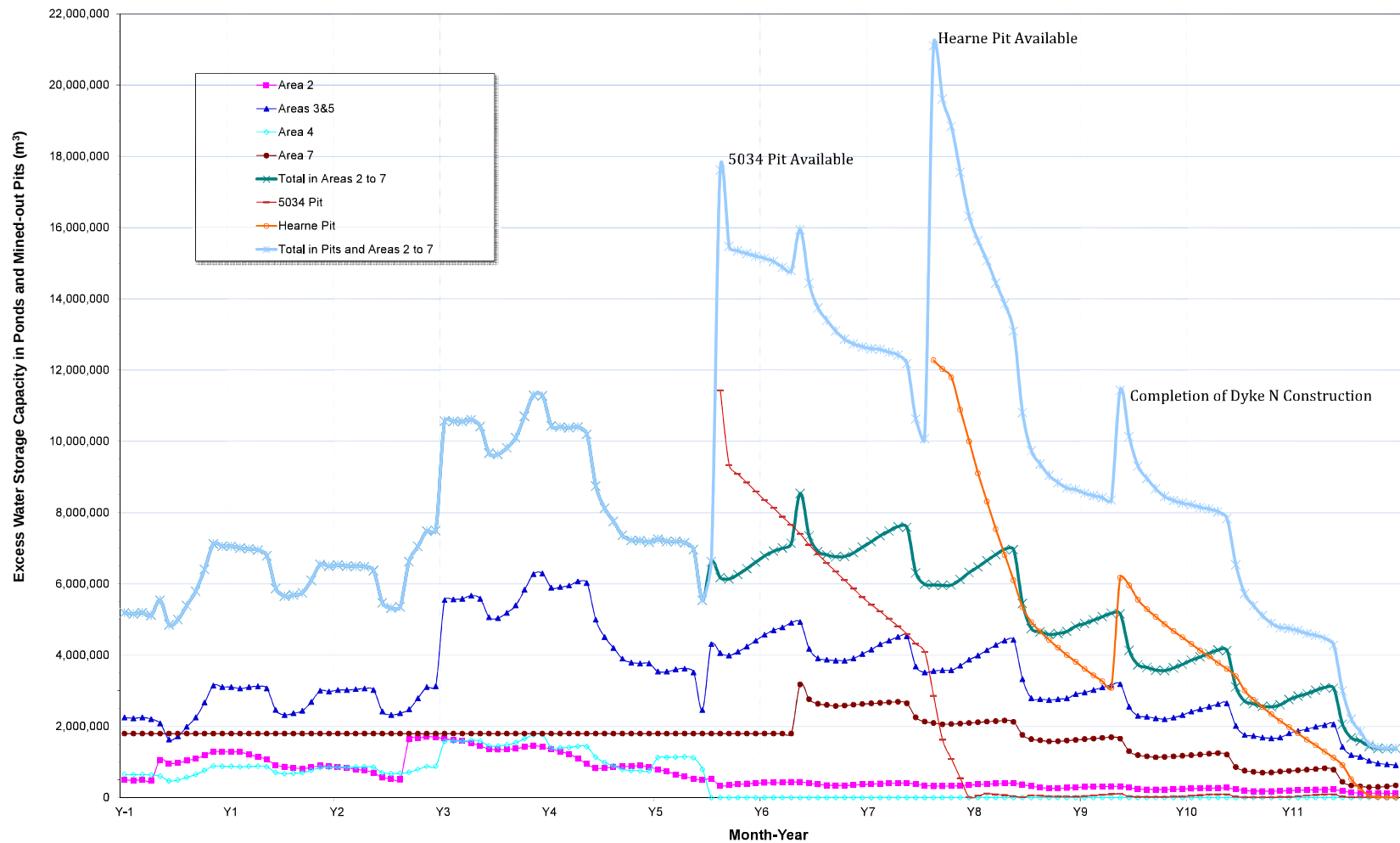




ATTACHMENT 8.II.2

**UPDATED SUMMARY OF PRELIMINARY WATER AND WASTE MANAGEMENT
CLOSURE PLAN FOR FEASIBILITY STUDY OF GAHCHO KUÉ PROJECT**

TECHNICAL MEMO

ISSUED FOR USE

TO:	Andrew Williams, De Beers Veronica Chisholm, De Beers	DATE:	April 17, 2012
C:	Wayne Corso, JDS, Dan Johnson, JDS John Faithful, Golder		
FROM:	Bill Horne, EBA Guangwen (Gordon) Zhang, EBA Hongwei Xia, EBA	EBA FILE:	E14101143
SUBJECT:	2012 Gahcho Kué EIS Supplement – Updated Summary of Water and Waste Management Closure Plan for Gahcho Kué Diamond Project, NWT, Canada		

1.0 INTRODUCTION

EBA Engineering Consultants Ltd. operating as EBA, A Tetra Tech Company (EBA) was retained by JDS Energy and Mining Inc. (JDS) to develop a water and waste management plan as a part of the project feasibility study for the Gahcho Kué Diamond Project. EBA completed the original water and waste management plan and submitted the report to JDS in September 2010. An assessment on the Gahcho Kué fine PK disposal alternatives was carried out through a Multiple Accounts Analysis (MAA) approach by Gahcho Kué project work teams in July 2011. A fine PK disposal alternative was selected based on the result of MAA as described in 2012 Gahcho Kué Project Alternative Report (De Beers 2012 in preparation).

The water and waste management plan has been updated accordingly to facilitate the selected fine PK disposal alternative. The water and waste management plan during mine operation for the Gahcho Kué Diamond Project has been summarized in EBA (2012). Figure 1 presents the overall site layout and the projected site conditions at the end of mine operation.

