

AUSTRALIAN NUCLEAR SCIENCE
AND TECHNOLOGY ORGANISATION
LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE

A REPORT TO QUASAR RESOURCES

on

ATTENUATION CHARACTERISTICS OF FOUR MILE PROJECT AREA CORES

by

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September 2008

EXECUTIVE SUMMARY

A study to determine the attenuation characteristics of drill core composites from the Four Mile deposit was undertaken. Local ground water was passed through horizontal columns packed with core material crushed to < 5.6 mm. The as-received ground water was treated to give the following baseline conditions:

- pH 1.7
- 560 mV
- 50 mg/L U

The composition of the doped groundwater is shown below.

Composition of Doped Column Feed Liquor (mg/L)

Element	Doped Feed
Al	4.8
Ca	115
Cl	1490
Fe	1.73
K	61
Mg	26.6
Na	950
S	851
Si	28.3
U	52.9
pH	1.63-1.69
ORP (mV)	550-570

Details of the four cores used are as follows, with the compositions given in the table below.

Hole ID	Sample ID's	From...to (m)
AKC028	84856-84863	188.25-190.83
AKC029	80910-80921	196.43-198.4
AKC030	83837-83841	213.4-216.0
AKC033	83944-83948	191.4-193.9

Composition of Core Samples before Attenuation Testing (wt%)

Core	Mg	Al	S	Si	P	K	Ca	Fe	U	C
AKC028	0.077	1.78	0.03	43.4	0.016	0.096	0.025	0.38	0.002	0.04
AKC029	0.033	2.26	0.10	42.7	0.008	0.12	0.034	0.39	0.010	0.22
AKC030	< 0.001	0.31	0.29	43.4	0.003	0.035	0.021	0.34	0.002	0.06
AKC033	0.032	2.88	0.069	41.6	< 0.001	0.28	0.075	0.44	0.003	0.02

The columns packed with core sample were initially flushed with ‘as received’ ground water to stabilise the material. The doped ground water was then passed through the columns until attenuation break-through occurred, as indicated by the pH and ORP of the column effluent.

Findings

Core materials AKC028-30 demonstrated relatively good permeability during acid contact, typical of sandy material, in that the target flow 0.9 mL/min (equivalent to 2.5 m/day) was achieved at a fluid-head of 1-2 m. Conversely, AKC033, which appeared clayey in nature, had a lower permeability, with only 0.3 mL/min discharged under a 4 m fluid head.

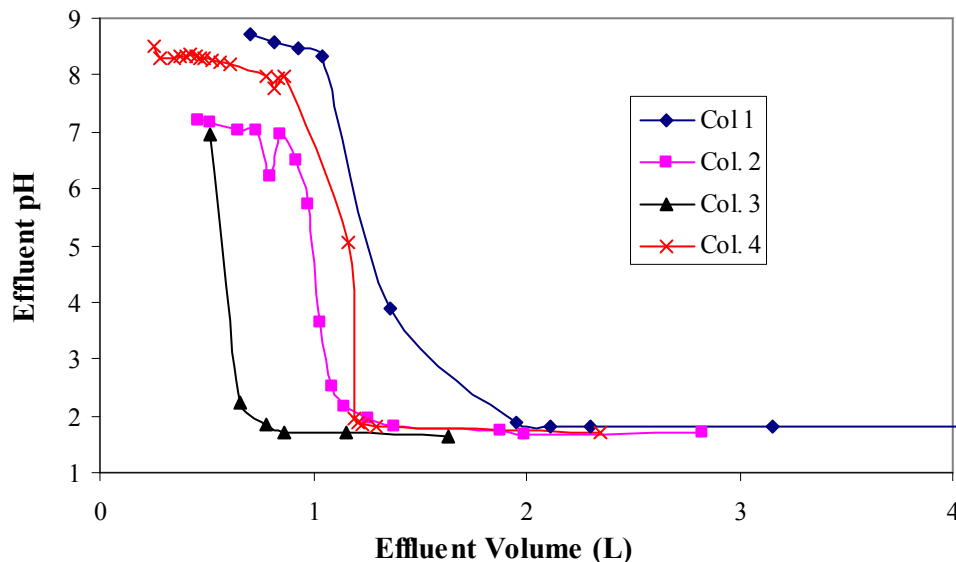
A summary of column data from the four tests is shown in the table below.

Summary of Column Data

Column	Core	Attenuation Limit		Breakthrough of Cl spike (h)
		Time (h)	Volume (L)	
1	AKC028	40	2.44	
2	AKC029	30	1.70	14
3	AKC030	20	1.09	13
4	AKC033	85	1.6	70

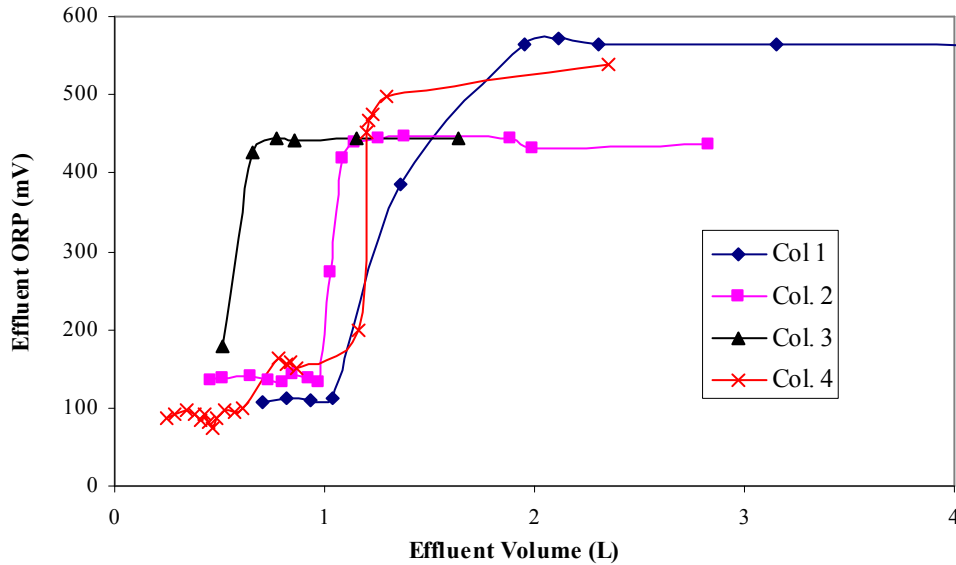
The effluent pH and ORP trends as a function of the volume of liquor passed through the columns are shown in the following figures. For pH attenuation, capacity decreased in the order below, with all column effluents reaching the feed liquor pH:

Col 1 > Col 4 \cong Col 2 >> Col 3



For ORP, attenuation capacity decreased in the order below, with only the effluents from columns 1 and 4 reaching the feed liquor ORP. The “final” ORP from columns 2 and 3 was 450 mV.

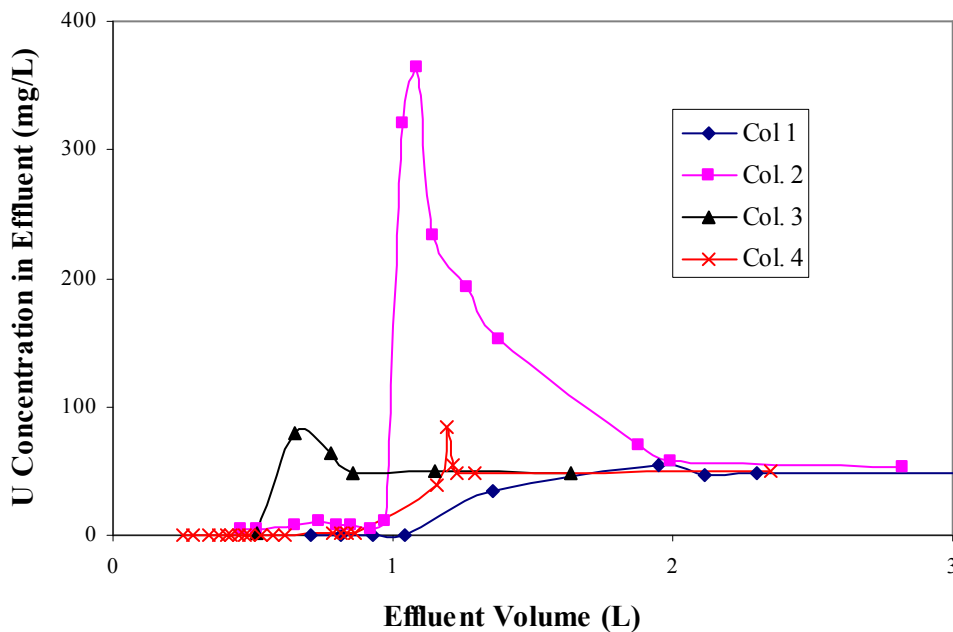
Col 1 > Col 4 > Col 2 >> Col 3



The uranium attenuation capacity decreased in the order shown below, which was the same for pH and ORP, see Figure below.

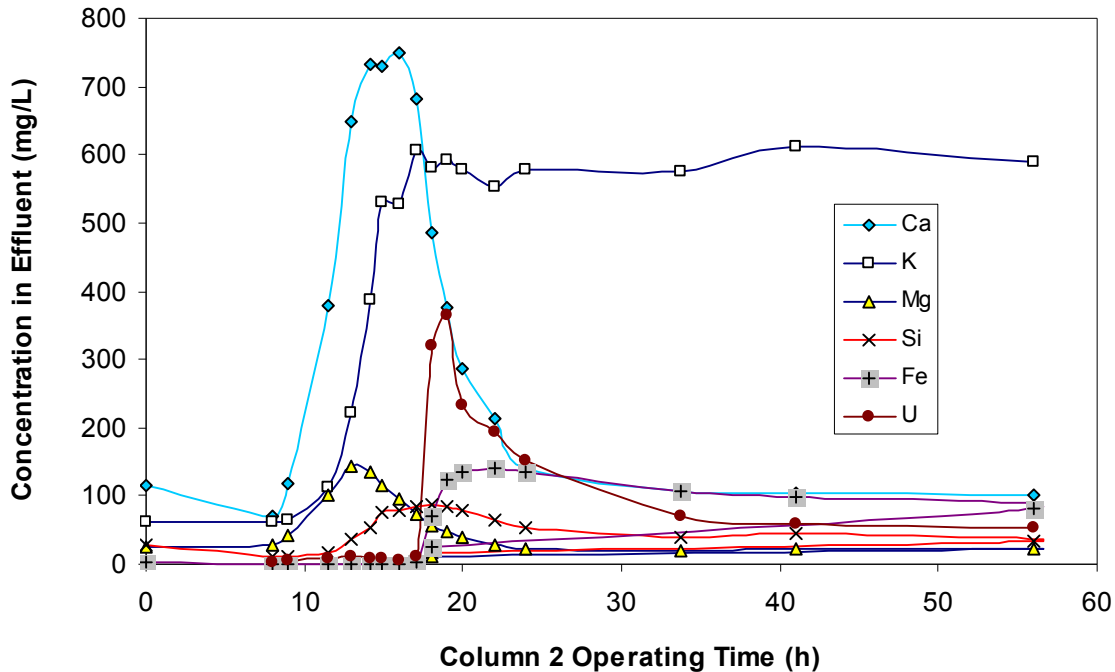
$$\text{Col 1} > \text{Col 4} \gg \text{Col 3}$$

However, the material in column 2 cannot be compared in the same way, as uranium was in fact leached from this core.



The concentration trends of gangue elements in the column effluents varied depending on their chemistry. Typical data for column 2 are shown in the figure below. The concentrations of Fe, Si and Al (not shown) persisted in the effluent, whereas Ca, Mg, Si and U showed distinct peaks. The trend in K concentration reflects the emergence of a KCl spike, while the gradual decrease in Fe at around 20 h acid contact coincides with ORP attenuation. The

timing of the peaks depended on the effluent pH and the amount of soluble element in the core material.



