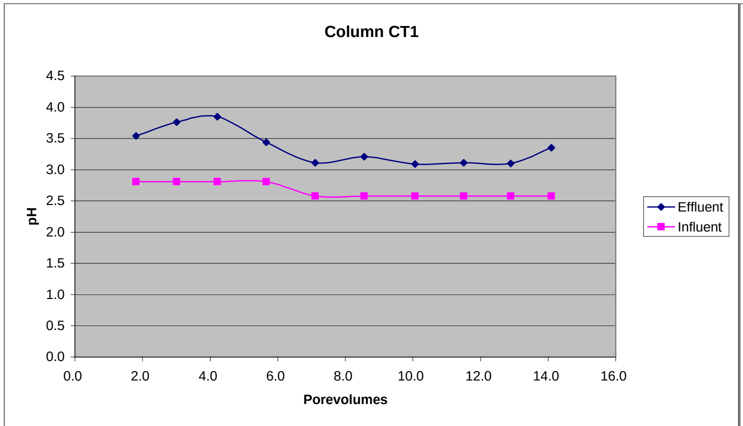
Appendix E4 - Column Test CT1

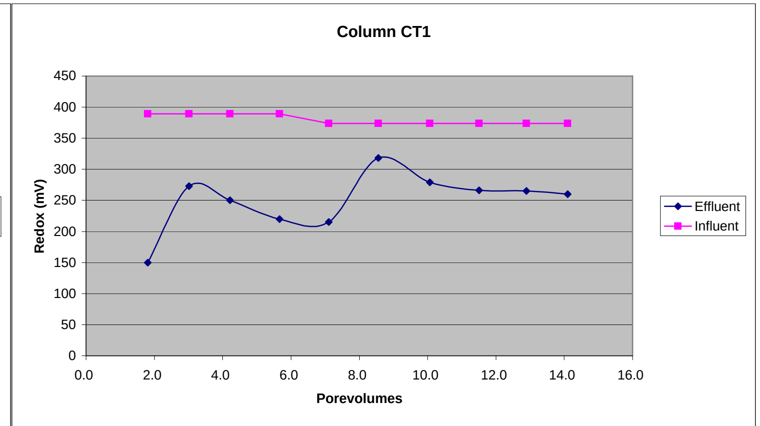
Description **CT1- Tailings Composite Sample**

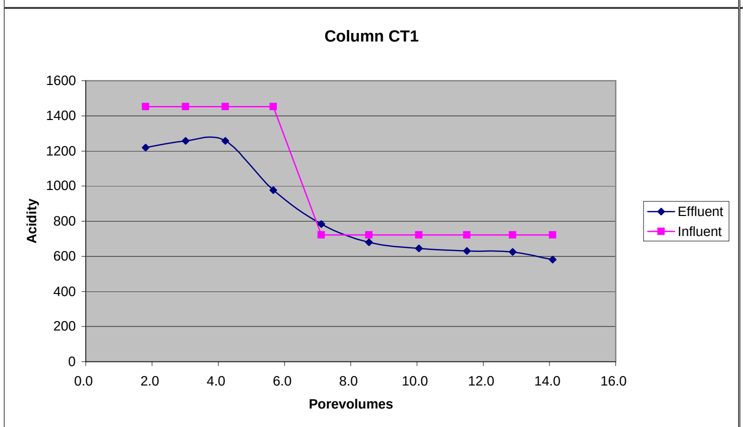
		P0109B2	X21A 96 2										
Parameter	**Units**	**Feed -1**	**Feed - 2**	**Effluent**									
Porevolume	0.083	0	0	1.8	3.0	4.2	5.7	7.1	8.6	10.1	11.5	12.9	14.1
DATE		22-Sep-04	28-Sep-04	22-Sep-04	23-Sep-04	24-Sep-04	28-Sep-04	30-Sep-04	4-Oct-04	6-Oct-04	8-Oct-04	12-Oct-04	14-Oct-04
LEACHATE	(L)			0.150	0.100	0.100	0.120	0.120	0.120	0.125	0.120	0.115	0.100
pH		2.81	2.58	3.54	3.76	3.85	3.44	3.11	3.21	3.09	3.11	3.10	3.35
REDOX.	(mV)	389	374	150	273	250	220	215	318	279	266	265	260
ACIDITY (pH 4.5)	(mg CaCO3/L)	195	310	45.0	65.5	65.5	28.0	107.0	95.0	200.0	480.0	135.0	303.3
ACIDITY (pH 8.3)	(mg CaCO3/L)	1452.5	722.5	1220.0	1257.0	1257.0	976.0	784.0	680.0	645.0	630.0	625.0	581.1
ALKALINITY	(mg CaCO3/L)	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Metals (mg/L)													
Aluminum	mg/L	<0.20	<0.20	<0.40	<0.40	<0.40	<0.40	0.25	0.31	0.22	0.24	<0.20	0.22
Antimony	mg/L	<0.20	<0.20	<0.40	<0.40	<0.40	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	mg/L	<0.20	<0.20	<0.40	<0.40	<0.40	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	mg/L	0.016	0.013	<0.020	<0.020	<0.020	<0.020	0.014	0.010	0.016	0.011	0.011	0.118
Beryllium	mg/L	<0.0050	<0.0050	<0.010	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	mg/L	<0.20	<0.20	<0.40	<0.40	<0.40	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	mg/L	<0.10	<0.10	<0.20	<0.20	<0.20	<0.20	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	mg/L	<0.010	<0.010	0.107	0.094	0.094	0.054	0.045	0.044	0.023	0.024	0.017	0.027
Calcium	mg/L	78.7	178	183	210	210	243	260	271	250	255	209	258
Chromium	mg/L	<0.010	<0.010	<0.020	<0.020	<0.020	<0.020	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	mg/L	0.15	0.011	0.401	0.341	0.341	0.195	0.091	0.067	0.040	0.034	0.026	0.024
Copper	mg/L	0.036	<0.010	0.166	0.138	0.138	0.112	0.213	0.302	0.151	0.156	0.163	0.098
Iron	mg/L	666	234	430	478	478	375	268	250	236	245	217	206
Lead	mg/L	<0.050	0.13	2.91	2.55	2.55	2.64	2.19	2.39	2.04	2.16	1.92	1.84
Lithium	mg/L	0.041	0.019	0.075	0.080	0.080	0.075	0.058	0.047	0.043	0.041	0.043	0.046
Magnesium	mg/L	25	203	350	297	297	324	332	319	283	284	261	277
Manganese	mg/L	27	32.6	221	197	197	169	135	120	90.7	89.9	73.2	96.0
Molybdenum	mg/L	<0.030	<0.030	<0.060	<0.060	<0.060	<0.060	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	mg/L	0.181	<0.050	0.71	0.66	0.66	0.51	0.364	0.254	0.177	0.145	0.163	0.194
Phosphorus	mg/L	<0.30	<0.30	<0.60	<0.60	<0.60	<0.60	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	mg/L	3.4	10.7	8.6	12.2	12.2	13.2	13.6	22.6	18.4	17.6	13.5	15.3
Selenium	mg/L	<0.20	<0.20	<0.40	<0.40	<0.40	<0.40	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	mg/L	11	6.1	8.27	9.51	9.51	8.52	7.52	7.40	7.16	7.30	6.92	6.90
Silver	mg/L	<0.010	<0.010	<0.020	<0.020	<0.020	<0.020	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	mg/L	19.7	92.4	16.5	18.7	18.7	46.6	83.5	89.5	92.4	95.2	86.6	85.5
Strontium	mg/L	0.226	0.405	0.329	0.438	0.438	0.565	0.627	0.643	0.610	0.639	0.573	0.706
Thallium	mg/L	<0.30	<0.20	<0.40	<0.40	<0.40	<0.40	<0.30	<0.20	<0.20	<0.40	<0.20	<0.20
Tin	mg/L	<0.030	<0.030	<0.060	<0.060	<0.060	<0.060	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	mg/L	<0.010	<0.010	<0.020	<0.020	<0.020	<0.020	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	mg/L	<0.030	<0.030	<0.25	<0.20	<0.20	<0.20	<0.15	<0.15	<0.10	<0.10	<0.030	<0.10
Zinc	mg/L	94	0.902	164	171	171	129	74.4	63.8	43.5	42.8	34.4	50.6