This memo summarizes the updated water and waste management plan during mine closure. This memo should supersede EBA's previous memo dated May 14, 2010, entitled "Updated Summary of Preliminary Water and Waste Management Closure Plan for Feasibility Study of Gahcho Kué Project, Memo 007 (Updated)" (EBA 2010).

2.0 WATER MANAGEMENT DURING MINE CLOSURE

One of the objectives of the water management plan during mine closure is to restore the natural flow regime and pre-disturbance conditions of Kennady Lake to the extent practical and allow the restored Kennady Lake to return to productive fish habitat as quickly as possible. The key water-related activities during mine closure include refilling the mined-out pits, reconnecting the surrounding watersheds, and restoring the drained basins of Kennady Lake back to its natural elevation of 420.7 m, and reconnecting the restored portions of Kennady Lake to the downstream (Area 8) after achieving appropriate water quality.

2.1 Kennady Lake Refilling Inputs

At the end of the mine operations, the mined-out pits together with the drained portions of Kennady Lake will be refilled using active and/or passive inflows. The potential refilling strategies include using natural runoff from its catchment area, pumping supplemental freshwater drawn from Lake N11 and breaching the diversion dykes to reconnect the surrounding watersheds to Kennady Lake. Table 1 presents the estimated average annual volume of water from each of the water sources for a mean (1 in 2) precipitation year. The annual net runoff values will vary for a wetter or drier precipitation year during mine closure. Even under a mean precipitation year, the annual net runoff values from several areas will not be constant and tend to decrease with time due to gradual increases in the open water surface areas while the water elevations in the areas rise with time. The volume of water to be pumped from Lake N11 is discussed in Section 2.3 and is not included in Table 1.

Table 1: Estimated Annual Volume of Water for Kennady Lake Refilling during Mine Closure

Water Source	Estimated Average Annual Volume of Natural Water Flowing into Areas 1 to 7 during Mine Closure (Mm ³)	Comments
Net runoff from the Watershed A	0.32	Removal of Berm 3 (the northernmost berm) of three Area 1 Perimeter Berms; the lowest natural ground elevation at Berm 3 is approximately 422.5 m
Net runoff from Area 2	0.31	Dykes A1 and D will remain in place; no open water in Area 2 after mine closure
Net runoff from Areas 3&5	0.52	
Net runoff from Areas 4 and 6, not including west of Dyke N	0.55 to 0.96	Dyke B will be lowered; During initial years of refilling, the open water surface area in Areas 4 and 6 will be relatively small (limited to the water surface area in the mined-out Tuzo pit) until the mined-out Tuzo pit is filled up.
Net runoff from the area west of Dyke N within Area 6	0.23	Dyke N will be lowered
Net runoff from Areas 7	0.62	Dyke K will be lowered; Dyke A remains in place during interim closure
Net runoff from the Watershed B after breach of Dyke E	0.22	Dyke E is breached
Net runoff from the Watershed D after breach of Dyke F	0.67	Dyke F is breached
Net runoff from the Watershed E after breach of Dyke G	0.21	Dyke G is breached
Underground inflows to mined-out Pits	0.11	Assumed 300 m ³ /day of underground inflow from mined-out pit bottoms
Total	4.06	All above

2.2 Stage Storage Curves

Table 2 summarizes the stage storage data for various areas. This data is used to estimate the volume of water required to fill the mined-out pits and restore the drained basins, as described in Section 2.3.

Table 2: Stage Storage Curves for Water Management during Mine Closure

Elevation (m)	Stage Storage Curves at End of Mine Operation (Year 11) (Mm ³)						
	a)	b)	c)	d)	e) = a) - b) - c) - d)	f)	g) = e) + f)
250	14.50	4.92		1.50	8.08		8.08
300	28.31	12.18		1.50	14.63		14.63
350	48.79	22.85		1.50	24.44	2.45	26.89
410	84.34	39.39		1.50	43.45	6.26	49.71
414	87.70	40.65	0.13	1.50	45.42	6.58	52.00
418	94.35	41.91	1.19	1.50	49.75	7.11	56.86
420	98.17	41.91	2.07	1.50	52.69	7.31	60.00
422	102.61	41.91	3.14	1.50	56.06	7.56	63.62

Note:

a) Area 4 and east portion of Area 6 enclosed by Dykes B, M, I, N and K and Area 1 Perimeter Berms; no mine rock and fine PK in mined-out 5034 Pit; no mine rock in south of Area 6; and no coarse PK pile in Area 4.

b) Mine rock placed in the mined-out 5034 Pit.

c) Mine rock placed in the south mine rock pile in Area 6.

d) Fine PK placed in the mined-out 5034 Pit.

e) The enclosed area in a) minus volumes occupied by mine rock and fine PK in the mined-out 5034 Pit and south mine rock pile. It was assumed that negligible volume of coarse PK placed below the elevation of 422 m in Area 4.

f) Voids in all the mine rock placed above water; 23% of porosity of in-place mine rock was assumed. It was assumed that water has filled in the voids in the mine rock placed below the elevation of 300 m in the mined-out 5034 Pit by the end of the mine operation.

g) Volume of water required to fill in the enclosed area for mine closure.

2.3 Pit Refilling and Restoring Drained Lake Basins

Pit refilling and restoring drained lake basins could be achieved by natural surface runoff only and/or pumping water from Lake N11 to Kennady Lake to expedite the refilling time. Table 3 summarizes the water volumes and estimated refilling times required. It is estimated that the total volume of water required to raise the water elevation in the entire area, including Areas 2 to 7 and the mined-out pits, to the original Kennady lake elevation of 420.7 m is 57.9 Mm³.