The total quantity of gangue elements in the effluent up to the time of break through was also calculated. The results showed that:

- there were minor differences in the amounts of Mg, Al and Si dissolved from all materials, although there was some correlation between silicate dissolution and attenuation time;
- the Ca dissolved from the material in column 3 was the lowest, indicating that dissolution of calcite was low, and possibly the reason for inferior attenuation properties of this material;
- the Fe dissolved for column 3, which showed the poorest attenuation properties, was the highest.

There appears to be good evidence that the presence of reactive iron had an adverse effect on the natural attenuation, in that acid generated from oxidative dissolution of sulphide minerals accelerated the breakthrough of the mining solution pH. Rapid dissolution of a calcium mineral appeared to control initial attenuation, while ongoing reaction of silicates/clays appeared to consume acid and prolong attenuation.

CONCLUSIONS

- The presence of clay minerals significantly decreased permeability and hence the flowrate of mining solution;
- Reactive iron sulphides had the capacity to accelerate breakthrough due to acid generation;

- The concentration of Ca, above baseline, was significantly greater than other elements in the initial column discharges, indicating that possibly calcite was the primary control of attenuation;
- The presence of reactive silicates/clays had the potential to prolong final breakthrough by consuming acid;
- Material from core AKC028 displayed the best attenuation characteristics. This was associated with low levels of dissolved Fe, and possibly greater silicate dissolution;
- Material from core AKC030 displayed the least favourable attenuation characteristics, and corresponded to the lowest dissolution of Ca.

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TABLE OF CONTENTS

1.	INTRODUCTION	1
2.	OBJECTIVES	1
3.	SCOPE OF WORK	1
4.	SAMPLE PREPARATION AND ANALYSES	1
4.1	Sample Preparation	1
5.	HORIZONTAL COLUMN SET-UP	3
5.1	Column Set-Up	3
5.2	Column Loading	3
5.3	Attenuation Test Procedure	4
6.	COLUMN TESTS	4
6.1	Attenuation Tests	5
6.1.1	Column 1 – AKC028	5
6.1.2	Column 2 – AKC029	7
6.1.3	Column 3 – AKC030	9
6.1.4	Column 4 – AKC031	11
6.2	Gangue Dissolution	13
6.3	Column Residue Washing	14
6.4	Overview of Results	14
7.	CONCLUSION	17
8.	ACKNOWLEDGMENTS	17
	APPENDIX A	Horizontal Column Data
	APPENDIX B	Gangue Element Dissolution

1. INTRODUCTION

Preliminary testing of drill core samples from Quasar's Four Mile Creek (FMC) deposit indicated high leachability of uranium. In horizontal columns, 80-90% uranium dissolution was recorded after 90 days leaching at 6-12 kg/t acid consumption (ANSTO Minerals Report C977). In light of this preliminary study, Heathgate Resources (HGR), on behalf of Quasar Resources, requested a follow-up study to determine the attenuation characteristics of drill core composites from FMC in terms of solution pH, ORP, and dissolved species.

2. OBJECTIVES

The objective of the work program was as follows:

- To determine the attenuation characteristics of drill core composites from the FMC area.

3. SCOPE OF WORK

The following tasks were undertaken:

- Task 1. Core samples were air dried at room temperature and representative composites prepared for column loading. All analytical fractions were pulverised and analysed for U by DNA. Major/minor elements were determined by XRF, and total C by Leco;
- Task 2. Ground water was doped with acid, hydrogen peroxide, U and Cl and analysed to establish baseline conditions;
- Task 3. Columns were loaded and packed to a suitable density;
- Task 4. Columns were flushed with 'as received' ground water to stabilise for leaching;
- Task 5. Columns were leached with doped ground water until attenuation was achieved, as indicated by pH/ORP trends. All discharge liquors were analysed by ICP and titrated for HCO₃;
- Task 6. Columns were dismantled and the residues washed for sampling.

4. SAMPLE PREPARATION AND ANALYSES

4.1 Sample Preparation

Approximately 12 kg of core material was selected from samples already delivered to ANSTO Minerals.

Details of the cores used are given below.

Hole ID	Sample ID's	From...to (m)
AKC028	84856-84863	188.25-190.83
AKC029	80910-80921	196.43-198.4
AKC030	83837-83841	213.4-216.0
AKC033	83944-83948	191.4-193.9

The cores were air dried and then combined as specified by the client to yield the composite samples. The composites were screened at 5.6 mm and the oversize crushed to < 5.6 mm and recombined with the bulk composite. The < 5.6 mm composites were split into ~ 200 g lots for column loading. One lot was retained for head analysis, after pulverising. The head assays are shown in **Table 1**. All samples were analysed for Al, Ca, Fe, K, Mg, Mn, P, Si, U and C, including the final washed leach residues.

The cores were generally similar in composition, with the most noticeable differences being:

- AKC030 is low in Al and K, indicating a lower silicate/clay content;
- AKC033 is high in Al and K, indicating a higher silicate/clay content;
- All cores contained a similar total Fe concentration;
- AKC029 was highest in total C, perhaps indicating a greater carbonate¹ content.

TABLE 1
Composition of Core Samples before Attenuation Testing (wt%)

Core	Mg	Al	S	Si	P	K	Ca	Fe	U	C
AKC028	0.077	1.78	0.03	43.4	0.016	0.096	0.025	0.38	0.002	0.04
AKC029	0.033	2.26	0.10	42.7	0.008	0.12	0.034	0.39	0.010	0.22
AKC030	< 0.001	0.31	0.29	43.4	0.003	0.035	0.021	0.34	0.002	0.06
AKC033	0.032	2.88	0.069	41.6	< 0.001	0.28	0.075	0.44	0.003	0.02

The client provided 2 x 20 L containers of 4 Mile East ground water, 10 L of which was set aside for column flushing and the remainder used for make-up of “Mining Solution”. Both samples were analyzed to ensure consistency, and then mixed. The bulk solution was analysed and this analysis was repeated after doping and adjustment of conditions, and repeated again before each column experiment. Solutions were analysed for Al, Ca, Cl, Fe, K, Mg, Mn, Na, S (SO₄), Si, P, HCO₃, CO₃ and U, including the ‘as received’ ground water, ‘doped’ mining solution, all discharge liquors and final wash solutions.

The composition of the two 20 L ground water samples are given in **Table 2**. The main component of the ground water was NaCl with lesser amounts of Ca, Mg and S, presumably as SO₄ species.

As received ground water was treated to give the following baseline conditions:

- pH 1.7 (1.93 g/L sulphuric acid)
- 560 mV (adjusted with hydrogen peroxide)
- 50 mg/L U

¹ Note, 0.22% C corresponds to 1.1% CO₃, which would consume 18 kg/t of sulphuric acid if all carbonate reacted.

TABLE 2
Composition of Four Mile Water (mg/L)

Element	Container 1	Container 2	Doped Feed
Al	< 1	< 1	4.8
Ca	107	115	115
Cl	1050	1050	1490
Fe	< 1	< 1	1.73
K	56.5	60.5	61
Mg	26.0	27.7	26.6
Mn	< 1	< 1	< 1
Na	919	985	950
P	< 1	< 1	< 1
S	140	147	851
Si	25.5	27.0	28.3
U	< 1	< 1	52.9
pH	8.34	8.34	1.63-1.69
ORP (mV)	80	80	550-570

5. HORIZONTAL COLUMN SET-UP

Sample preparation, horizontal column construction and configuration, and set-up was the same as used in a previous study, and is described in ANSTO Mineral Report C977. Core samples were dried at room temperature and a total of 4 columns packed with composite ore for attenuation testing.

5.1 Column Set-up

Liquor supply to the columns was controlled via the dynamic fluid head system illustrated in **Figure 2**. In this arrangement, the volumetric flow to the column is held constant while the head pressure, *i.e.* height of fluid above the column, varies naturally in response to changes in the resistance of the ore to fluid migration. Factors affecting permeability include, fines migration and compaction, CO₂ gas generation, and clay expansion.

Ground water was initially pumped into the open feed line to stabilise the packing and its permeability. As a guideline, for a measured bed volume of ~1200 mL for a 1 m column, a flow rate of approximately 0.6-0.65 mL/min would achieve the target solution migration rate of approximately 2.5 m/day through the column during leaching, assuming a porosity factor of 0.3 for permeable sands, where porosity = voidage volume/total volume. However a feed rate of 0.9 mL/min into the Column 1 feed line was required to achieve a fluid migration rate of 2.5 m/day through the packed column. Therefore, the actual porosity of the packed ore in Column 1 was ~ 0.43, which confirms the sandy nature of the material.

5.2 Column Loading

A 200 g parcel of AKC028 crushed to < 5.6 mm was loaded into Column 1, to give a packed volume of 1188 mL. After several attempts to tamp the ore, it was apparent that the material in question was relatively sandy in nature in comparison to ore previously used in in-situ

leach simulation tests, and thus exhibited more elastic packing characteristics. After 10 tamps at a height of 10 cm, the ore was packed down to approx. 11 cm. Further tamps at 10 cm had little significant impact. This compaction gave a packing density of approx. 1.5 g/cm³. Consequently, all columns were packed using 10 tamps at 10 cm.

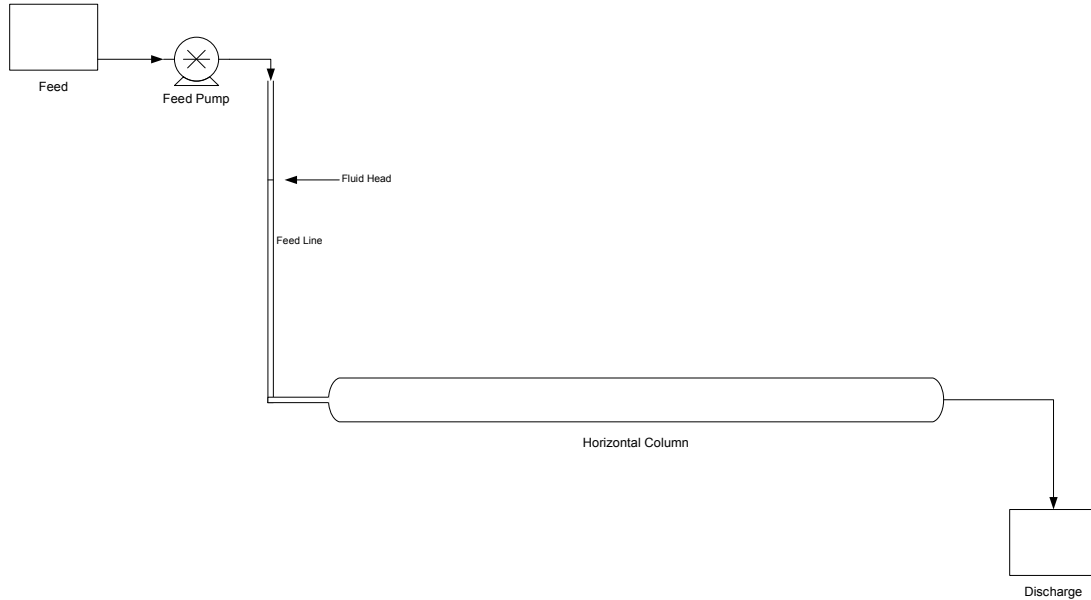


FIGURE 2 Dynamic Fluid Head Configuration for Horizontal Column Leaching

5.3 Attenuation Test Procedure

All horizontal column tests were conducted at a constant temperature of 30°C by placing the columns in a water bath. The pH and ORP of all column effluents were monitored, and the effluents analysed for the suite of elements specified in **Section 4.1**.

Loaded columns were initially flushed with ground water to consolidate the packed material prior to leaching. Columns were flushed overnight, and after approx. 16 hours, the fluid head had essentially stabilised, i.e. feed rate equalled discharge rate. In the initial stages of flushing, fluid migration was monitored through the one transparent column and the feed rate adjusted to achieve a migration rate of 2.5 m/day. Acidified leach solution was introduced following consolidation of the packing, with samples taken at regular intervals until the effluent was deemed to show no signs of attenuation.