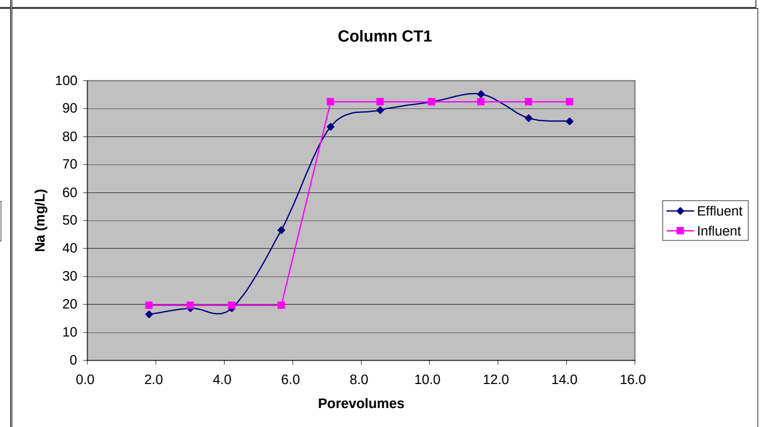
Sample Weight: 432 g
Acidity in: 1101 mg CaCO3 eq/L
Acidity out: 1013 mg CaCO3 eq/L
Acidity Consumed 87 mg CaCO3 eq/L
NP Equivalent 0.20 kgCaCO3eq/tonne

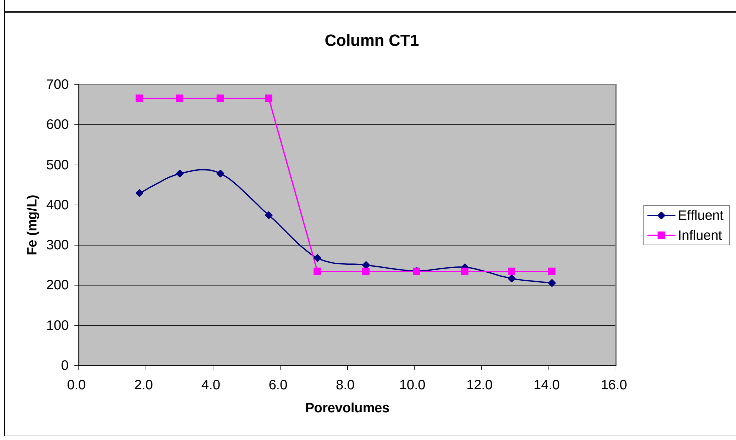
Zinc in	mg	14	24	33	44	44	44	45	45	45	45
Zinc out	mg	25	42	59	74	83	91	96	101	105	110
Accumulated	mg	-11	-18	-26	-30	-39	-46	-52	-57	-61	-66
Iron in	mg	100	167	233	313	341	369	398	427	453	477
Iron out	mg	65	112	160	205	237	267	297	326	351	372
Accumulated	mg	35	54	73	108	104	102	102	100	102	105

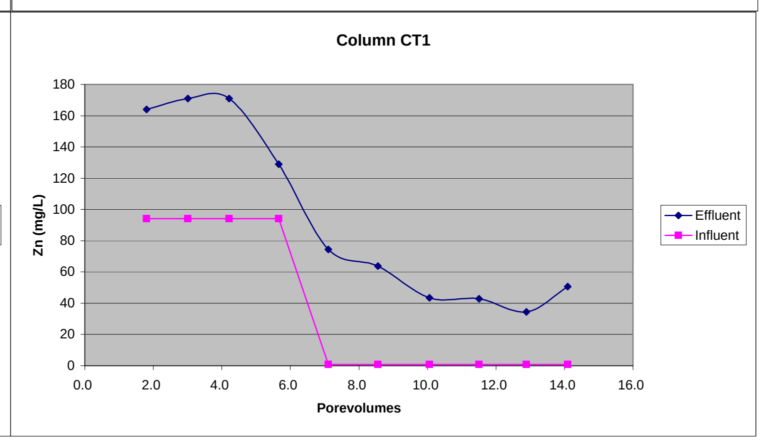

Column CT1
pH
Porevolumes
Effluent
Influent


Column CT1
Redox (mV)
Porevolumes
Effluent
Influent


Column CT1
Acidity
Porevolumes
Effluent
Influent


Column CT1
Na (mg/L)
Porevolumes
Effluent
Influent


Column CT1
Fe (mg/L)
Porevolumes
Effluent
Influent


Column CT1
Zn (mg/L)
Porevolumes
Effluent
Influent

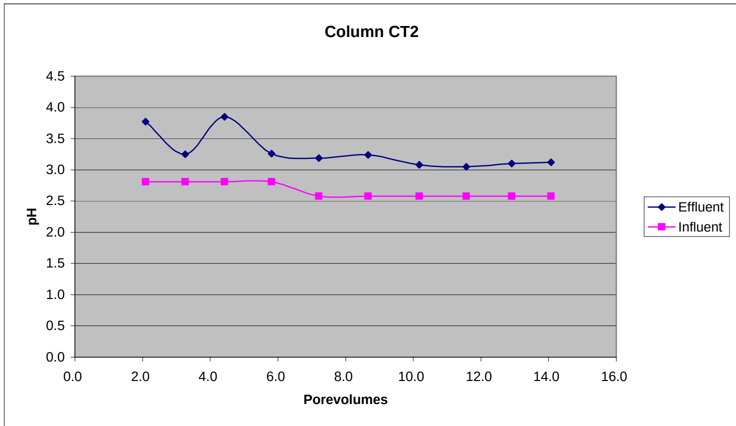
Appendix E5 - Column Test CT2

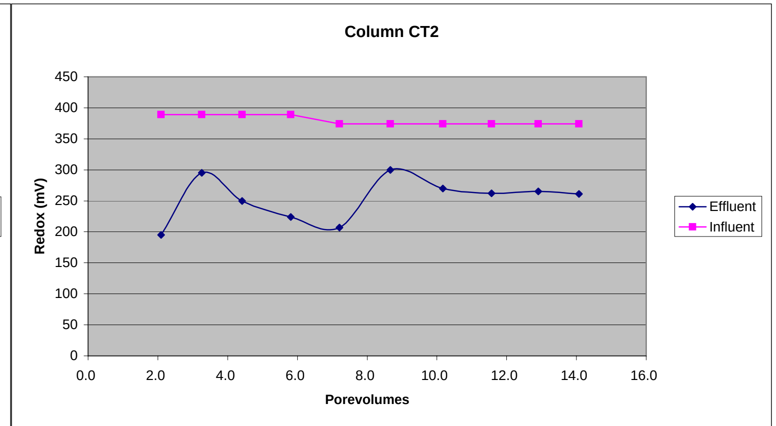
Description **CT2- Tailings Composite Sample**