Table 3: Estimated Water Volumes and Filling Times Required

Item	Value	Comments
Estimated volume of water required to fill in the basins in Area 4 and east portion of Area 6 to the original lake elevation of 420.7 m after end of mine operation	61.3 (Mm ³)	Volume including the voids in the mine rock between elevations of 300 m and 418 m in the mined-out 5034 Pit and in the mine rock below 420.7 m in the West and South mine rock piles
Net volume of water stored above the original lake elevation of 420.7 m in Areas 2 to 7 by end of mine operation	3.4 (Mm ³)	Lower water elevations in Areas 2 and 3&5 to 420.7 m or lower during mine closure
Additional volume of water required to raise the water elevations in Areas 2 to 7 to the original lake elevation of 420.7 m	57.9 (Mm ³)	Volume needed for filling in the pits and restoring the drained lake basins
Estimated time required for raising the water elevations in Areas 2 to 7 to the original lake elevation of 420.7 m by natural runoff but without pumping water from external water sources	15 years	Assuming that natural runoff water from all water sources in Table 1 is used.
Assumed average yearly volume of water pumped from Lake N11 to Area 3 for refilling during mine closure	3.7 (Mm ³ /year)	Value from Golder EIS (2010)
Estimated time required for raising the water elevations in Areas 2 to 7 to the original lake elevation of 420.7 m by both natural runoff water and annually pumping water from Lake N11 to Area 3 during mine closure	8 years	Assuming that natural runoff water from all water sources in Table 1 is used; annual pumping of water of 3.7 Mm ³ /year from Lake N11 to Area 3

To expedite the refilling time, water pumping from Lake N11 to Areas 3&5 may be required during the mine closure. The average annual volume of water that can be pumped from Lake N11 has been estimated to be 3.7 Mm³ per year (Golder EIS 2010). The following information is quoted from the EIS report:

To expedite the refilling of Kennady Lake, water will be pumped from Lake N11. Pumping will occur during the early, high water season. It will typically begin in June and end in July, although pumping may extend into August in wet years. Flow forecasts, based on snow pack conditions and seasonal precipitation trends, will be used to estimate annual water yield from Lake N11. Planned pumping rates will be set accordingly to ensure that the total annual outflow from Lake N11 does not drop below the 1 in 5-year dry condition. During the pumping season, pumping rates will be adjusted, as required, to meet this objective. In years where the Lake N11 outflow is forecast to naturally fall below the 5-year dry condition, no pumping will occur.

The total annual average diversion from Lake N11 will be in the order of 3.7 million cubic metres per year, which represents no more than 20% of the normal annual flow to Lake N11. The 20% cut-off will be used to ensure that sufficient water remains in, and flows out of, Lake N11 to support downstream aquatic systems in the N watershed.

The value of 3.7 Mm³/y represents the difference between the flow reporting to Lake N11 under median/normal flow conditions and that which occurs under 1 in 5-year dry conditions. Based on a

six-week pumping period, the average pumping rate will be in the order of 88,100 m³/d. It is anticipated that more water will be withdrawn during wet years, up to a maximum of 175,200 m³/d. In drier years, less water will be withdrawn. At no time will the diversion result in outflow from Lake N11 dropping below that which occurs under 1 in 5-year dry conditions.

2.4 Current Adopted Water Management Plan during Mine Closure

The following closure water management plan is adopted in consideration of various factors such as refilling time, water quality in Area 3&5, and closure cost. The plan requires annually pumping water from Lake N11 to Area 3 to reduce the overall time for the closure process. The required filling time is estimated to be approximately 8 years of both pumping from Lake N11 and natural runoff accumulation. Figure 2 shows the facilities and components for the interim mine closure plan. Figure 3 presents the site plan after final closure and reclamation.

The key steps for the closure water management plan include as follows:

- Lower the water elevations in all water storage areas within Areas 2 to 7 to 417.0 m by siphoning the water from Area 3&5, west of Area 6 and Area 7 to the mined-out Tuzo Pit after the end of mine life.
- Breach sections of Dykes B, N, and K to an elevation of 417.0 m, flatten the downstream slope, and place 1 m thick erosion protection material over the excavated dyke crests and flattened downstream slopes.
- Place erosion protection materials over the downstream natural channels (or engineered channel if, and as, required) to limit erosion along the flow paths to the mined-out Tuzo Pit.
- Allow the extra runoff water from Area 3&5, west of Area 6, and Area 7 to flow over the breached sections of Dykes B, N, and K.
- Pump water from Lake N11 to Area 3 at an average annual volume of 3.7 Mm³/y.
- Remove Berm 3 (the northernmost berm) of the three Area 1 Perimeter Berms to create a new outlet channel from the watershed A to Area 3.
- Breach Dyke E to allow the runoff from the watershed B to flow into Area 3.
- Breach Dyke F to allow the runoff from the watershed D to flow into Area 5.
- Breach Dyke G to re-establish the watershed E recharge to the west of Area 6 in Kennady Lake.
- Monitor water quality in Kennady Lake areas, and adjust the closure water management plan as required.
- Raise the water elevation in the entire basin to the original lake elevation of 420.7 m.
- Breach and/or partially remove Dyke A to connect the reclaimed basins of Kennady Lake with Area 8 once the water quality in the basins meets appropriate discharge criteria.

This plan has the following major advantages:

- Reduce the overall time to fill in the mined-out pits and drained basins.
- Improve the water quality in Areas 3&5 and west of Area 6 by siphoning/pumping the potential saline water down to the bottom of the mined-out Tuzo Pit.
- No need to excavate spillway channels to discharge the extra water from Areas 3&5 and west of Area 6.
- Fewer requirements for maintenance of Dykes B, K, and N.

Table 4 summarizes the estimated total volume of the water pumped from each of the areas to lower the water elevation down to 417.0 m after the end of mine life.