Initial sampling of column discharge was delayed to account for the 10 h residence time in the column and the first column was run independently, in order to establish the necessary timeframe and sampling regime for the remaining 3 columns. On completion of the attenuation tests, columns were dismantled and the residue washed in pH 1.7 sulphuric acid solution and filtered (see **Appendix A**).

6. COLUMN TESTS

Four horizontal column tests were performed to simulate migration of ISL solution. Operating conditions are shown in **Table 3**, with detailed leach data given in **Appendix A**. Following completion of the Column Test 1, it was also decided to introduce a KCl tracer into the feed

solution of the remaining 3 columns to assist with mathematical modelling. This adjustment is apparent in the assays shown in **Table 3**.

TABLE 3
Leach Conditions for Four Mile Horizontal Columns

Column	Material in (g)	pH	ORP (mV)	U (mg/L)	Cl (mg/L)	Ore out (g)	Mass Loss (%)
1	1756.3	1.69	560	54.5	1030	1738.7	1.0
2	1682.7	1.67	552	52.9	1490	1661.0	1.3
3	1876.5	1.63	566	52.9	1490	1865.8	0.6
4	1888.2	1.67	544	52.9	1490	1869.1	1.0

The compositions of the cores and washed column residues are compared in **Table 4**. As gangue dissolution was minimal, variations between the head and tails assays reflect difficulties in obtaining representative samples for assay.

TABLE 4
XRF Head analyses for Four Mile Horizontal Columns (%)

Column	Mg	Al	Si	P	K	Ca	Mn	Fe	U
1									
Head	0.007	1.78	43.4	0.016	0.096	0.025	0.003	0.376	0.02
Tail	0.003	1.77	43.2	0.008	0.087	0.119	0.001	0.433	0.004
2									
Head	0.033	2.26	42.7	0.008	0.123	0.034	0.004	0.385	0.01
Tail	0.037	2.25	46.2	0.014	0.195	0.169	0.009	0.402	0.007
3									
Head	<0.001	0.31	43.4	0.003	0.035	0.021	<0.001	0.339	0.002
Tail	<0.001	0.35	43.2	0.009	0.113	0.023	0.001	0.409	0.001
4									
Head	0.032	2.88	41.6	<0.001	0.279	0.075	0.003	0.440	0.003
Tail	0.016	2.86	42.8	0.009	0.160	0.030	0.004	0.498	0.001

6.1 Attenuation Tests

6.1.1 Column 1 – AKC028

During flushing of Column 1 material with as-received ground water, good permeability was initially observed with the fluid head stabilising at 15 cm. Following the introduction of acidified feed, the fluid head increased to approx. 100 cm over the first 6 hours and then slowly increased to 140 cm after 1.5 days of contact. Bubbles of gas were noted in the discharge during the initial stages, presumably due to the generation of CO₂ from carbonate minerals. This may at least partly account for the observed increase in head pressure during acid leaching. Towards the end of the experiment, some minor fracture zones were observed

as the packing began to destabilise with time. Accordingly, the fluid head decreased to 123 cm after 6 days.

A plot of pH v time for Column 1, shown in **Figure 4**, illustrates that feed solution approached attenuation after 40 h contact, i.e., the feed and discharge pH converged. This conclusion is supported by the ORP curve, which essentially mirrors the pH data. Although the material continued to slowly consume acid after 40 hours, the attenuation curves have effectively begun to level off at this stage and the bulk of acid consuming minerals have been depleted. Only Al, Fe, and Si concentrations remained above baseline levels after breakthrough occurred. Therefore, these elements could affect attenuation on the acidic side of the inflexion curve shown in **Figure 4**. The concentration of carbonate in the column discharge liquor was insignificant.

Although no Cl tracer was added to the feed of column 1, changes in the concentrations of some of the major ions, as shown in **Appendix A**, indicate that the residence time in the column was close to 10 h, consistent with observations during flushing of the dry column with ground water and a fluid migration rate of 2.5 m/day. In view of the increase in fluid head height during acid addition, some delay in fluid migration through the column is expected. **Figure 5** shows concentration peaks for Ca, K and Mg close to the 12.5 h discharge sample, with the doped feed baseline shown at 0 hours. Fe, and Si concentration peaks showed expected delays owing to their pH dependencies. Similarly, the U spike in the feed did not emerge until the pH of the discharge solution became sufficiently acidic. An increase in the retention time of ionic species relative to water alone is also anticipated purely on the basis of weak ion exchange interactions through the packed column. The data indicated that no uranium was leached from the ore, consistent with a low XRF head grade of 0.002%.

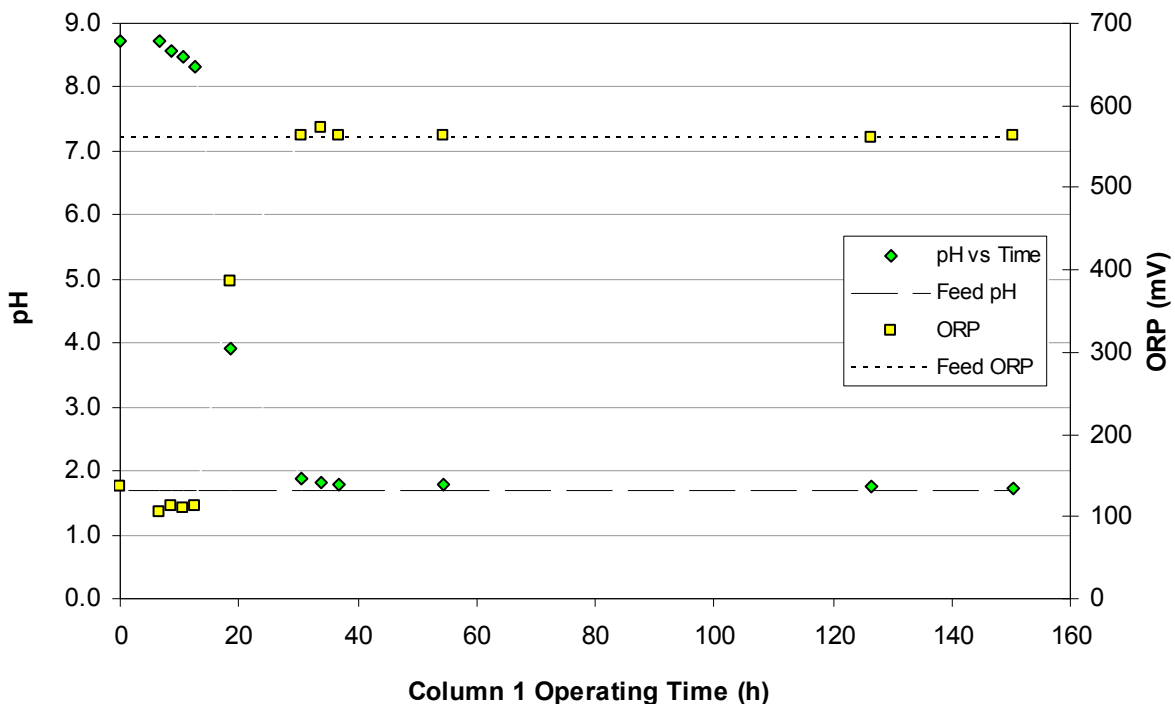


FIGURE 4 Column 1 Attenuation Curves (AKC028)

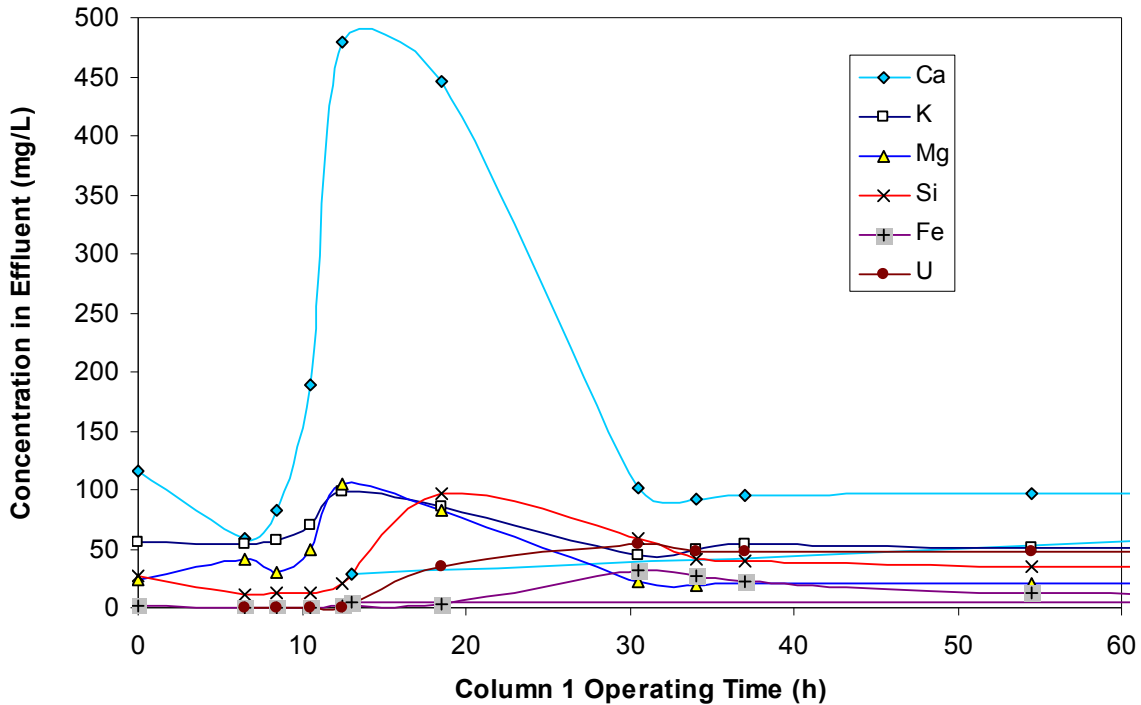


FIGURE 5 Column 1 Gangue Dissolution During Acid Contact (AKC028)

6.1.2 Column 2 – AKC029

The fluid head of Column 2 was consistent with Column 1 during flushing, but peaked at over 200 cm during acid leaching, double that of Column 1. The inflexion points of both attenuation curves for Column 2 were also relatively steeper and indicate that breakthrough was reached around 30 h (**Figure 6**). Significantly, ORP attenuation occurred below the baseline, consistent with the consumption of oxidant by iron sulphides and the presence of Fe and S in the column discharge with increasing ORP (see **Section 5.2** and **Appendix B**). Discharge concentrations for Ca, K, Fe, Mg, and Si are shown in **Figure 7**, with the most significant observation being the increase in Fe levels. This should be considered in light of the reduction in ORP when attenuation was reached. A steady increase in K concentration was also noted over time, as evident in **Appendix B**, consistent with the emergence of the KCl tracer. Again only Al, Fe and Si remained above the baseline at the completion of the test.

The Cl tracer added to Column 2 peaked at approx. 14 h (**Figure 8**). Decreased permeability was anticipated given the observed increase in fluid head height of Column 2 with respect to Column 1. This may be related to increased levels of fines or clays and/or increased CO₂ gas generation. Fines tend to migrate and compact toward the discharge end of a column and restrict flow, whilst clays tend to expand and plug the column in general. Consequently, head pressure naturally increases in the feed line in response to flow restrictions. Finally, as a result of the relatively higher U head grade (**Table 3**), U dissolution from Column 2 peaked at 364 ppm after 19 h leaching.