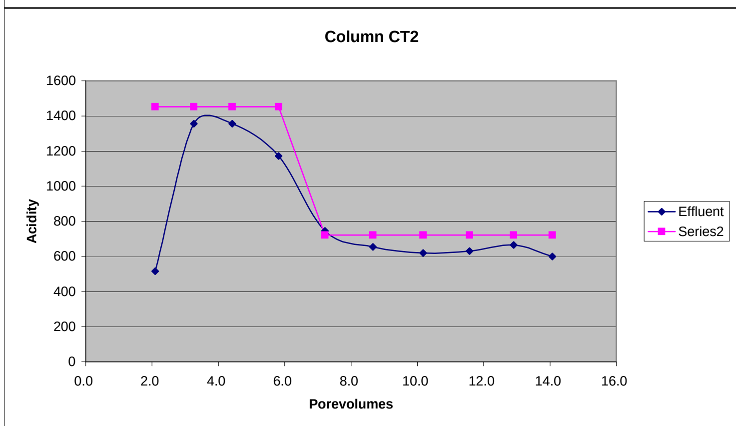
Parameter	Units	P0109B2 Feed -1	X21A 96 2 Feed - 2	Effluent									
Porevolume	0.086			2.1	3.3	4.4	5.8	7.2	8.7	10.2	11.6	12.9	14.1
DATE		22-Sep-04	28-Sep-04	22-Sep-04	23-Sep-04	24-Sep-04	28-Sep-04	30-Sep-04	4-Oct-04	6-Oct-04	8-Oct-04	12-Oct-04	14-Oct-04
LEACHATE	(L)			0.180	0.100	0.100	0.120	0.120	0.125	0.130	0.120	0.115	0.100
pH		2.81	2.58	3.77	3.25	3.85	3.26	3.19	3.24	3.08	3.05	3.10	3.12
REDOX.	(mV)	389	374	195	295	250	224	207	300	270	262	265	261
ACIDITY (pH 4.5)	(mg CaCO3/L)	195	310	15.0	55.6	55.6	45.0	350.0	125.0	430.0	480.0	150.0	400.0
ACIDITY (pH 8.3)	(mg CaCO3/L)	1452.5	722.5	515.0	1355.6	1355.6	1172.0	745.0	655.0	620.0	630.0	665.0	600.0
ALKALINITY	(mg CaCO3/L)	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Metals (mg/L)													
Aluminum	mg/L	<0.20	<0.20	<0.20	0.38	0.38	0.35	0.66	0.59	0.53	0.52	0.56	0.54
Antimony	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	mg/L	0.016	0.013	0.012	<0.010	<0.010	<0.010	0.016	0.010	<0.010	0.011	<0.010	1.25
Beryllium	mg/L	<0.0050	<0.0050	<0.0050	<0.010	<0.010	<0.0050	0.0077	<0.0050	0.0063	<0.0050	<0.0050	<0.0050
Bismuth	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	mg/L	<0.010	<0.010	0.065	0.057	0.057	0.049	0.041	0.059	0.045	0.047	0.036	0.014
Calcium	mg/L	78.7	178	121	144	144	171	244	244	239	241	226	205
Chromium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	mg/L	0.15	0.011	0.157	0.187	0.187	0.177	0.091	0.062	0.045	0.037	0.035	0.025
Copper	mg/L	0.036	<0.010	0.307	0.727	0.727	0.591	0.986	0.759	0.919	0.809	0.855	0.696
Iron	mg/L	666	234	202	662	662	574	245	237	187	208	230	236
Lead	mg/L	<0.050	0.13	3.14	2.66	2.66	2.57	2.21	2.12	2.62	2.51	2.6	2.72
Lithium	mg/L	0.041	0.019	0.025	0.046	0.046	0.047	0.041	0.044	0.038	0.038	0.034	0.034
Magnesium	mg/L	25	203	84.1	60.6	60.6	126	255	266	241	245	265	215
Manganese	mg/L	27	32.6	58.6	52.2	52.2	73.8	85.3	90.8	67.2	69.1	71.6	57.0
Molybdenum	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	mg/L	0.181	<0.050	0.248	0.288	0.288	0.319	0.226	0.208	0.083	0.098	0.153	0.089
Phosphorus	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	mg/L	3.4	10.7	4.2	4.5	4.5	7.6	15.9	15.1	17.9	17.3	13.6	12.2
Selenium	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	mg/L	11	6.1	4.04	10.9	10.9	10.2	7.88	7.05	6.95	7.07	7.12	6.28
Silver	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	mg/L	19.7	92.4	7.5	19.2	19.2	32.7	85.2	84.3	92.3	92.5	90.3	80.1
Strontium	mg/L	0.226	0.405	0.274	0.288	0.288	0.385	0.514	0.514	0.481	0.532	0.57	0.474
Thallium	mg/L	<0.30	<0.20	<0.30	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	mg/L	<0.030	<0.030	<0.030	<0.060	<0.060	<0.10	<0.10	<0.10	<0.10	<0.10	<0.030	<0.050
Zinc	mg/L	94	0.902	60.6	111	111	105	52.6	49.1	30.6	31.5	34.3	24.9

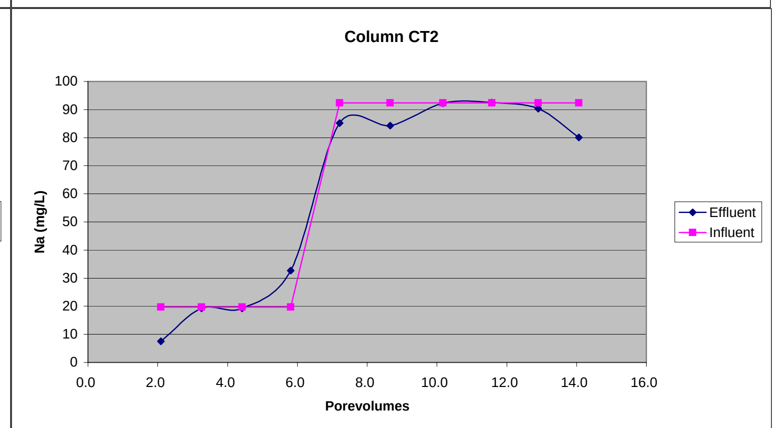
Sample Weight: 432 g
Acidity in: 1152 mg CaCO3 eq/L
Acidity out: 968 mg CaCO3 eq/L
Acidity Consumed 183 mg CaCO3 eq/L
NP Equivalent 0.42 kgCaCO3eq/tonne

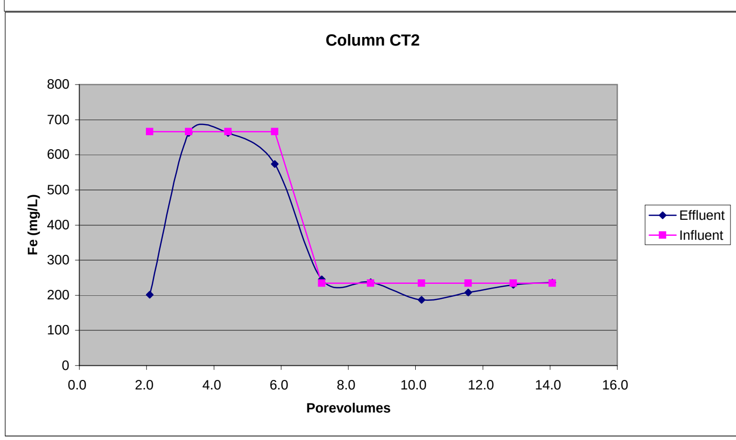
Zinc in	mg	17	26	36	47	47	47	47	47	48	48
Zinc out	mg	11	22	33	46	52	58	62	66	70	72
Accumulated	mg	6.0	4.3	2.6	1.3	-5	-11	-15	-18	-22	-25
Iron in	mg	120	186	253	333	361	390	421	449	476	499
Iron out	mg	36	103	169	238	267	297	321	346	372	396
Accumulated	mg	84	84	84	95	94	94	100	103	103	103