Table 4: Estimated Volumes of Water to Lower Water Elevations in Several Areas to 417.0 m after End of Mine Life

Area	Volume of Water to be Pumped (Mm ³)
Areas 3 and 5 (including seepage from Area 2)	10.80
West of Dyke N in Area 6	1.77
Area 7	2.36
Total	14.93

3.0 PK AND MINE ROCK AREAS

3.1 Fine PK Storage Area

The fine PK storage area in Area 2 will be progressively reclaimed during the mine operation since fine PK will not be deposited in the area after August Year 5 of mine operations. After that time, the fine PK will be placed into the bottom of the mined-out 5034 and Hearne Pits.

The reclamation of the Fine PK Facility will include the progressive cover of non-acid generating (NAG) mine rock on stable areas of the facility; coarse PK may also be used as a transitional cover between the fine PK and mine rock. This will limit surface erosion from runoff and eliminate potential dust production over dry surfaces during the mine operation and closure. The mine rock layer thickness will depend on topography, local conditions, and equipment used for mine rock placement. The cover thickness will be 2 m. The final geometry of the cover layer will be graded so that any surface runoff will allow to flow towards Area 3. A section of Dyke L crest close the northwest abutment will be lowered down to an elevation of 421.0 m to create a drainage path across the dyke. Permafrost development in the settled fine PK in Area 2 is expected to occur over time. Thermistors are recommended to be installed in the fine PK storage area to monitor the formation of permafrost in the solids.

The settled fine PK in the mined-out 5034 pit will be covered with the mine rock placed later during mine operation. The maximum thickness of settled fine PK in the mined out 5034 pit is approximately 64 m. The

top elevation of the mine rock backfilled in the mined-out 5034 pit will be limited to 418.0 m to create fish habitat when the original lake elevation of 420.7 m is restored after final mine closure.

The settled fine PK in the mined-out Hearne Pit will have a final top elevation of approximately 320 m, which is well below the final lake elevation of 420.7 m after mine closure. The settled fine PK in the mined-out Hearne pit will be submerged under the water and no further closure action is required during mine closure.

3.2 Coarse PK Pile

The coarse PK pile will be progressively reclaimed during the mine life. The coarse PK pile will be shaped and covered with a layer of mine rock of a minimum of 1 m to limit surface erosion. Runoff from the coarse PK pile will naturally flow into Area 4.

3.3 Mine Rock Piles

Approximately 226 Mt of mine rock will be produced over the mine life. Of this total, approximately 143 Mt of mine rock will be placed in two designated mine rock piles (South Mine Rock Pile and West Mine Rock Pile) during mine operations. Closure of the mine rock piles will involve contouring and re-grading to a 2.4 H: 1V overall side slopes or flatter, and will occur progressively (starting as early as Year 5 for the South Mine Rock Pile and Year 7 for the West Mine Rock Pile). The piles will not be covered or vegetated, consistent with the approaches in place at other northern diamond mines, such as EKATI, Diavik, and Jericho diamond mines. Thermistors are recommended to be installed within the mine rock pile to monitor the progression of permafrost development.

The mine rock pile placed in the mined-out 5034 Pit will be submerged in water with a minimum water cover of 2.7 m when the water level in the drained basins is raised to the original lake elevation of 420.7 m.

4.0 DYKES AND BERMS

After the end of mine life, the water elevations in all water storage areas within Areas 2 to 7 will be lowered to 417.0 m by siphoning the water from Area 3&5, west of Area 6, and Area 7 to the mined-out Tuzo Pit. After the water elevations are lowered, a portion of the dyke crest for each of Dykes B, N, and K will be excavated down to an elevation of 417.0 m to create a temporary spillway for extra runoff water flowing from the upstream side to the downstream side during early years of mine closure when the water elevations in the drained basins are below 417.0 m. The downstream slopes around the excavated sections will be flattened to a tentative slope of 10(H):1(V). A layer of 1 m thick erosion protection material will be placed over both the excavated dyke crests and flattened downstream slopes. The excavated section width will depend on hydraulic requirements and other considerations such as creating fish habitats. Tentative minimum widths of 50 m, 100 m, and 150 m were selected at this stage for Dykes N, K, and B, respectively. The remaining portions of Dykes B, N, and K will be lowered to a top crest elevation of 418.0 m to limit net fish habitat losses.

Dykes E, F, and G will be breached during mine closure to allow the runoff from the watersheds B, D, and E to recharge into Kennady Lake, respectively. Berm 3 (the northernmost berm) of the three Area 1

Perimeter Berms will be removed during mine closure to allow the excess runoff from the watershed A to flow into Area 3.

A section (100 m width) of Dyke L crest close the northwest abutment will be lowered down to an elevation of 421.0 m to create a drainage path across the dyke. The final PK surface elevations close to the lowered section will be approximately 417.0 m, which is about 4 m below the lowered dyke crest.

Dyke J will be lowered to a top crest elevation of 418.0 m to limit net fish habitat losses. Dykes H, I, and M are not required once the water elevation in Areas 3&5 are lowered to 417.0 m after the end of mine life. The berms for water collection ponds will also not be required after the end of mine life and will be completely submerged below water under the water elevation of 420.7 m in the restored basins. These dykes/berms can remain in place after mine closure.