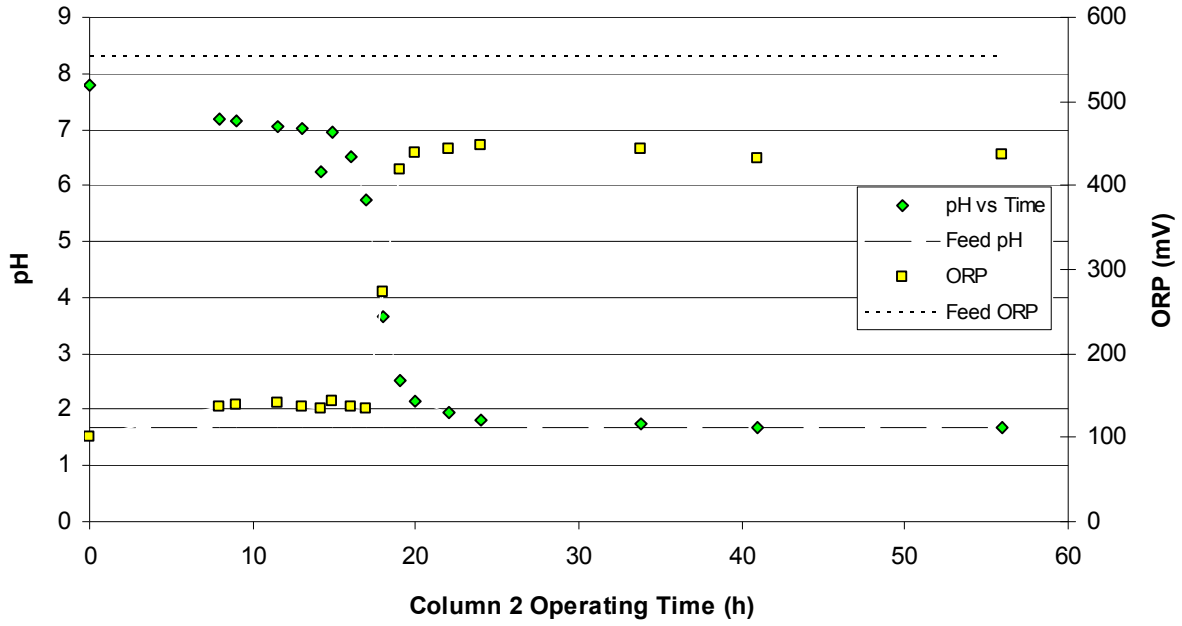


FIGURE 6 Column 2 Attenuation Curves (AKC029)

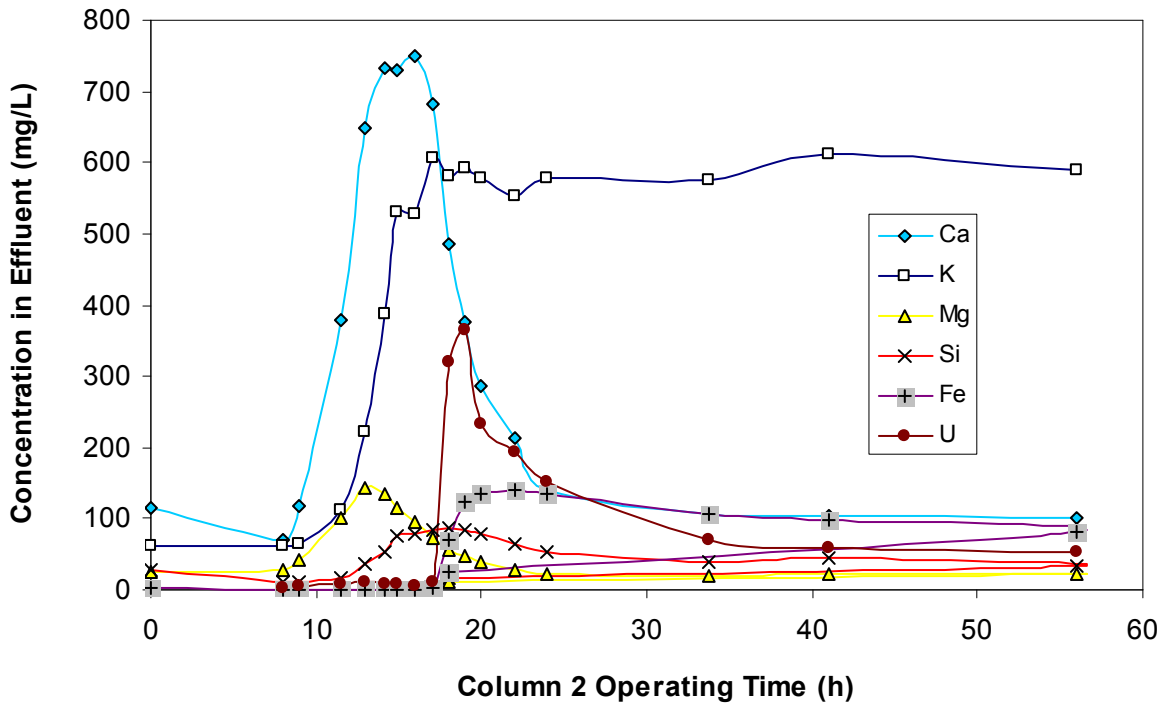


FIGURE 7 Column 2 Gangue Dissolution During Acid Contact (AKC029)

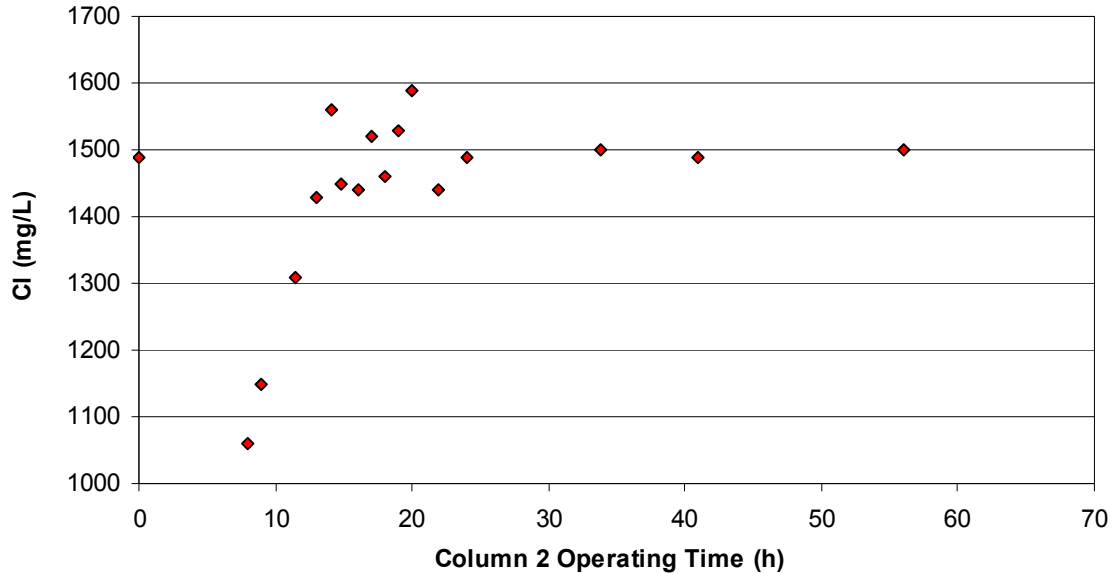


FIGURE 8 Column 2 Cl Tracer (AKC029)

6.1.3 Column 3 – AKC030

The fluid head of Column 3 increased above 4 m into the feed reservoir during the early stages of acid leaching. The resultant head pressure caused the silicon seal at the feed end of the column to develop a leak after 14 h, as indicated in **Appendix A** by the rapid decrease in head height. The column feed line was thus allowed to empty and the end cap resealed after 15 h leaching. Only 200 mL of discharge was collected over this period and the discharge pH was stable. Since the leak was at the feed end of the column, it is likely that only a small amount of feed solution had permeated through the column. ICP data support this view in that no significant increase in ionic concentration was recorded. Furthermore, the Cl concentration prior to the detection of the leak did not indicate the emergence of the Cl spike. However, after the column was resealed and acid re-introduced, the Cl spike appeared after 8.5 h and peaked around 13 h (**Figure 9**). Similar observations were noted in U trends. These observations are consistent with the calculated residence time and data from Column 2, where the Cl tracer also peaked at approx. 14 h.

Following repair of Column 2, the fluid head remained relatively low with good permeability. In view of this, it seems likely that the breach was due to some form of isolated restriction at the feed end of the column. Assuming limited acid migration through the column prior to repair, **Figure 10** shows that attenuation commenced around 15 h, assuming 0 h after the repair. As observed in **Figure 6** for Column 2, ORP attenuation in Column 3 also occurred below the baseline, and should again be considered in the context of elevated Fe and S in the column discharge (see **Section 5.2** and **Appendix B**). In fact, Fe and S levels from Columns 2 & 3 discharge were significantly higher than Columns 1 & 4, both of which displayed more protracted attenuation. Trends in Fe dissolution are illustrated in **Figure 11**, and show a steep increase in Fe concentration at 11.5 h in response to an apparent rapid increase in ORP. The Fe concentration peak at 14 h was relatively short-lived and levels began to slowly decrease thereafter. Again, Al, Fe, and Si concentrations were above baseline after pH breakthrough occurred, but the dominance of Fe for this test appeared to govern attenuation characteristics.

Given that some 200 mL of solution was discharged prior to repair, and accounting for a flow rate of 0.9 mL/min, it is reasonable to assume that attenuation of Column 3 was in fact achieved at around 20 h. The decreased attenuation time of Column 3 may also be in keeping with relatively low levels of Ca dissolved from this ore, as reflected by XRF and ICP data.

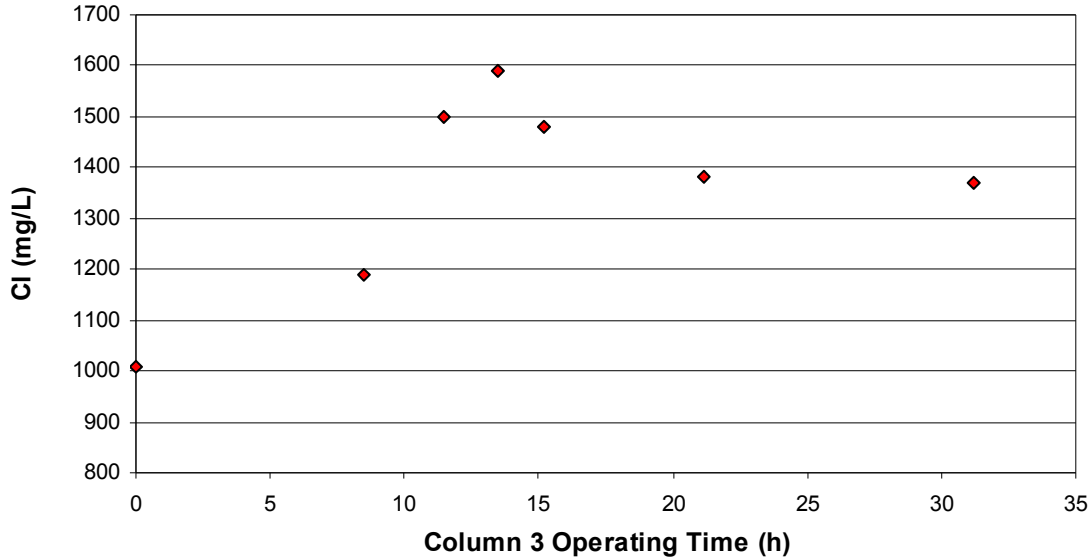


FIGURE 9 Column 3 Cl Tracer (AKC030)