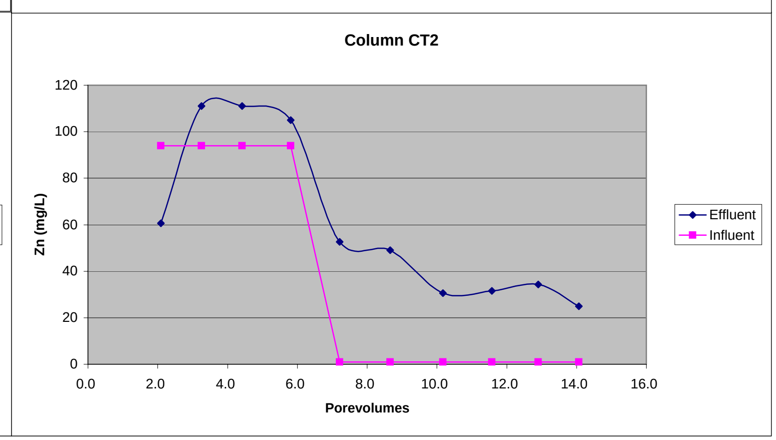

Column CT2
pH
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Porevolumes
Effluent
Influent


Column CT2
Redox (mV)
450
400
350
300
250
200
150
100
50
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Porevolumes
Effluent
Influent


Column CT2
Acidity
1600
1400
1200
1000
800
600
400
200
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Porevolumes
Effluent
Series2


Column CT2
Na (mg/L)
100
90
80
70
60
50
40
30
20
10
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Porevolumes
Effluent
Influent


Column CT2
Fe (mg/L)
800
700
600
500
400
300
200
100
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Porevolumes
Effluent
Influent


Column CT2
Zn (mg/L)
120
100
80
60
40
20
0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0
Porevolumes
Effluent
Influent

Appendix E6 - Column Test CT3

Soil Sample P03-04-GS2*

Water P10-6A3

Parameter	Units	Feed	Effluent									
Cycle	0.092	0	1.3	2.6	3.9	5.3	6.6	7.7	9.1	10.3	11.4	12.7
DATE			22-Sep-04	27-Sep-04	29-Sep-04	1-Oct-04	5-Oct-04	6-Oct-04	11-Oct-04	13-Oct-04	15-Oct-04	19-Oct-04
LEACHATE	(L)		0.115	0.120	0.125	0.125	0.120	0.105	0.125	0.110	0.105	0.120
pH		3.5	6.37	6.31	6.60	6.20	5.79	6.22	6.24	5.72	3.75	5.63
REDOX.	(mV)	339	212	205	167	133	120	209	165	246	280	185
ACIDITY (pH 4.5)	(mg CaCO3/L)	35	0.0	-	-	0.0	0.0	0.0	0.0	28.0	20.0	0
ACIDITY (pH 8.3)	(mg CaCO3/L)	392.5	7.0	*13.0*	*19.0*	25.0	*25.0*	25	57	58	60	43
ALKALINITY	(mg CaCO3/L)	0	8.8	51.5	45.8	8.0	0.0	39.0	21.0	0.0	0.0	10
Total Metals (mg/L)												
Aluminum	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	0.32	<0.20	<0.20	1.41	0.57	<0.20
Antimony	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	mg/L	0.03	0.026	0.021	0.018	0.064	0.032	0.019	0.014	0.062	0.025	0.019
Beryllium	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	mg/L	<0.10	0.21	0.15	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	mg/L	446	433	569	571	357	531	556	474	501	503	539
Chromium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	mg/L	0.182	0.018	0.076	0.091	0.091	0.144	0.118	0.143	0.15	0.17	0.16
Copper	mg/L	<0.010	<0.010	<0.010	<0.020	0.059	0.011	<0.010	<0.010	<0.010	0.064	<0.010
Iron	mg/L	170	<0.030	7.04	11	<0.030	29.2	15.5	20.5	40.1	11.8	10.5
Lead	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	mg/L	<0.010	0.050	0.055	0.042	0.013	0.016	0.018	0.017	0.014	<0.010	0.016
Magnesium	mg/L	128	47.2	104.0	120.0	80.3	121	124	128	120	124	132
Manganese	mg/L	42	7.96	29.70	38.20	27.2	42.1	40.8	41.3	40.7	41.7	43.3
Molybdenum	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	mg/L	0.073	0.062	0.067	<0.050	<0.050	0.097	0.075	0.082	0.086	0.079	0.094
Phosphorus	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	mg/L	9.3	20.0	21.0	21.8	17.8	23.1	25.3	20	13.7	10.4	14.2
Selenium	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	mg/L	6.74	4.06	6.18	6.33	4.48	6.79	6.03	5.81	7.79	6.74	6.15
Silver	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium	mg/L	49.3	35.4	48.2	50.3	31.4	48.2	48.1	48.3	46.4	46.7	50.3
Strontium	mg/L	1.41	1.19	1.72	1.79	1.11	1.69	1.75	1.67	1.6	1.6	1.71
Thallium	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	0.014	<0.010	<0.010	0.059	<0.010	<0.010
Vanadium	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	mg/L	4.46	2.00	4.73	4.97	4.4	8.44	5.8	6.95	7.45	9.91	7.76