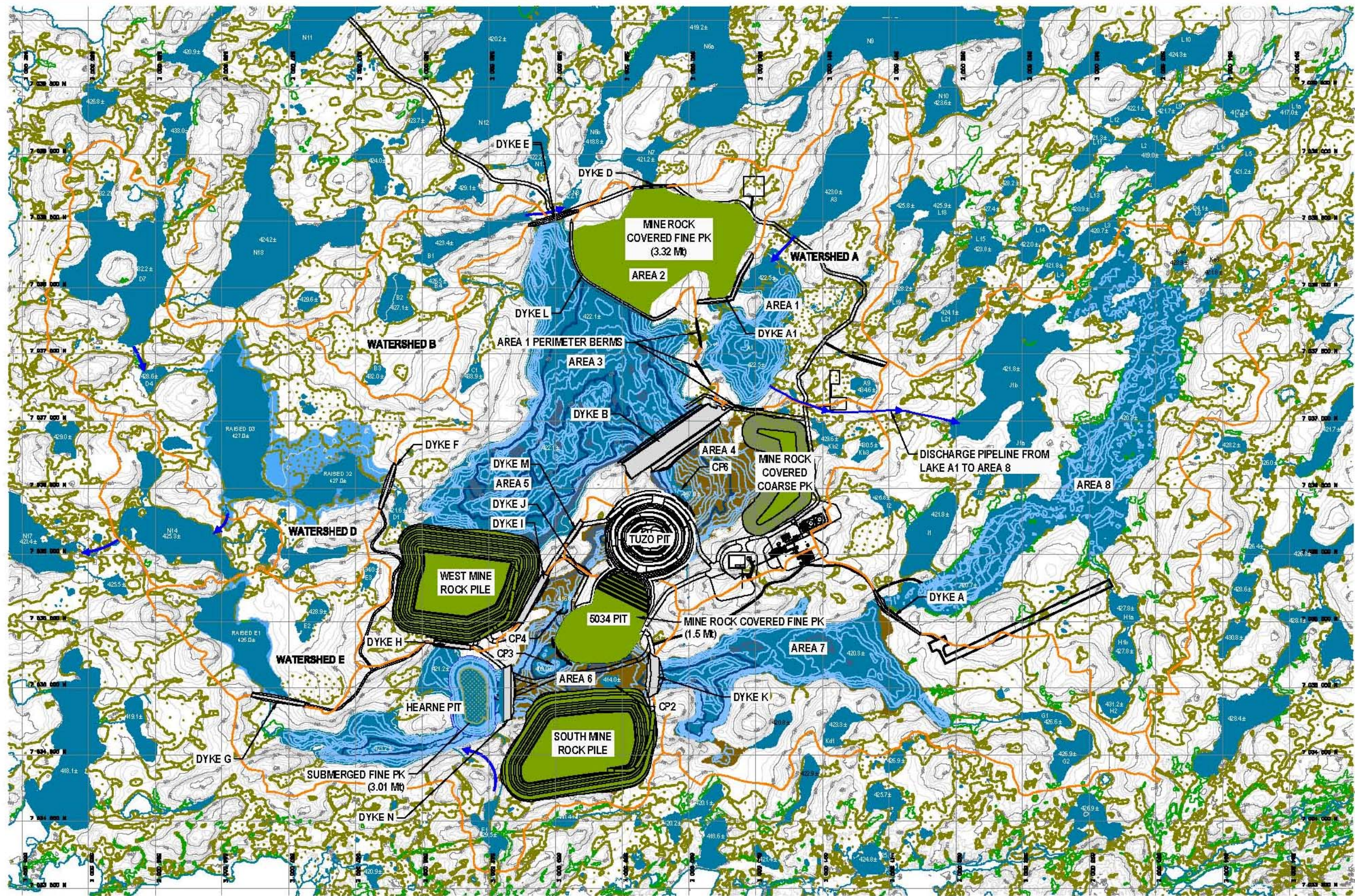
Dykes A1 and D will become permanent structures after mine closure. The dyke performance during the mine operation and early closure stages will be evaluated to address any potential issues and to minimize the requirements of long-term maintenance and monitoring. The requirement of long-term maintenance and monitoring of these dykes will be assessed during mine closure. Potential measures to be considered during the final design of these dykes for closure may include placing extra fills (fill and mine rock) on the downstream sides of each dykes and flattening the slopes to shape each dyke into a very wide landform with flat slopes. These measures will improve the long-term dyke performance and lower the risk of consequence of dyke failure.

Dyke A will be breached to connect the reclaimed basins of Kennady Lake to Area 8 during final mine closure once the water quality in the basins meets appropriate discharge criteria.

REFERENCES

- EBA, 2010. Updated Summary of Preliminary Water and Waste Management Closure Plan for Feasibility Study of Gahcho Kué Project, Memo 007 (Updated). A memo submitted to JDS by EBA, May 14, 2010.
- EBA, 2012. 2012 Gahcho Kué EIS Supplement – Updated Summary of Water Management Plan during Mine Operation for Gahcho Kué Diamond Project, NWT, Canada. A memo submitted to De Beers and JDS by EBA, A Tetra Tech Company, April 12, 2012.
- De Beers, 2012. Project Alternatives Relevant to the Harmful Alternation, Disruption or Destruction (HADD) of Fish Habitat (Draft). De Beers, in preparation.
- De Beers (De Beers Canada Inc.). 2010. Environmental Impact Statement for the Gahcho Kué Project. Volumes 1, 2, 3a, 3b, 4, 5, 6a, 6b, 7 and Annexes A through N. Submitted to Mackenzie Valley Environmental Impact Review Board. December 2010

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LEGEND:

430 EXISTING GROUND CONTOURS
5 m INDEX - 1 m INTERMEDIATE

445 BATHYMETRY CONTOURS
5 m INDEX - 1 m INTERMEDIATE

MARSH AREA

SCRUB

CATCHMENT BOUNDARY

DRAINAGE FLOW DIRECTION

LAKE/POND

DRAINED AREA

MINE ROCK

0 1 000 m
Scale: 1: 30 000

NOTES
• ZONE 12, UTM NAD83 PROJECTION CENTRED ON 111°

STATUS
ISSUED FOR USE

CLIENT



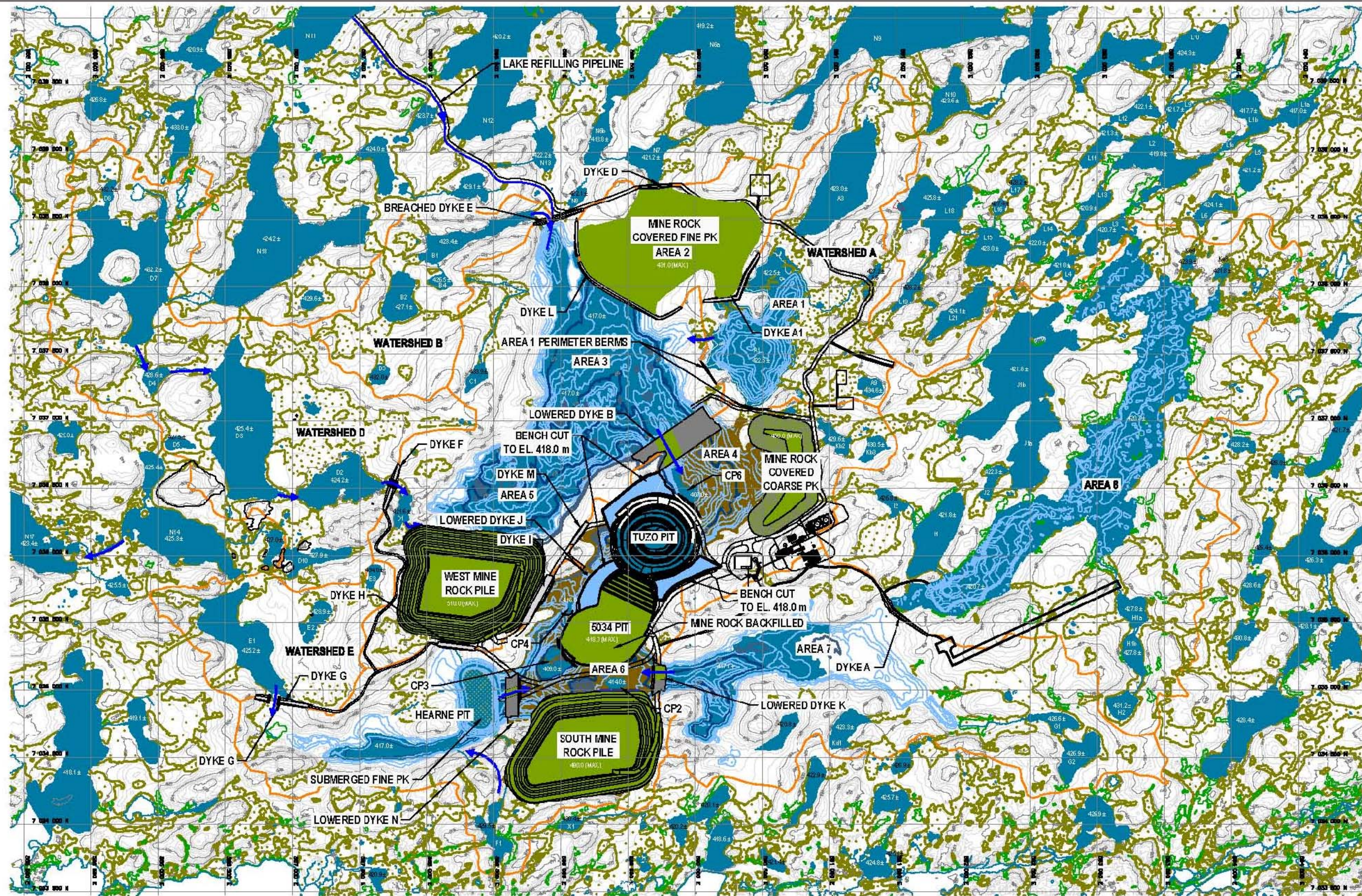
2012 GAHCHO KUÉ EIS SUPPLEMENT
NWT, CANADA

OVERALL SITE LAYOUT AND THE PROJECTED
SITE CONDITIONS AT THE END OF MINE
OPERATION

PROJECT NO. E 14101143	DWNN DBD/EL	CKD GZ	REV 0
OFFICE EDM	DATE March 29, 2012		

Figure 1

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LEGEND:

430 EXISTING GROUND CONTOURS
5 m INDEX - 1 m INTERMEDIATE

445 BATHYMETRY CONTOURS
5 m INDEX - 1 m INTERMEDIATE

0 1 000 m
Scale: 1:30 000

MARSH AREA
SCRUB
CATCHMENT BOUNDARY
DRAINAGE FLOW DIRECTION

LAKE/POND
DRAINED AREA
MINE ROCK
BENCH CUT

NOTES

• ZONE 12, UTM NAD83 PROJECTION CENTERED ON 111°

STATUS
ISSUED FOR USE

CLIENT



2012 GAHCHO KUÉ EIS SUPPLEMENT
NWT, CANADA

INTERIM RECLAMATION

PROJECT NO. E 14101143	DOIN DBD/EL	CKD GZ	REV 0
OFFICE EDM	DATE March 16, 2012		

Figure 2

APPENDIX 8.III

METAL LEACHING AND ACID ROCK DRAINAGE REPORT

Note: This appendix of the 2012 Environmental Impact Statement Supplemental Information Submission includes text highlighted in Yellow to identify revisions to the previous version of the appendix found in the 2011 EIS Update document.

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8.III METAL LEACHING AND ACID ROCK DRAINAGE

8.III.1 INTRODUCTION

8.III.1.1 Background

When minerals that naturally occur in ore and the enclosing mine rock are disturbed by mining processes, exposure to the atmosphere (i.e., oxygen and water) can enhance natural rates of chemical weathering, which could result in the release of acidity, sulphate, and trace metals to water that comes in contact with the disturbed materials.