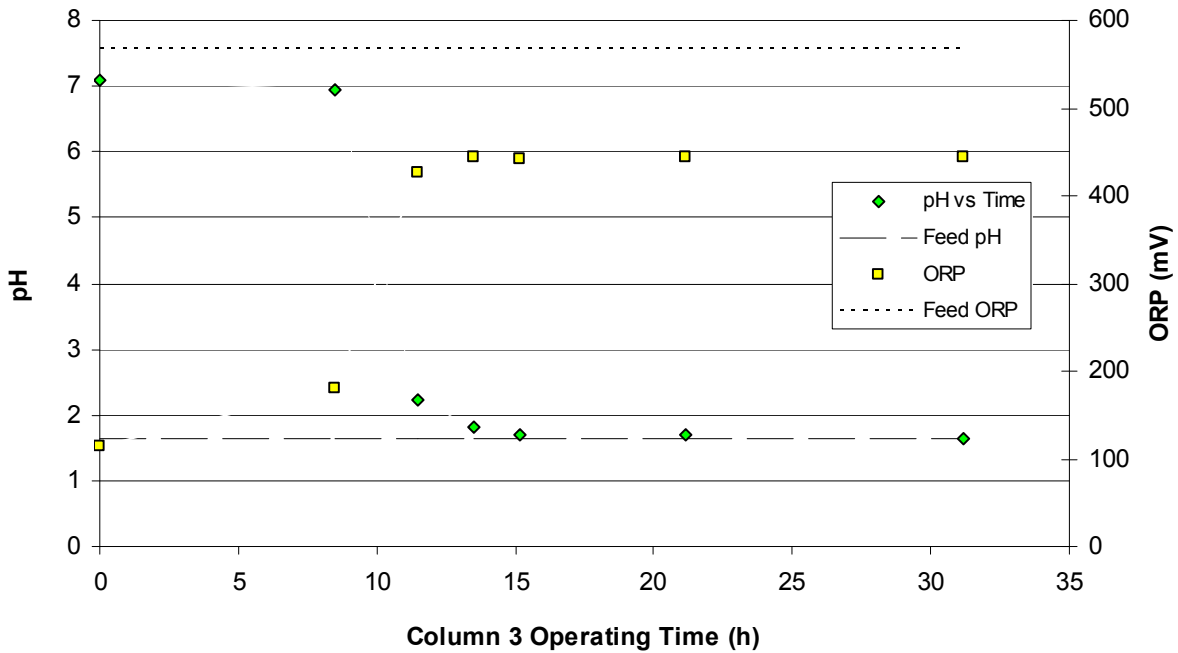


FIGURE 10 Column 3 Attenuation Curves (AKC030)

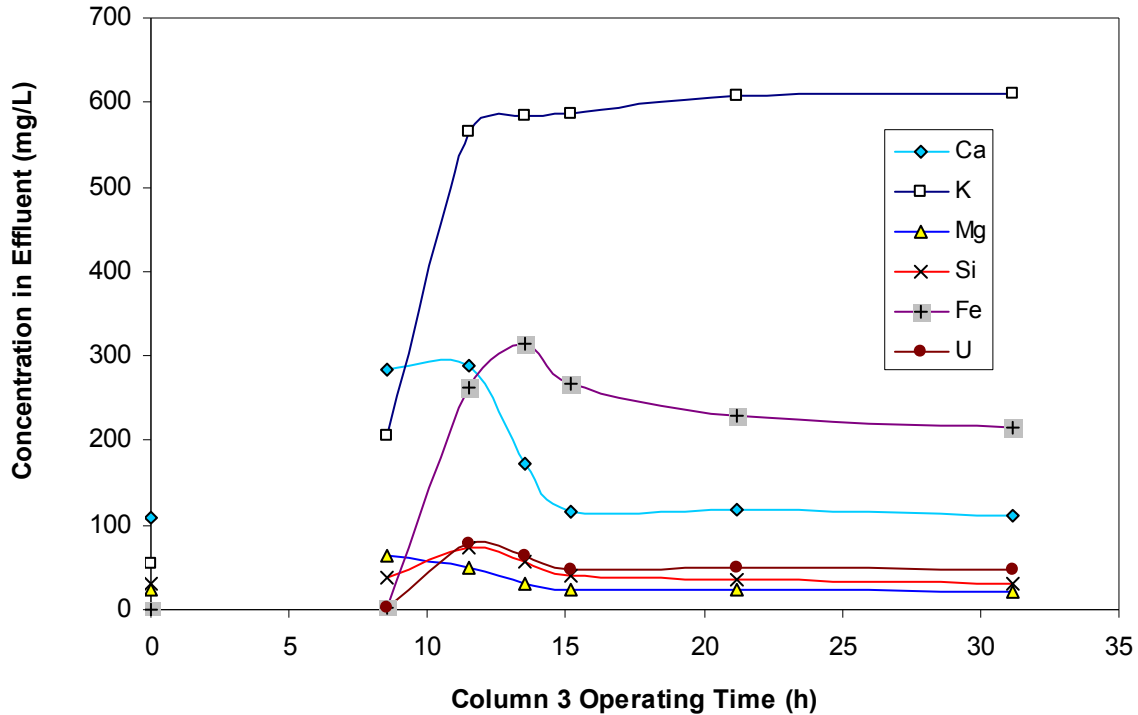


FIGURE 11 Column 3 Gangue Dissolution During Acid Contact (AKC030)

6.1.4 Column 4 – AKC031

From the onset of acid leaching, the fluid head of Column 4 slowly increased to the feed reservoir and remained there for the duration of the experiment. Consequently, feed flow rates were periodically decreased to avoid excessive build-up in the header reservoir. This observation reflects increased levels of clays, which typically decrease permeability. Closer inspection of the ore during washing revealed colloidal material and supported this view. Discharge rates during operation of Column 4 were a factor of three less than those from the first 3 columns, consistent with less permeable clayey material. Accordingly, attenuation was reached around 85 h for pH and ORP (**Figure 12**), with the latter approaching baseline ORP significantly later. Correspondingly, the Cl tracer peak was observed at around 40 h (**Figure 13**). Again, no significant amounts of carbonate were detected in the discharge from Column 4.

Discharge peaks for Ca, Fe, K, Mg, and Si concentrations are illustrated in **Figure 14**, with Ca and Mg peaks consistent with the Cl tracer. Once again, a steady increase in K from the tracer was noted until 60 h contact, after which discharge concentrations expectedly plateaued. As for all columns, Al, Fe and Si concentrations were greater than baseline after breakthrough. Concentration trends from Column 4 may be influenced by the ion-exchange properties of clay components, in particular those involving H^+ and OH^- equilibria. In general, clay minerals have a tendency to liberate H^+ , which would negatively impact on attenuation.

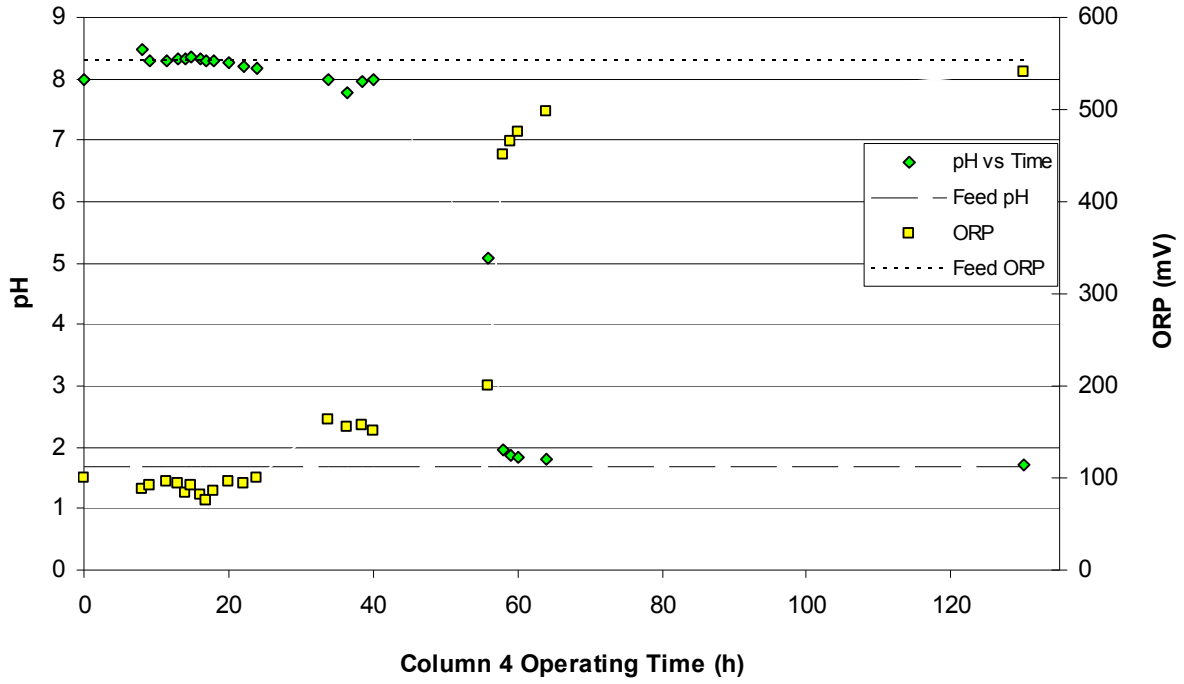


FIGURE 12 Column 4 Attenuation Curves (AKC033)

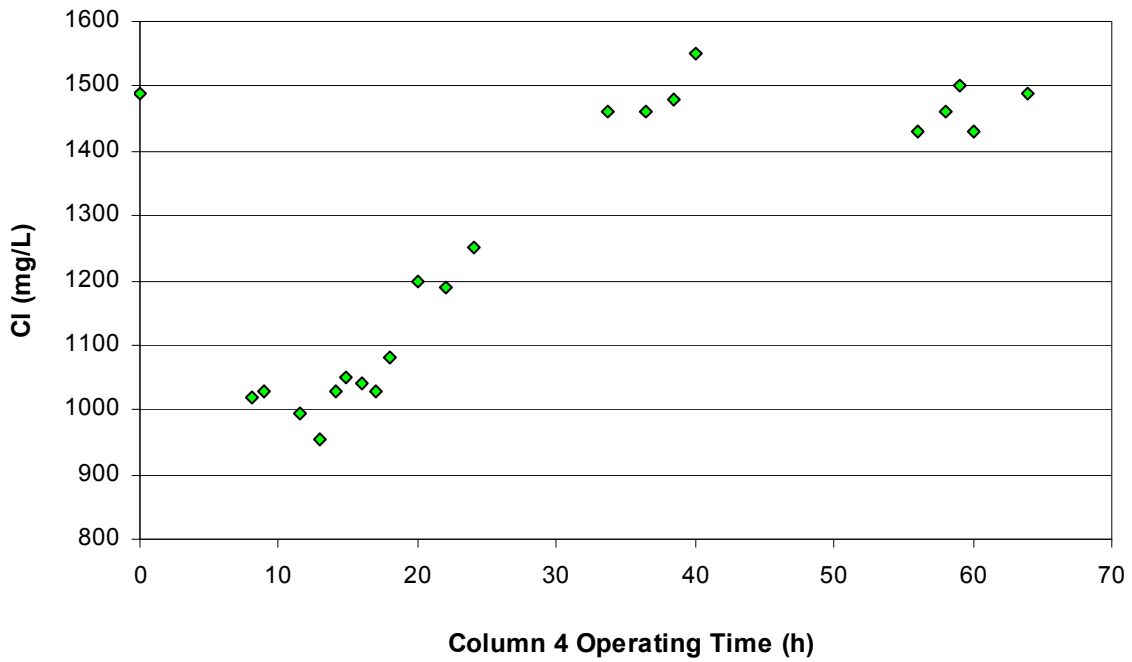


FIGURE 13 Column 4 Cl Tracer (AKC033)