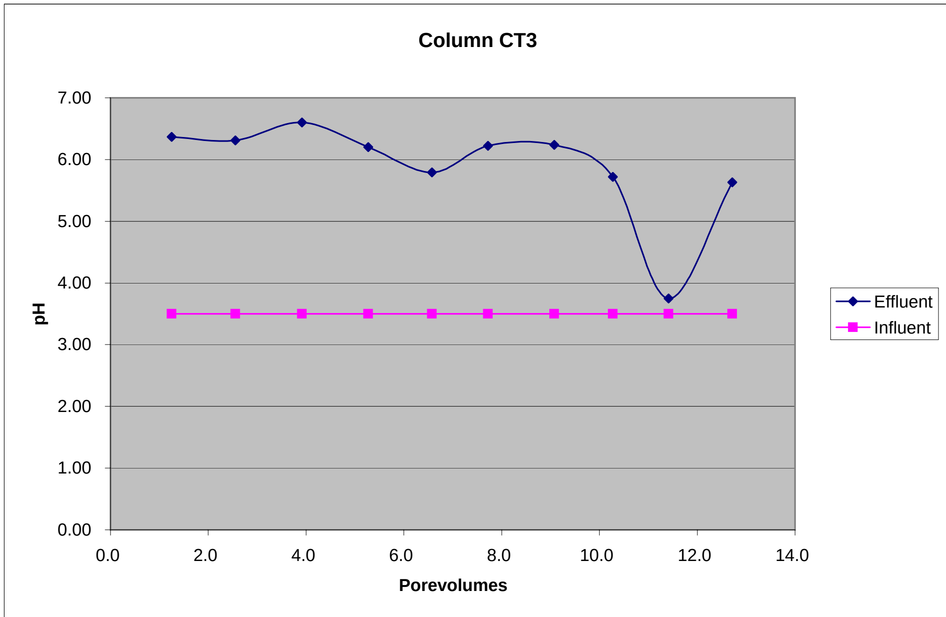
Column Test CT3

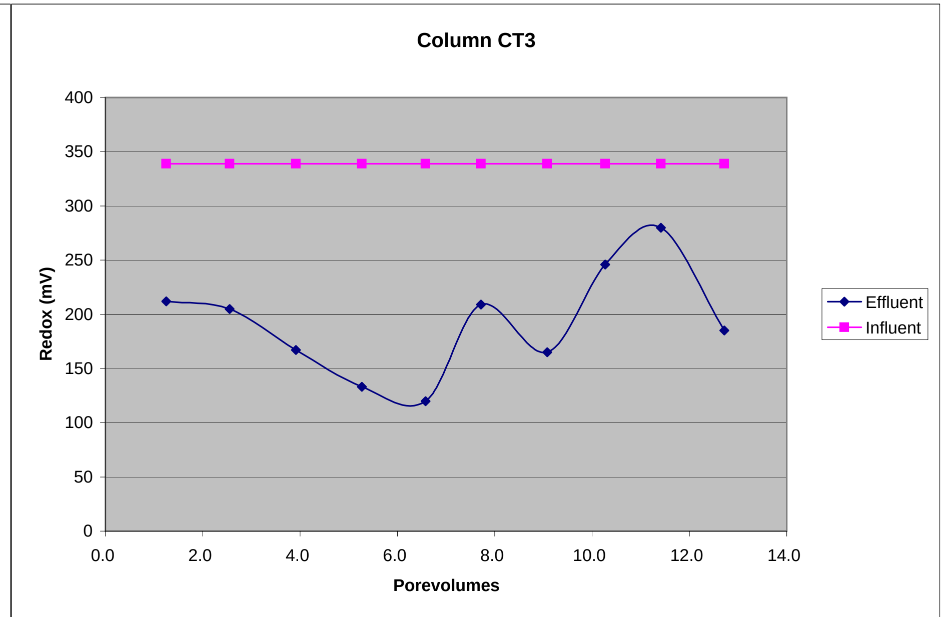
Summary Calculations

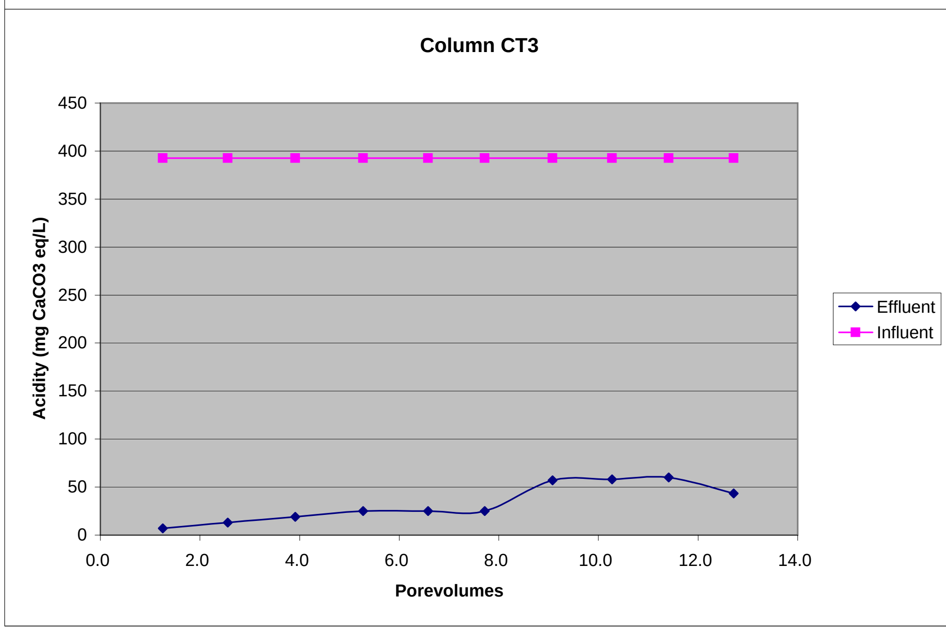
Sample Weight	g	379										
Acidity in	kgCaCO3 /tonne		0	0.12	0.24	0.37	0.50	0.63	0.74	0.86	0.98	1.09	1.21
Acidity out	kgCaCO3 /tonne		0	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01
Accumulated	kgCaCO3 /tonne		0	0.12	0.24	0.37	0.49	0.62	0.73	0.85	0.96	1.07	1.20
Iron in	mg/kg		0	52	105	161	218	271	318	375	424	471	525
Iron out	mg/kg		0	0.0	2	6	0	9	14	20	32	35	39
Accumulated	mg/kg		0	52	103	156	218	262	305	354	392	436	486
Zn in	mg/kg		0	1.4	2.8	4.2	5.7	7.1	8.4	9.8	11.1	12.4	13.8
Zn out	mg/kg		0	0.6	2.1	3.7	5.2	7.9	9.5	11.8	13.9	16.7	19.1
Accumulated	mg/kg			0.75	0.66	0.49	0.51	-0.75	-1.12	-1.94	-2.81	-4.32	-5.36
Zinc													
C(Liquid)	mg/L			1.0	3.4	4.9	4.7	6.4	7.1	6.4	7.2	8.7	8.8
C(solids)	mg/kg			0.7	0.7	0.5	0.5	-0.7	-1.1	-1.9	-2.8	-4.3	-5.4
Kd	L/kg			0.7	0.2	0.1	0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6
Zn / Fe	mg Zn / mg Fe			0.014	0.006	0.003	0.002	-0.003	-0.004	-0.005	-0.007	-0.010	-0.011