The metal leaching (ML) and acid rock drainage (ARD) potential of kimberlite, processed kimberlite (PK), and mine rock from the Gahcho Kué Project (Project) is based on the conclusions of the ongoing geochemical characterization program. The geochemical characterization program was initiated in 1996 in support of ongoing environmental baseline studies at the Project. The work has been completed in several stages, including Canamara (1996), AMEC (unpublished), and Golder in 2002, 2010, and 2011. This appendix to the 2012 Environmental Impact Statement (EIS) Supplement provides an update to the 2010 EIS (De Beers 2010, Section 8), including the results from supplemental geochemical characterization initiated in 2010 and 2011. The principal conclusions provided relate to the Project Description in this 2012 EIS Supplement (De Beers 2012, Section 3).

The results of geochemical characterization of kimberlite, PK, and mine rock were used to develop representative water quality inputs for water expected to come into contact with various site facilities. A summary of the water quality inputs that were assumed for use in the site water quality predictions is provided herein.

8.III.1.2 Objectives

The objective of this appendix to the 2012 EIS Supplement is to present and evaluate the results of the geochemical characterization programs in the context of potential environmental impacts and mitigation alternatives for the Project. Specific objectives of the metal leaching and acid/alkaline rock drainage assessment program for the Project are as follows:

- development of a geochemical dataset to address the geochemical implications of kimberlite, PK, and mine rock management to the Project at a level consistent with that required for ongoing feasibility level engineering studies, and the 2012 EIS Supplement;

- **evaluation** of the ML and ARD potential of kimberlite, PK, and mine rock that will be produced during mining at the Project; **and**
- **development** of **possible** environmental management strategies **and** options, material handling strategies **and** options, or mitigation measures (if required) in consideration of **available geochemical information**.

8.III.2 PROGRAM DEVELOPMENT

A comprehensive, defensible geochemical characterization program evolves dynamically in response to changes in the Project Description and advances in technical understanding. The focus of a typical geochemical characterization program is to develop a geochemical dataset that is spatially and compositionally representative of the materials that will be produced during the life-of-mine (Price 1997; **MEND 2009**).

Preliminary geochemical characterization of kimberlite and mine rock took place in 1996 (Canamara 1996) and 2002 (Golder 2002). Prior to 2004, the geochemical dataset for the Project included 13 mine rock and 10 kimberlite samples. The objective of the **sampling** programs presented in Canamara (1996) and Golder (2002) was to provide a screening level overview of the geochemical characteristics of kimberlite and mine rock. The programs were not intended to provide sufficient information required for the EIS.

The **second, more** detailed, geochemical assessment was initiated by AMEC in 2004 and continued through 2008 **and included** the collection of a total of 489 kimberlite, 40 PK, and 1,274 mine rock samples (**AMEC unpublished**). Sample selection and collection, and sample analysis were performed under the guidance of **AMEC**. This report includes results from the AMEC program.

Additional geochemical testing of PK was initiated in 2010 to address updates to the Project Description that could affect the ML and **ARD potential of PK**. **A supplemental program was initiated in 2011 to expand the knowledge of (and possibly refine) the geochemical dataset, particularly with respect to the evaluation of phosphorus leachability from PK and mine rock.**

The results of geochemical characterization presented in Canamara (1996), Golder (2002), **AMEC (unpublished)**, and ongoing geochemical testing of PK **and mine rock** (this report) were used to develop the geochemistry dataset for the Project. The geochemistry dataset was then evaluated in the context of the following factors:

- the mine geology and environment;

- the mine plan, tonnage, and disposal options for the various materials according to the Project Description in the 2012 EIS Supplement (Table 8.III-1);
- the requirement for selecting a sufficient number of adequate and representative samples (spatially and compositionally) according to the sample frequency recommended by MEND (2009) and Price (1997) (Table 8.III-2);
- the requirement for the selection of proper laboratory testing procedures based on the proposed configuration of the Project and amenable to comparisons with similar sites in the North; and
- regulatory requirements and expectations.

Table 8.III-1 Summary of Mine Waste Tonnages and Management

Waste Stream	Quantities	Waste Management	Minimum Number of Samples Required (Price 1997)
Lake Bed Sediment & Overburden	7.3 Mt	- pond dyking and grading - stockpiled for site reclamation	80
Kimberlite	31.2 Mt	- majority to process - barren included with waste rock	>80
Waste Rock	226.4 Mt	- West Mine Rock Pile and South Mine Rock Pile - 5034 Pit (following completion of mining in pit) - site and dam construction - cover material for Coarse PK Pile and Fine PKC Facility	>1,000 ^(a)
Fine PK	7.83 Mt	- Fine PK Facility (mitigated) - Hearne Pit and 5034 Pit (following completion of mining in pit)	Tailings are homogenized products, therefore at least one representative sample of each type of tailings is analyzed.
Coarse PK	23.49 Mt	- Coarse PK Pile - possible deposition in mined out Hearne Pit	

Note: PKC - Processed Kimberlite Containment; PK = Processed Kimberlite; Mt = million tonnes.

^(a) As noted by Price (1997), larger pits "may lead to more than 1,000 ABA samples".

Table 8.III-2 Suggested Initial Sampling Frequency Based on Tonnage when Sampling without Prior Information

Tonnage of Unit [metric tonnes]	Minimum Number of Samples
<10,000	3
<100,000	8
<1,000,000	26
<10,000,000	80

Source: Adapted from Price 1997.

8.III.3 METHODS

8.III.3.1 Sample Collection

This section provides a general overview of the sample collection programs undertaken in support of geochemical characterization of kimberlite, mine rock, and PK. The Project geochemical database presented in this report includes 1,804 samples of exploration drill core and PK collected during several geochemical test programs, including Canamara (1996), AMEC (unpublished), Golder (2002) as well as the more recent 2010 and 2011 programs.

No details are available regarding the Canamara (1996) sample collection program. The Canamara (1996) program was limited in scope, and included the collection of 10 samples for geochemical testing.