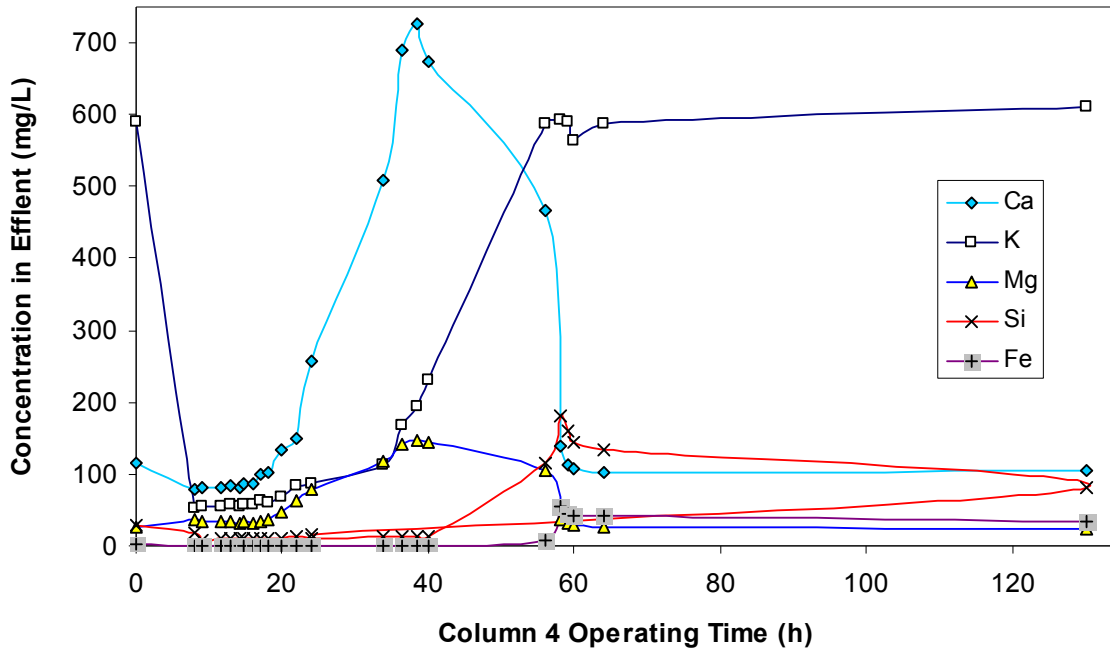


FIGURE 14 Column 4 Gangue Dissolution During Acid Contact (AKC033)

6.2 Gangue Dissolution

A summary of gangue dissolution in the column tests is shown in **Appendix B**. Tabulated values refer to dissolution in cumulative mg from respective columns, taking into account the baseline concentrations present in acidic feed solutions. In cases where discharge concentrations were considered within error of the baseline feed concentration, no dissolution was assumed. Al and Fe dissolution showed characteristic pH dependence, whilst no significant amounts of Mn and P were detected, although head grades for these elements were at trace levels to begin with. No additional Na was evident in the column discharges and no S was leached from Columns 1 and 4 above the baseline. Ca dissolution from Column 1 reached about 150 mg.

Typical of sandy minerals, relative low levels of gangue dissolution were recorded for all columns. Of the gangue elements leached, a potential correlation exists between Fe dissolution and attenuation time (see **Table 5**), with those columns containing greater discharge Fe concentrations breaking through at a faster rate. This suggests that Fe-bearing minerals present in the materials generate acid, thereby reducing the capacity for natural attenuation. The propensity of iron sulphides, such as pyrite, to generate acid during aqueous oxidation is well known. Furthermore, subsequent hydrolysis of Fe^{3+} generates additional acid. Consequently, there is an adverse impact on attenuation under acidic conditions. Conversely, ORP attenuation occurs below baseline feed levels due to oxidant consumption. It is worth noting that the discharges from Columns 2 and 3 contained the greatest amounts of Fe. Moreover, these were the only columns in which S dissolution was recorded. The fact that in both cases S only emerged with increasing ORP under relatively neutral pH is good evidence that acid is generated by the oxidative dissolution of iron sulphide minerals. As expected, these reactions were inhibited to some extent as the effluent became acidic and as ORP decreased.

The data also indicate that Si and Al concentrations slowly increased as column effluents became acidic (see **Appendix B**). In particular, Si dissolution from all columns peaked as effluent solutions became acidic. This is consistent with the well known solubility of silicates/clays in acidic environments.

6.3 Column Residue Washing

At the completion of leach tests, the column residues were emptied into a 5 L beaker and washed with pH 1.7 water (**Appendix A**). The resultant slurry was stirred manually for several minutes, and allowed to soak overnight prior to filtering and further washing with approx. 1.5 L of pH 1.7 water (with the exception of Column 2 which was washed with approx. 0.5 L of pH 1.7 water). Dried residues were weighed, crushed and pulverised, and representative samples taken for XRF analysis (**Tables 3 & 4**). The contents of wash solutions are shown in **Appendix A**.

6.4 Overview of Results

A summary of column data from the four column tests is shown in **Table 5**. Columns 1-3 demonstrated good permeability during wetting and acid contact, typical of sandy material. However, Column 4 appeared more clayey in nature and was significantly less permeable when acid and peroxide was introduced.

TABLE 5
Summary of Column Data

Column	Core	Flow mL/min	Attenuation Limit		Breakthrough of Cl spike (h)
			Time (h)	Volume (L)	
1	AKC028	0.9	40	2.44	
2	AKC029	0.9	30	1.70	14
3	AKC030	0.9	20	1.09	13
4	AKC033	0.3	85	1.6	70

Figure 15 compares the effluent pH and ORP trends as a function of the volume of liquor passed through the column. For pH attenuation capacity decreased in the order below, with all column effluents reaching the feed liquor pH:

$$\text{Col 1} > \text{Col 4} \cong \text{Col 2} \gg \text{Col 3}$$

The ORP attenuation capacity decreased in the order below, with only the effluents from columns 1 and 4 reaching the feed liquor ORP. The “final” ORP from columns 2 and 3 was 450 mV:

$$\text{Col 1} > \text{Col 4} > \text{Col 2} \gg \text{Col 3}$$

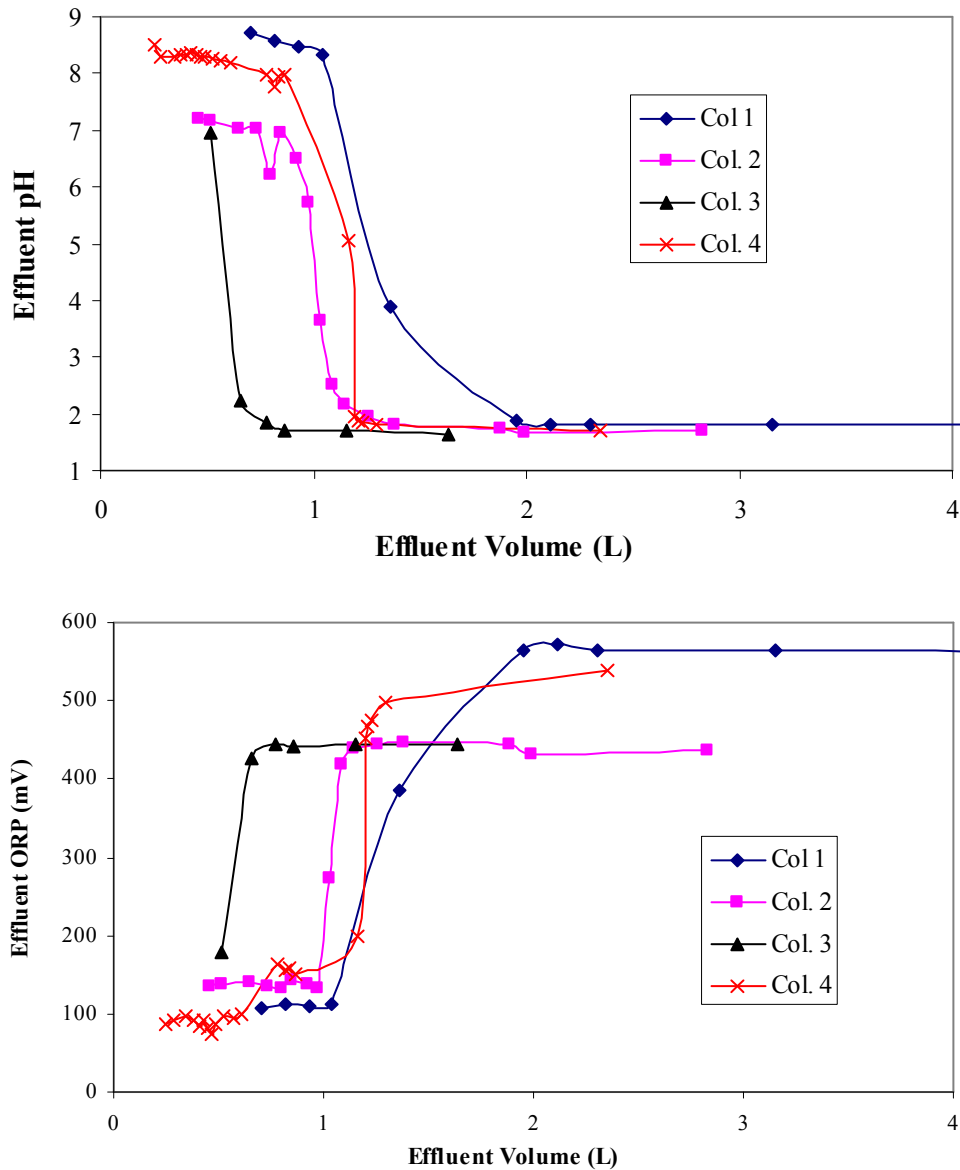


FIGURE 15 Effluent pH and ORP versus Effluent Volume

The uranium concentrations in column effluents are compared in **Figure 16**. The uranium attenuation capacity decreased in the order shown below, which is the same for pH and ORP.

$$\text{Col 1} > \text{Col 4} \gg \text{Col 3}$$

However, the material in column 2 cannot be compared in the same way, as uranium was in fact leached from this core.

The data for Cl for the spiked columns, 2-4, are shown in **Figure 17**. As expected the breakthrough of the feed Cl concentration occurred after approximately the same volume of liquor had passed through all columns, indicating that the composition of the cores and gangue reactions were not impacting on the concentration of the chloride ion.