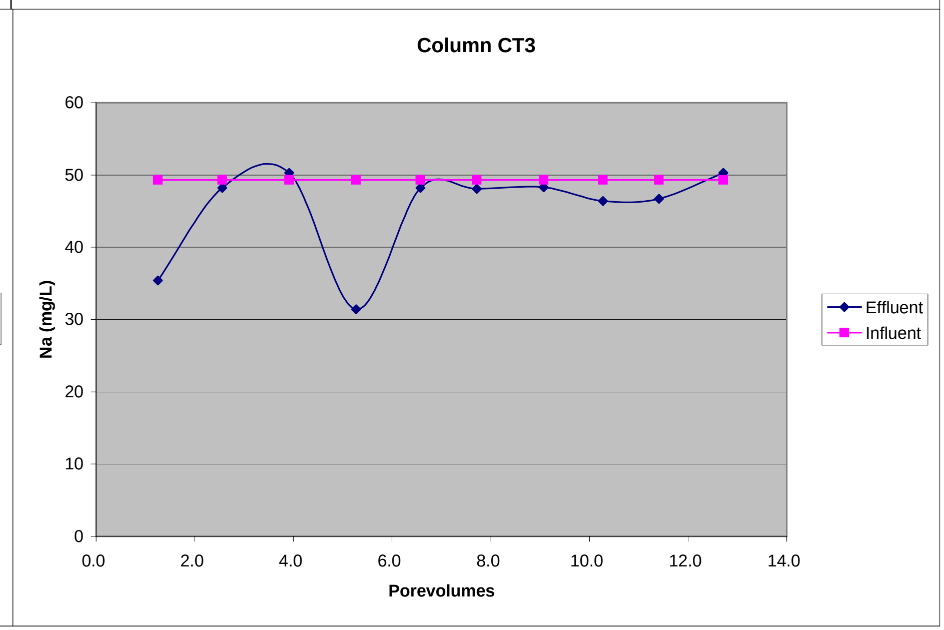
Breakthrough Kd Estimation

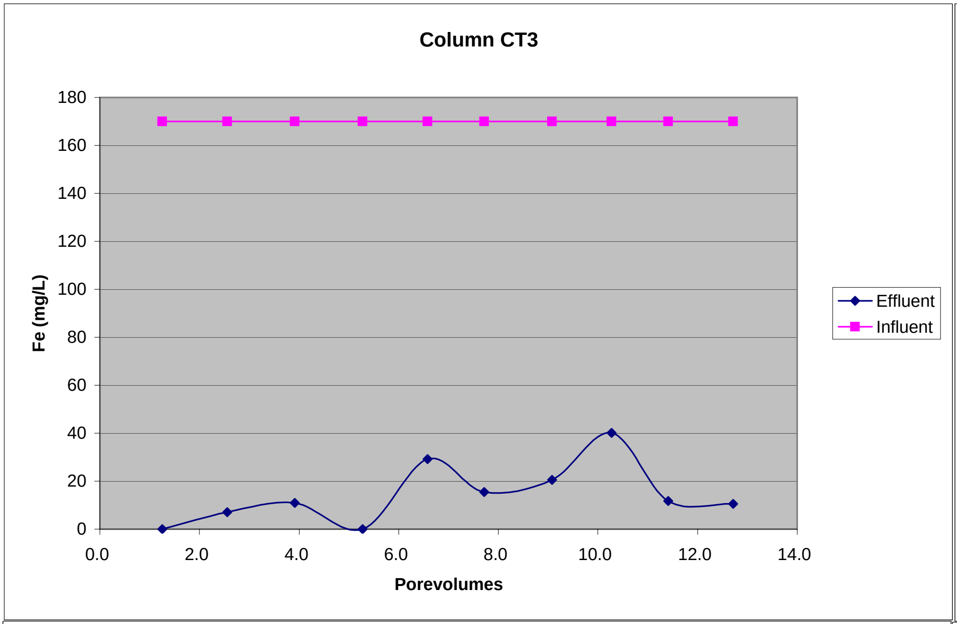
Mass	379	g
Dry Bulk Density	1.6	g/ml
Solids SG	2.6	g/ml
Volume solids	146	ml
Total Volume	237	ml
Calculated Pore Volume	91	ml
Theta	0.385	
Retardation	1.3	(breakthrough concentration at 50 % of influent)
Kd	0.07	kg/L

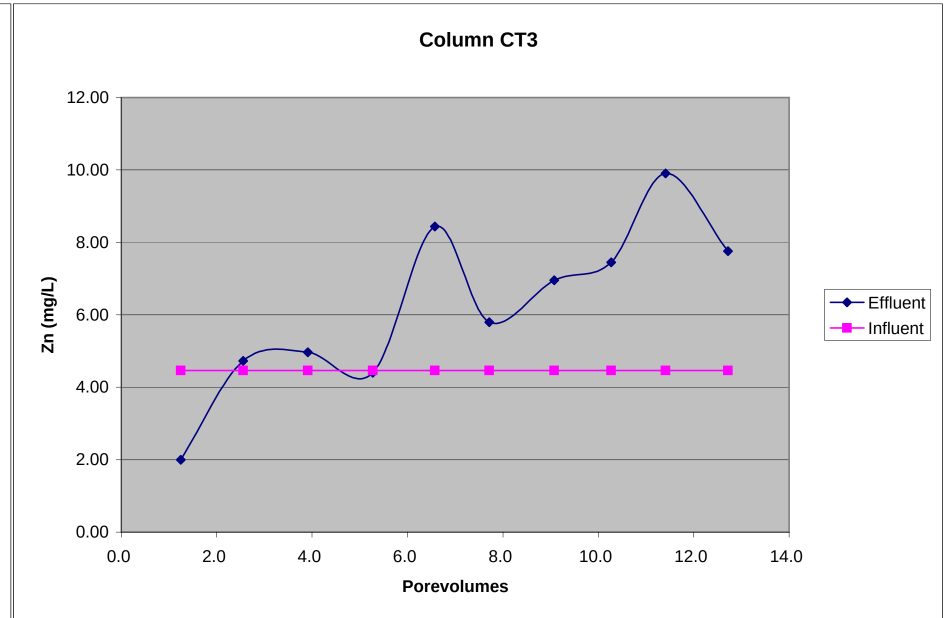

Column CT3
pH
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent

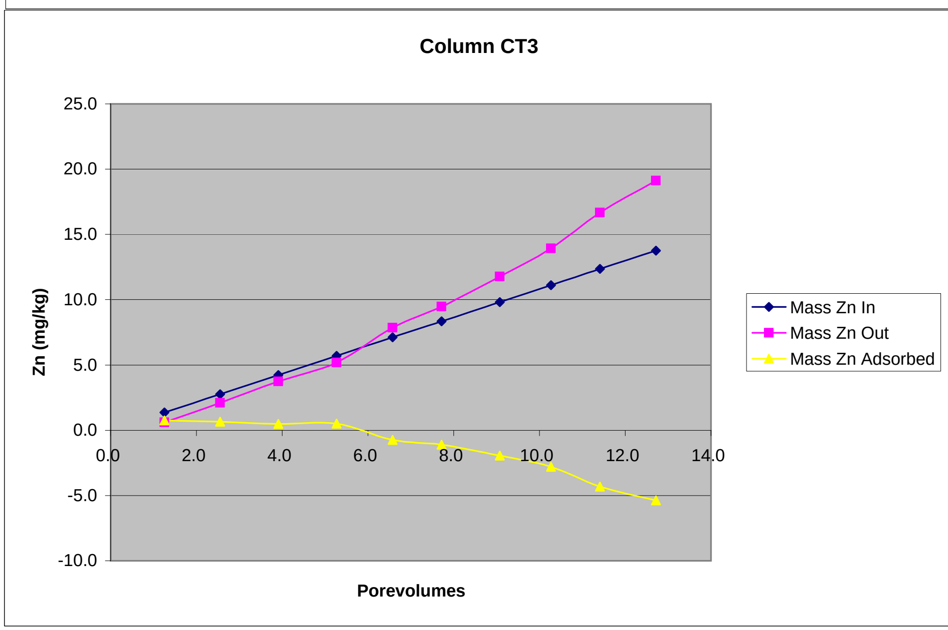

Column CT3
Redox (mV)
400
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent

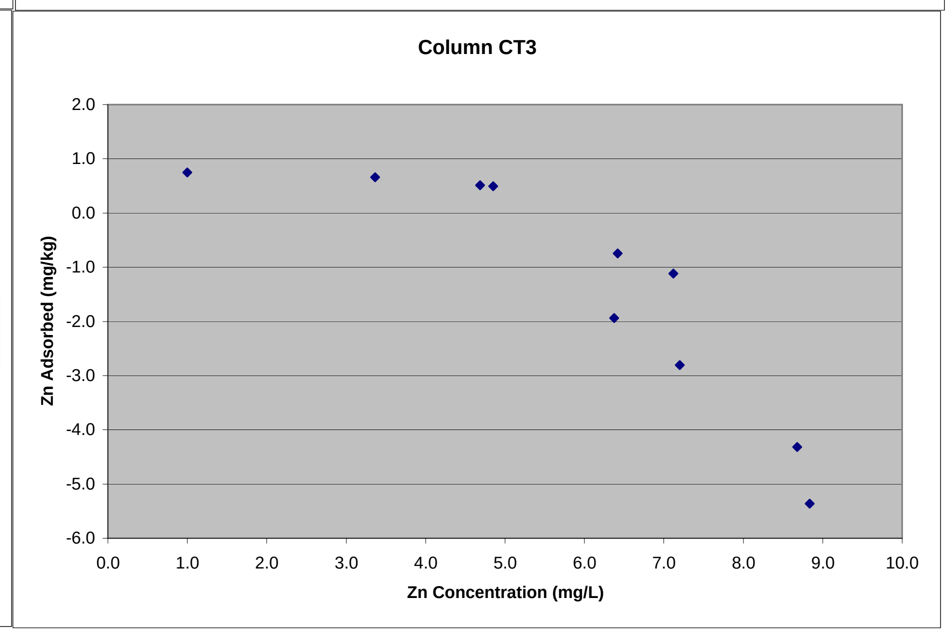

Column CT3
Acidity (mg CaCO3 eq/L)
450
400
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent