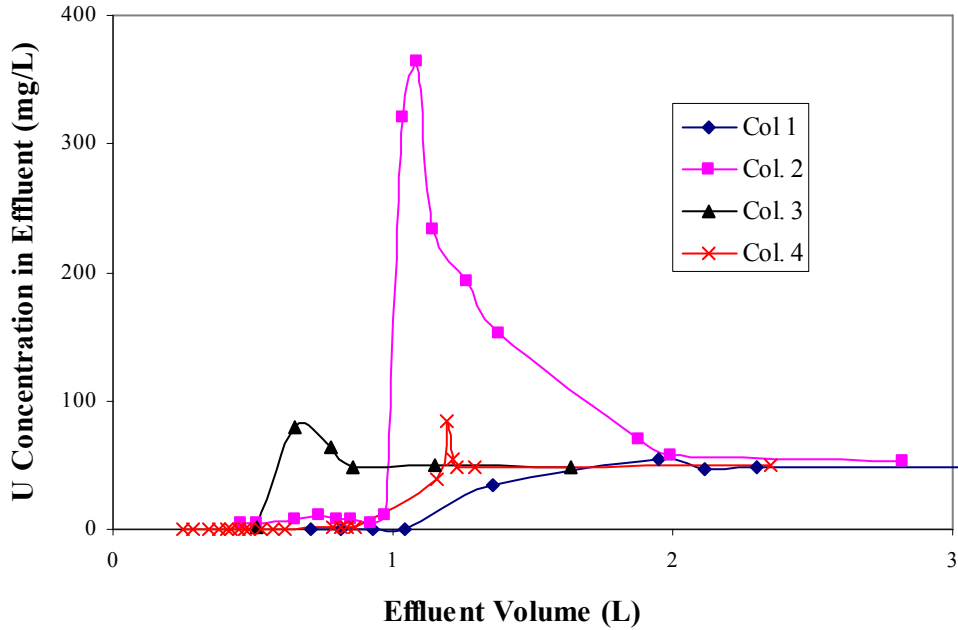


FIGURE 16 Concentration of Uranium in Column Effluents

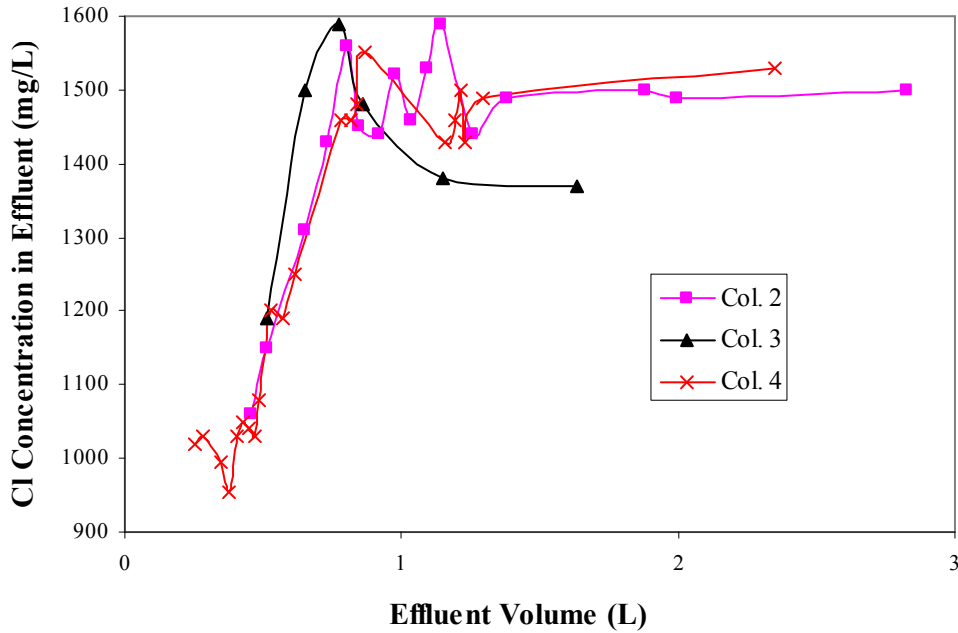


FIGURE 17 Concentration of Chloride in Column Effluents

Table 6 compares the total quantity of gangue elements in the effluent up to the time of break through. Note that 100 mg of element corresponds to dissolution of only 0.006% from the material packed into the column. The data show:

- there were minor differences in the amounts of Mg, Al and Si dissolved from all materials, although there was some correlation between silicate dissolution and attenuation time;

- the Ca dissolved from the material in column 3 was the lowest, indicating that dissolution of calcite was low, and possibly the reason for the inferior attenuation properties of this material;
- the Fe dissolved for column 3, which showed the poorest attenuation properties, was the highest.

There appears to be good evidence that the presence of reactive iron had an adverse effect on the natural attenuation, in that acid generated from oxidative dissolution of sulphide minerals accelerated the breakthrough of the mining solution pH. Rapid dissolution of a calcium mineral appeared to control initial attenuation, while ongoing reaction of silicates/clays appeared to consume acid and prolong attenuation.

TABLE 6
Summary of Gangue Dissolution

Column	Core	Volume (L)	Total (mg) in Effluent up to Breakthrough				
			Mg	Al	Si	Ca	Fe
1	AKC028	2.44	40	16	50	154	30
2	AKC029	1.70	44	14	30	285	100
3	AKC030	1.09	13	10	18	83	164
4	AKC033	1.6	58	25	45	227	10

7. CONCLUSIONS

- The presence of clay minerals significantly decreased permeability and hence the flowrate of mining solution;
- Reactive iron sulphides had the capacity to accelerate breakthrough due to acid generation;
- The concentration of Ca, above baseline, was significantly greater than other elements in the initial column discharges, indicating that possibly calcite was the primary control of attenuation;
- The presence of reactive silicates/clays had the potential to prolong final breakthrough by consuming acid;
- Material from core AKC028 displayed the best attenuation characteristics. This was associated with low levels of dissolved Fe, and possibly greater silicate dissolution;
- Material from core AKC030 displayed the least favourable attenuation characteristics, and corresponded to the lowest dissolution of Ca.

8. ACKNOWLEDGMENTS

The authors wish to thank Kelly Hilliard, Clint Jennison and Mathew Tabrett for assistance with column tests, and Chris Chipeta and Patricia Gadd for analytical support.

APPENDIX A

Horizontal Column Data

NA01 (ID: 84856-84863) LOI Mg Al Si P K Ca Mn Fe U
% Composition (XRF) 2.0 0.007 1.78 43.4 0.016 0.096 0.025 0.003 0.376 0.002

Column Number 1
Ore Packing 1756.3 g AKC028
Column Volume 1188 mL

Column Samples	Time h	Flow mL/min	Head cm	Vol mL	pH	ORP mV-AgCl	Cl mg/L	HCO ₃ M	Al mg/L	Ca mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	P mg/L	S mg/L	Si mg/L	U mg/L
Ground Water 1 (as received)					8.34	80	1050	0.005	<1	107	<1	56.5	26.0	<1	919	<1	140	25.5	<1
Ground Water 2 (as received)					8.34	80	1050	0.005	<1	115	<1	60.5	27.7	<1	985	<1	147	27.0	<1
Ground Water Average								0.005	<1	111	<1	58.5	26.9	<1	952	<1	144	26.3	<1
Ground Water Flush	0		15	793	8.72	136	1380	0.006	<1	49.6	<1	39.2	37.8	<1	998	<1	187	7.45	<1
Column Feed	0				1.69	560	1030	0	2.02	116	1.42	55	24.1	<1	844	<1	835	27.2	54.5
4 mile 28-2	6.5	0.91	103	705	8.73	106	1070	0.005	<1	58.7	<1	54.7	41.0	<1	615	<1	128	11.0	<1
4 mile 28-3	8.5	0.90	108	112	8.58	112	1060	0.006	<1	82	<1	56.7	30.2	<1	646	<1	143	12.2	<1
4 mile 28-4	10.5		114	113	8.48	110	985	0.006	<1	189	<1	70.6	48.8	<1	906	<1	454	13.2	<1
4 mile 28-5	12.5		119	110	8.33	112	1000	0.007	<1	480	1.36	98.7	104	<1	766	<1	673	20.0	<1
4 mile 28-6	18.5	0.90	124	320.5	3.90	385	985	0	5.82	446	3.85	86.5	81.9	3.32	631	<1	685	96.1	34.7
4 mile 28-7	30.5	0.78	130	593	1.87	564	985	0	16.3	102	31.8	44.4	22.6	<1	616	<1	732	58.9	54.0
4 mile 28-8	34	0.98	136	159	1.82	572	965	0	14.1	92.0	27.4	49.2	19.7	<1	610	<1	735	42.0	47.4
4 mile 28-9	37		140	190	1.80	563	985	0	13.8	96.0	22.8	53.7	20.3	<1	625	<1	752	39.7	47.9
4 mile 28-10	54.5	0.85	137	853	1.80	563	1000	0	13.2	96.1	12.5	51.4	20.2	<1	628	1.15	749	35.4	48.3
4 mile 28-11	126.5	0.86	137	3599	1.77	560	1000	0	12.8	99.8	5.81	47.4	20.6	<1	637	<1	767	31.3	50.2
4 mile 28-12	150.5		123	1421	1.73	563	1020	0	11.6	108	4.79	52.3	20.9	<1	692	<1	808	29.6	50.6
Wash				2750			429	0	3.0	29.1	5.33	15.2	13.6	2.98	408	<1	213	10.2	3.43

NA02 (ID: 80910-80921) LOI Mg Al Si P K Ca Mn Fe U
% Composition (XRF) 1.9 0.033 2.26 42.7 0.008 0.123 0.03 0.004 0.385 0.010

Column Number 2
Ore Packing 1682.7 g AKC029
Column Volume 1188 mL

Column Samples	Time hours	Flow mL/min	Head cm	Vol mls	pH	ORP mV-AgCl	Cl mg/l	HCO ₃ M	Al mg/L	Ca mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	P mg/L	S mg/L	Si mg/L	U mg/L
Ground Water 1 (as received)					8.34	80	1050	0.005	<1	107	<1	56.5	26.0	<1	919	<1	140	25.5	<1
Ground Water 2 (as received)					8.34	80	1050	0.005	<1	115	<1	60.5	27.7	<1	985	<1	147	27.0	<1
Ground Water Average								0.005	<1	111	<1	58.5	26.9	<1	952	<1	144	26.3	<1
Ground Water Flush	0		15	1332	7.78	100		0.005	1.67	84.4	4.02	44.3	30.1	<1	876	<1	203	16	<1
Column Feed	0				1.67	552	1490	0	4.76	115	1.73	591	26.6	0	950	<1	851	28.3	52.9
29-1 18/6 0800	8	0.94	200	455.7	7.20	136	1060	0.005	<1	70.1	<1	61.1	29.1	<1	682	<1	161	11.9	4.04
29-2 18/6 0900	9	0.91	200	60.7	7.16	138	1150	0.005	<1	119	<1	64.1	41.5	<1	869	<1	315	10.4	5.06
29-3 18/6 1130	11.5		200	134.5	7.04	140	1310	0.004	<1	380	<1	113	101	<1	977	<1	674	18.1	7.92
29-4 18/6 1300	13		200	82.8	7.01	136	1430	0.004	<1	648	<1	223	142	<1	803	<1	849	36.2	10.4
29-5 18/6 1410	14.17	0.92	200	68.4	6.23	134	1560	0.004	<1	732	<1	388	135	<1	764	<1	853	52.1	7.87
29-6 18/6 1450	14.83		198	46.4	6.94	144	1450	0.004	<1	731	<1	530	115	<1	717	<1	980	75.4	7.47
29-7 18/6 1600	16		196	71	6.51	137	1440	0.003	3.28	750	<1	529	95.9	2.38	711	<1	866	77.5	4.39
29-8 18/6 1700	17		195	55.5	5.73	134	1520	0.002	13.9	683	2.06	605	74.3	5.66	733	<1	924	84.6	11.3
29-9 18/6 1800	18	0.94	197	58	3.66	273	1460	0	28.6	487	71.0	582	55.8	3.91	701	<1	884	86.0	320
29-10 18/6 1900	19		197	55.4	2.52	418	1530	0	38.1	377	124	593	47.5	2.74	714	<1	940	83.3	364
29-11 18/6 2000	20		203	56.2	2.16	438	1590	0	37.5	287	135	579	39.1	2.07	660	<1	949	77.5	234
29-12 18/6 2200	22		210	116.7	1.96	443	1440	0	33.0	213	141	554	28.6	1.38	697	<1	912	65.5	193
29-13 19/6 0000	24		217	119.8	1.82	448	1490	0	28.5	139	135	577	23.5	<1	672	<1	923	53.7	152
29-14 19/6 0945	33.75	0.92	79	499.9	1.73	443	1500	0	21.7	108	108	576	20.9	<1	702	2.8	926	38.8	69.3
29-15 19/6 1700	41		160	113.2	1.68	431	1490	0	21.6	104	97.2	613	22.5	<1	664	1.17	949	43.7	57.8
29-16 20/6 0800	56		195	830	1.69	436	1500	0	16.8	100	81.5	589	21.4	<1	639	<1	921	32.4	53.3
Wash				1530					5.2	40.0	24.6	177	10.4	<1	389	2.0	724	18.2	18.1

APPENDIX A

Horizontal Column Data

NA03 (ID: 83837-83841) LOI Mg Al Si P K Ca Mn Fe U
 4.8 <0.001 0.31 43.4 0.003 0.035 0.02 <0.001 0.339 0.002