Column CT3
Na (mg/L)
60
50
40
30
20
10
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent


Column CT3
Fe (mg/L)
180
160
140
120
100
80
60
40
20
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent


Column CT3
Zn (mg/L)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent


Column CT3
Zn (mg/kg)
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Mass Zn In
Mass Zn Out
Mass Zn Adsorbed


Column CT3
Zn Adsorbed (mg/kg)
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Zn Concentration (mg/L)

Appendix E7 - Column Test CT4

Soil Sample P03-04-GS2*

Water P01-09B1

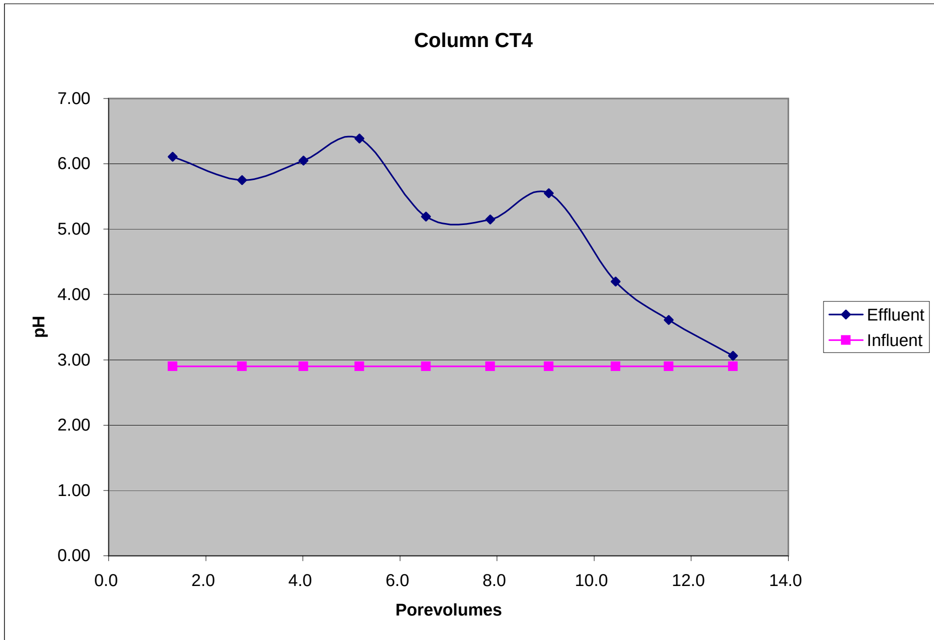
Parameter	Units	Feed	Effluent									
Cycle	0.091	0	1.3	2.7	4.0	5.2	6.5	7.9	9.1	10.4	11.5	12.9
DATE			22-Sep-04	27-Sep-04	29-Sep-04	1-Oct-04	5-Oct-04	6-Oct-04	11-Oct-04	13-Oct-04	15-Oct-04	19-Oct-04
LEACHATE	(L)		0.120	0.130	0.115	0.105	0.125	0.120	0.110	0.125	0.100	0.120
pH		2.9	6.11	5.75	6.05	6.39	5.19	5.15	5.55	4.20	3.61	3.06
REDOX.	(mV)	399	66	230	89	100	167	200	200	162	260	227
ACIDITY (pH 4.5)	(mg CaCO3/L)	147.5	0.0	-	-	0.0	-	285.0	0.0	97.0	178.6	185.5
ACIDITY (pH 8.3)	(mg CaCO3/L)	890	102	*134*	*165*	197	*302*	407	406	450	306	302
ALKALINITY	(mg CaCO3/L)	0	4.3	-	-	0.0	-	0.0	2.0	0.0	0.0	0
Total Metals (mg/L)												
Aluminum	mg/L	<0.20	<0.20	0.2	<0.20	<0.20	<0.20	0.23	<0.20	1.54	1.18	0.96
Antimony	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium	mg/L	0.018	0.031	0.024	0.021	0.042	0.023	0.021	0.016	0.057	0.025	0.015
Beryllium	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron	mg/L	<0.10	<0.10	0.13	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium	mg/L	72.5	306	293	320	203	218	214	202	196	221	234
Chromium	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	mg/L	0.146	0.056	0.110	0.116	0.092	0.143	0.157	0.137	0.172	0.19	0.184
Copper	mg/L	0.082	<0.010	<0.010	<0.010	0.044	<0.010	0.031	0.032	0.074	0.363	0.357
Iron	mg/L	376	41.1	126.0	122.0	076	167	252	149	211	63.6	112
Lead	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium	mg/L	0.044	0.050	0.067	0.062	0.041	0.056	0.065	0.051	0.06	0.062	0.064
Magnesium	mg/L	21	24.6	26.4	30.0	22.4	28.3	30.7	32.3	31.6	39	42
Manganese	mg/L	24.7	10.5	20.7	23.4	17.8	24.3	26.7	24.4	26.6	27.3	27.7
Molybdenum	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel	mg/L	0.218	0.087	0.134	0.150	0.109	0.162	0.181	0.19	0.222	0.24	0.245
Phosphorus	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium	mg/L	3.3	14.7	15.3	13.4	28.4	16.6	19	26.3	9.3	14.2	13.8
Selenium	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon	mg/L	11.1	5.92	8.93	9.15	7.11	9.57	10.5	9.2	12.4	11.3	10.5
Silver	mg/L	<0.010	<0.010	0.016	0.012	<0.010	0.029	0.01	<0.010	0.038	<0.010	0.015
Sodium	mg/L	18.2	24.6	20.7	21.0	14.8	17.7	19.3	17.6	18.8	18.5	19
Strontium	mg/L	0.218	0.858	0.845	0.937	0.609	0.654	0.64	0.655	0.605	0.653	0.699
Thallium	mg/L	<0.30	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium	mg/L	<0.010	<0.010	0.011	<0.010	<0.010	<0.010	<0.010	<0.010	0.057	<0.010	<0.010
Vanadium	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc	mg/L	59.4	16.0	32.8	35.8	30.3	46.3	49.9	43	55.5	58.3	50.1