Column Number 3
 Ore Packing 1876.5 g AKC030
 Column Volume 1185 mL

Column Samples	Time h	Flow mL/min	Head cm	Vol mL	pH	ORP mV-AgCl	Cl mg/L	HCO ₃ M	Al mg/L	Ca mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	P mg/L	S mg/L	Si mg/L	U mg/L	
Ground Water 1 (as received)					8.34	486	1050	0.005	<1	107	<1	56.5	26.0	<1	919	<1	140	25.5	<1	
Ground Water 2 (as received)					8.34	486	1050	0.005	<1	115	<1	60.5	27.7	<1	985	<1	147	27.0	<1	
Ground Water Average								0.005	<1	111	<1	58.5	26.9	<1	952	<1	144	26.3	<1	
Ground Water Flush	0		15	1696	7.09	115	0.006	15.9	113	6.49	598	21.8	<1	729	<1	806	42	51.4		
Column Feed	0				1.63	566	1490	0	4.76	115	1.73	591	26.6	<1	950	<1	851	28.3	52.9	
30-1 18/6 0810	8	0.98	res	175.8	8.30	91	1020	0.006	<1	99.1	<1	51.7	22.9	<1	731	<1	158	26.6	<1	
30-2 18/6 0910	9				10.5	8.12	96	1040	0.007	<1	101	<1	52.5	22.1	<1	713	<1	156	24.3	<1
30-3 18/6 1130	11.5		res	11.0	8.03	99	1060	0.006	<1	100	<1	52.9	22.6	<1	709	<1	159	26.9	<1	
30-4 18/6 1300	13	0.95	res	9.9	7.91	101	1030	0.007	<1	97.6	<1	50.5	21.9	<1	678	<1	153	28.6	<1	
30-5 18/6 1410	14.17			45	0.0						<1									
30-6 18/6 1450	0		43	4.8	8.36	100	1010	0.007	<1	108	0	54.7	23.1	<1	729	<1	163	31.2	<1	
Column Leak detected																				
30-7	8.5		17	300.5	6.94	180	1190	0.007	1.18	284	2.23	205	63.5	<1	661	<1	527	37.1	1.25	
30-8	11.5	0.92	18	140.3	2.24	426	1500	0	33.2	288	263	566	48.5	1.43	605	<1	1000	73.5	79.1	
30-9	13.5		20	122.9	1.83	443	1590	0	27.0	172	314	583	30.5	<1	672	1.75	1050	57.0	64.2	
30-10	15.17	0.89	21	84.5	1.70	442	1480	0	17.6	117	267	587	22.5	<1	720	2.81	1040	41.0	47.7	
30-11	21.17		33	290.5	1.70	444	1380	0	14.0	118	229	607	22.6	<1	721	2.29	1080	36.2	49.2	
30-12	31.17		41	483.6	1.63	445	1370	0	10.2	111	216	610	21.9	<1	721	1.14	1080	30.3	48.4	
Wash				2720					2.3	23.0	45.1	85.0	4.4	<1	102	<1	548	11.6	7.1	

NA04 (ID: 83944-83948) LOI Mg Al Si P K Ca Mn Fe U
 % Composition (XRF) 1.0 0.032 2.88 41.6 <0.001 0.279 0.08 0.003 0.440 0.003

Column Number 4
 Ore Packing 1888.2 g AKC033
 Column Volume 1259 mL

Column Samples	Time h	Flow mL/min	Head cm	Vol mL	pH	ORP mV-AgCl	Cl mg/L	HCO ₃ M	Al mg/L	Ca mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	P mg/L	S mg/L	Si mg/L	U mg/L
Ground Water 1 (as received)					8.34	80	1050	0.005	<1	107	<1	56.5	26.0	<1	919	<1	140	25.5	<1
Ground Water 2 (as received)					8.34	80	1050	0.005	<1	115	<1	60.5	27.7	<1	985	<1	147	27.0	<1
Ground Water Average								0.005	<1	111	<1	58.5	26.9	<1	952	<1	144	26.3	<1
Ground Water Flush	0	0.92	15	1570	7.98	100	0.006	<1	82.9	<1	34.4	49.6	<1	931	<1	211	11.4	3.82	
Column Feed	0				1.67	554	1490	0	4.76	115	1.73	591	26.6	0	950	<1	851	28.3	52.9
31-1 18/6 0810	8		res	251.2	8.49	88	1020	0.006	<1	79.6	<1	52.3	37.5	<1	702	<1	146	17.5	<1
31-2 18/6 0910	9		res	31.7	8.30	92	1030	0.006	<1	81.5	<1	54.8	35.3	<1	692	<1	144	8.59	<1
31-3 18/6 1130	11.5		res	61.5	8.30	96	994	0.006	<1	81.7	<1	55	34.1	<1	691	<1	145	9.23	<1
31-4 18/6 1300	13		res	34.6	8.32	93	954	0.005	<1	84.2	<1	56.7	33.8	<1	664	<1	149	9.92	<1
31-5 18/6 1410	14.17	0.89	res	28.3	8.33	84	1030	0.005	<1	81.5	<1	54.4	31.8	<1	718	<1	141	9.25	<1
31-6 18/6 1450	14.83		res	17.2	8.35	92	1050	0.008	<1	87.7	<1	58.5	33.4	<1	699	<1	152	10.5	<1
31-7 18/6 1600	16		res	24.8	8.33	82	1040	0.005	<1	85.4	<1	56.7	31.9	<1	692	<1	149	10.4	<1
31-8 18/6 1700	17		res	19.1	8.30	75	1030	0.004	<1	99	<1	62.3	34.1	<1	688	<1	168	11.3	<1
31-9 18/6 1800	18	0.9	res	19.3	8.29	86	1080	0.005	<1	101	<1	60.3	36.0	<1	756	<1	199	10.8	<1
31-10 18/6 2000	20		res	39	8.27	96	1200	0.005	1.09	135	<1	67.8	46.3	<1	850	<1	305	11.6	<1
31-11 18/6 2200	22		res	41.3	8.21	94	1190	0.006	<1	149	<1	83	62.4	<1	724	<1	439	12.2	<1
31-12 19/6 0000	24		res	44.9	8.18	100	1250	0.005	<1	256	<1	86.1	77.5	<1	978	<1	495	10.4	<1
31-13 19/6 0945	33.75		res	170.9	7.99	163	1460	0.003	<1	508	<1	113	117	<1	842	<1	648	12.2	1.11
31-14 19/6 1230	36.5	0.91	res	33.4	7.77	155	1460	0.005	<1	690	<1	169	142	<1	667	<1	755	14.2	1.21
31-15 19/6 1430	38.5		res	22	7.95	158	1480	0.004	<1	727	<1	194	147	<1	687	<1	762	12.9	1.16
31-16 19/6 1600	40		res	28.2	7.98	151	1550	0.004	<1	673	<1	232	144	<1	696	<1	739	13.7	1.12
31-17 20/6 0800	56		res	292.5	5.07	200	1430	0.001	20.5	468	6.67	588	106	6.70	683	<1	770	115	39.1
31-18 20/6 1000	58		res	35.4	1.96	451	1460	0	74.6	139	54.8	593	37.4	2.29	702	1	828	180	84.7
31-19 20/6 1100	59		res	18.8	1.88	466	1500	0	72.7	113	45.8	589	31.1	1.22	690	<1	848	160	54.0
31-20 20/6 1200	60		res	14.9	1.84	476	1430	0	66.7	107	41.2	565	27.9	<1	684	<1	823	144	48.6
31-21 20/6 1600	64		res	65.2	1.82	498	1490	0	65.5	101	41.9	588	26.6	<1	669	<1	867	135	48.7
31-22 23/6 1000	130		res	1056	1.70	540	1530	0	41.7	104	33.8	612	23.7	<1	686	<1	890	82	49.6
Wash				2950					3.4	21.2	3.7	117	4.2	<1	93	<1	607	15.1	10.3

APPENDIX B – Gangue Element Dissolution

Total Element in Effluent (mg)

Cum. Time (h)	Cum. Effluent Vol. (L)	Col 1 – AKC028									
		Al	Ca	Fe	K	Mg	Mn	Na	P	S	Si
6.5	0.71	0	0	0	0	12	0	0	0	0	0
8.5	0.82	0	0	0	0	13	0	0	0	0	0
10.5	0.93	0	8	0	2	15	0	0	0	0	0
12.5	1.04	0	48	0	7	24	0	0	0	0	0
18.5	1.36	1	154	1	17	43	0	0	0	0	22
30.5	1.95	10	154	19	17	42	0	0	0	0	41
34	2.11	12	154	23	17	41	0	0	0	0	43
37	2.30	14	154	27	17	40	0	0	0	0	46
54.5	3.16	23	154	36	17	40	0	0	0	0	53
120.5	6.75	62	154	52	17	40	0	0	0	0	67
150.5	8.2	76	154	57	17	40	0	0	0	0	71
		Col 2 – AKC029									
8	7.2	0	0	0	0	1	0	0	0	0	0
9	14.4	0	0	0	0	2	0	0	0	0	0
11.5	21.4	0	36	0	0	12	0	0	0	0	0
13	28.4	0	80	0	0	22	0	0	0	0	1
14.2	34.6	0	122	0	0	29	0	0	0	0	2
14.8	41.6	0	151	0	0	33	0	0	0	6	4
16	48.1	0	196	0	0	38	0	0	0	7	8
17	53.8	1	227	0	0	41	1	0	0	11	11
18	57.5	2	249	4	0	42	2	0	0	13	14
19	60	4	264	11	0	44	2	0	0	18	17
20	62.2	6	273	18	0	44	2	0	0	24	20
22	64.1	9	285	35	0	44	2	0	0	31	25
24	65.9	12	287	51	0	44	0	0	0	39	28
33.8	67.7	20	284	104	0	41	0	0	0	77	33
41	69.4	22	283	114	0	41	0	0	0	88	35
56	71	32	283	181	0	36	0	0	0	146	38

APPENDIX B – cont

		Col 3 – AKC030									
Cum. Time (h)	Cum. Effluent Vol. (L)	Al	Ca	Fe	K	Mg	Mn	Na	P	S	Si
8.5	0.51	0	51	0	0	11	0	0	0	0	0
11	0.65	4	75	37	0	14	0	0	0	21	3
13.5	0.78	7	82	75	0	15	0	0	0	45	7
15.2	0.86	8	82	98	0	14	0	0	0	61	11
21.2	1.15	10	83	164	5	13	0	0	0	128	18
31.2	1.63	13	81	267	14	11	0	0	0	239	28
		Col 4 – AKC033									
8	0.25	0	0	0	0	3	0	0	0	0	0
9	0.28	0	0	0	0	3	0	0	0	0	0
11.5	0.34	0	0	0	0	3	0	0	0	0	0
13	0.38	0	0	0	0	4	0	0	0	0	0
14.2	0.41	0	0	0	0	4	0	0	0	0	0
14.8	0.42	0	0	0	0	4	0	0	0	0	0
16	0.45	0	0	0	0	4	0	0	0	0	0
17	0.47	0	0	0	0	4	0	0	0	0	0
18	0.49	0	0	0	0	4	0	0	0	0	0
20	0.53	0	1	0	0	5	0	0	0	0	0
22	0.57	0	2	0	0	7	0	0	0	0	0
24	0.61	0	9	0	0	9	0	0	0	0	0
33.8	0.78	0	76	0	0	24	0	0	0	0	0
36.5	0.82	0	95	0	0	28	0	0	0	0	0
38.5	0.84	0	108	0	0	31	0	0	0	0	0
40	0.87	0	124	0	0	34	0	0	0	0	0
56	1.16	5	227	1	0	57	2	0	0	0	25
58	1.20	7	228	3	0	58	2	0	0	0	31
59	1.21	8	228	4	0	58	0	0	0	0	33
60	1.23	9	228	5	0	58	0	0	0	0	35
64	1.29	13	227	7	0	58	0	0	0	0	42
130	2.35	52	227	41	22	55	0	0	0	0	99