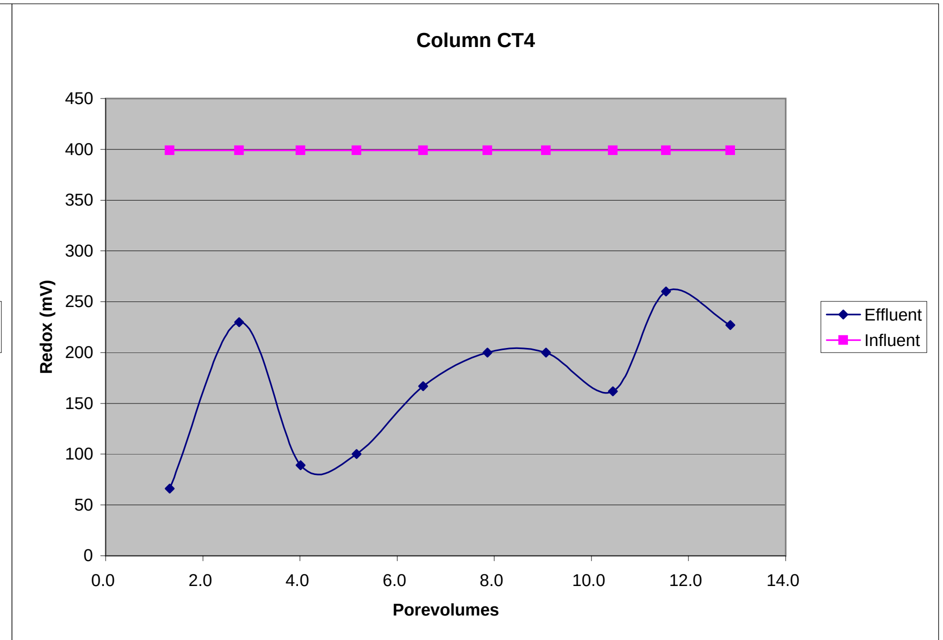
Column Test CT4
Summary Calculations

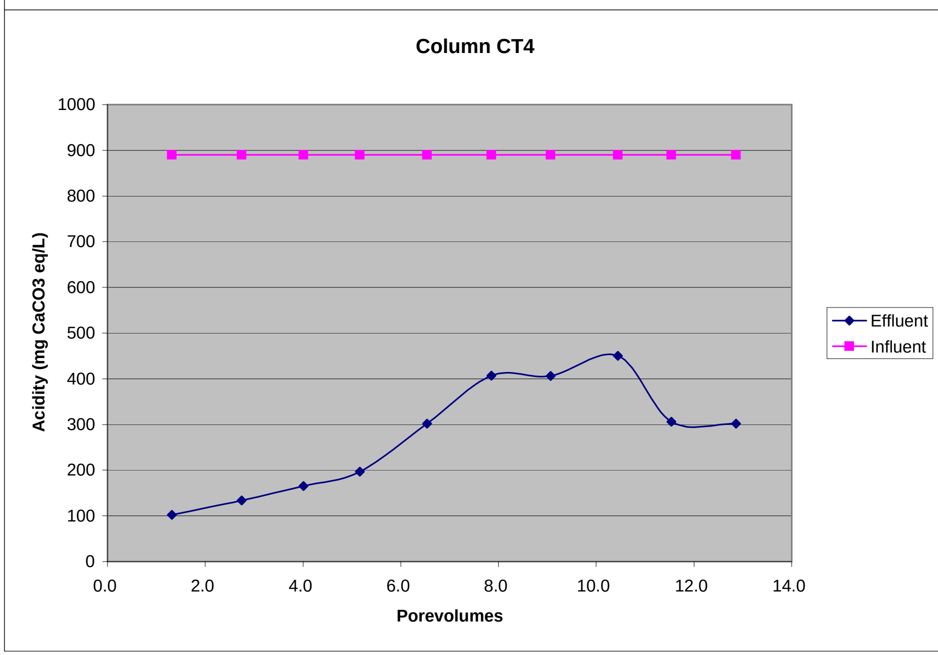
Sample Weight	g	379										
Acidity in	kgCaCO3 /tonne		0	0.28	0.59	0.86	1.10	1.40	1.68	1.94	2.23	2.47	2.75
Acidity out	kgCaCO3 /tonne		0	0.03	0.05	0.05	0.05	0.10	0.13	0.12	0.15	0.08	0.10
Accumulated	kgCaCO3 /tonne		0	0.25	0.54	0.81	1.05	1.30	1.55	1.82	2.08	2.38	2.65
Iron in	mg/kg		0	119	248	362	466	590	709	818	942	1042	1161
Iron out	mg/kg		0	13.0	56	93	114	169	249	292	362	379	414
Accumulated	mg/kg		0	106	192	269	352	421	460	526	581	663	747
Zn in	mg/kg		0	18.8	39.2	57.2	73.7	93.3	112.1	129.3	148.9	164.6	183.4
Zn out	mg/kg		0	5.1	16.3	27.2	35.6	50.8	66.6	79.1	97.4	112.8	128.7
Accumulated	mg/kg			13.7	22.9	30.0	38.1	42.4	45.4	50.2	51.5	51.8	54.7
Zinc													
C(Liquid)	mg/L			8.0	24.4	34.3	33.1	38.3	48.1	46.5	49.3	56.9	54.2
C(solids)	mg/kg			13.7	22.9	30.0	38.1	42.4	45.4	50.2	51.5	51.8	54.7
Kd	L/kg			1.7	0.9	0.9	1.2	1.1	0.9	1.1	1.0	0.9	1.0
Zn / Fe	mg Zn / mg Fe			0.130	0.119	0.112	0.108	0.101	0.099	0.095	0.089	0.078	0.073

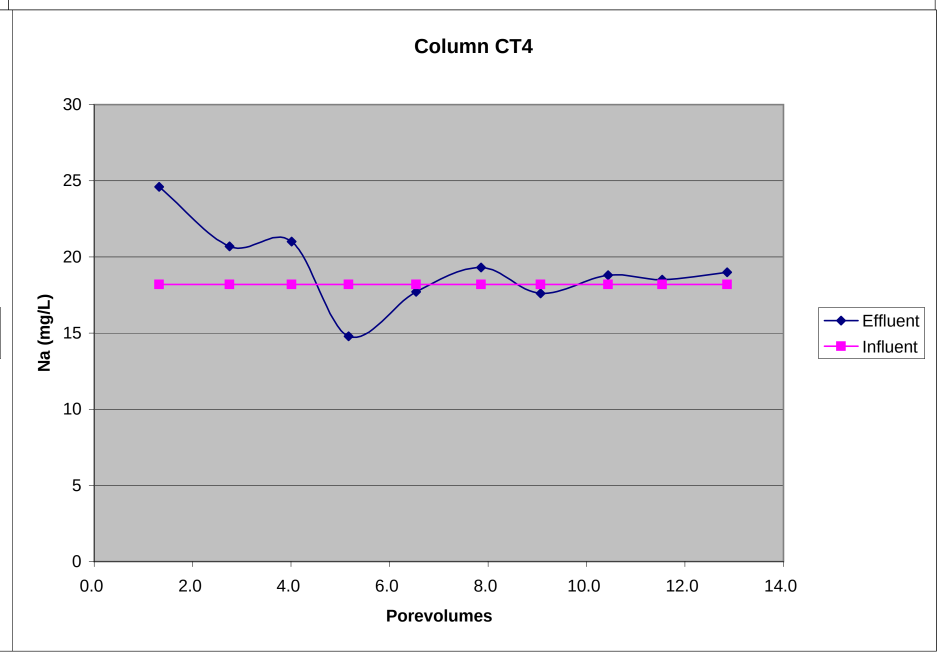
Breakthrough Kd Estimation

Mass	379	g
Dry Bulk Density	1.6	g/ml
Solids SG	2.6	g/ml
Volume solids	146	ml
Total Volume	237	ml
Calculated Pore Volume	91	ml
Theta	0.385	
Retardation	4	(breakthrough concentration at 50 % of influent)
Kd	0.72	kg/L


Column CT4
pH
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent


Column CT4
Redox (mV)
450
400
350
300
250
200
150
100
50
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent


Column CT4
Acidity (mg CaCO3 eq/L)
1000
900
800
700
600
500
400
300
200
100
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent


Column CT4
Na (mg/L)
30
25
20
15
10
5
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Porevolumes
Effluent
Influent