For the preliminary geochemical test program outlined in Golder (2002), 10 samples were collected by a geochemist to provide an initial screening level understanding of the geochemical conditions that might be present in the deposit. The Golder (2002) program was not intended to provide EIS related data, and samples were selected to represent specific aspects of the material, as such these data do not represent the overall Project materials.

An expanded testing plan was implemented for kimberlite and the surrounding mine rock (primarily granite) in 2004. The objective of the expanded geochemical program presented in AMEC (unpublished) was to choose representative samples of all the different types of materials that will be excavated or exposed at the Project site. Sample collection was based on the proposed outline of the open pits (exploration drill core samples of mine rock and kimberlite) and the proposed metallurgical process at the time of sampling (PK). In 2004, an expanded testing plan was implemented for kimberlite and mine rock. The objective of this geochemical program was to choose representative samples of all the different types of materials that will be excavated or exposed at the Project site. Sample collection began during the 2004 winter drilling program and continued through July 2008. In 2004, discrete samples were collected every 6 m of drilled core length. Sampling in subsequent years was changed to discrete samples every 6 m for mine rock and 12 m for kimberlite. Locations of each of the drill holes used for collecting geochemical samples are shown in Attachment 8.III.1.

The AMEC (unpublished) dataset, which represents the majority of the geochemical sample dataset, appears reasonable and consistent with current guidelines. The information in the AMEC (unpublished) dataset includes the results of geochemical tests that are commonly used for the purpose of ARD and

ML assessment, which are consistent with the current guidelines. These data are considered reasonable for inclusion in the current assessment.

Samples of PK in the AMEC (unpublished) dataset, and subsequent testing conducted in 2010 (this report) comprise material that was produced during metallurgical test work. PK samples are considered to be more representative of the waste material to be managed on-site than the raw kimberlite samples due to the homogenization which occurs during processing.

The PK testing initiated by Golder in 2010 includes a total of 21 samples of PK provided by De Beers for geochemical testing. Nine PK samples were divided into coarse and fine fractions, and were provided for analysis, for a total of nine individual fine PK and nine coarse PK samples. Portions of each of the nine coarse PK samples were combined to make one coarse PK composite sample. Similarly, portions of each of the nine fine PK samples were combined to make two fine PK composite samples. In total, 21 samples of PK were submitted for static geochemical testing in 2010, including acid base accounting (ABA), metal analysis, and short-term leach testing. Of the three composite samples, the coarse PK composite and one of the fine PK composites were submitted for humidity cell testing and submerged column tests.

The testing initiated by Golder in 2011 was conducted to provide supplementary data with respect to phosphorus leachability from PK and mine rock. The following samples were collected or generated for the 2011 supplemental program:

- nine samples of coarse PK provided by the process plant testing previously conducted;
- three samples of fine PK generated by crushing and grinding three of the representative coarse PK samples;
- six samples of mine rock were collected from drill core; and
- two samples of fine PK and two samples of coarse PK were collected from pilot plant testing.

Analyses included ABA, metal analysis and short-term leach testing. A sub-set of three coarse PK samples and three fine PK samples were submitted for submerged column testing, humidity cell testing, and detailed mineralogical work focusing on phosphorus deportment and liberation. Additionally, kinetic testing was conducted on three of the mine rock samples and all four pilot plant samples.

8.III.3.2 Sample Analysis

The methods used for testing the **ARD** and **ML** potential include static and kinetic laboratory tests, as recommended in the following guidance documents:

- Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia (Price 1997);
- Guidelines for Acid Rock Drainage Prediction in the North (DIAND 1992);
- Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. MEND Report 1.20.1 (MEND 2009); and
- Global Acid Rock Drainage Guide (GARD Guide).internet site <http://www.gardguide.com/> (INAP 2009).

Samples were submitted for a suite of analytical tests, including ABA, metal analysis, short-term leach testing, **mineralogy**, and humidity cell testing. **Table 8.III-3** summarizes the number of analyses completed for each main rock type for the geochemical samples collected from the Project. **Table 8.III-4** provides a list of the kinetic test sample **locations** and status by rocktype with associated duration, sulphur content, and ABA results.

Table 8.III-3 Number of Samples Analyzed for Geochemical Testing Programs

Material Type	Static Tests						Kinetic Tests	
	Mineralogy	WRA	Bulk Metals	ABA	NAG	SFE	Humidity Cells	Columns
Kimberlite								
Kimberlite	1	150	150	391	0	21	5	5
Hypabyssal Kimberlite	1	24	24	63	0	2	1	0
Hypabyssal Kimberlite Transitional Zone	0	4	4	9	0	1	0	0
Tuffistic Kimberlite	1	12	12	21	0	1	0	0
Tuffistic Kimberlite Breccia	1	10	10	24	0	2	1	0
Total Kimberlite	4	200	200	508	0	27	7	5
Processed Kimberlite								
Fine Processed Kimberlite	15	0	25 ^(a)	28 ^(a)	11 ^(a)	16 ^(a)	12	6
Coarse Processed Kimberlite	17	0	22	49	10	21	6	6
Total Processed Kimberlite	32	0	31	61	21	21	18	12
Mine Rock								
Granodiorite	0	1	1	6	0	0	1	0
Altered Granodiorite	0	0	0	16	0	0	0	0
Granite	3	880	880	1,189	6	40	14	8
Altered Granite	0	3	3	10	0	0	0	0
Diabase	0	5	5	7	0	0	1	0
Gneissic Granite	0	9	9	9	0	0	0	0
Diorite	0	1	1	1	0	0	1	0
Pre-leached Granite	0	0	0	4	0	0	4	0
Total Mine Rock	3	899	899	1,242	0	40	21	8
TOTAL SAMPLES ANALYZED	39	1,099	1,130	1,811	0	88	46	25

Note: WRA = whole rock analysis; ABA = acid base accounting; NAG = net acid generation; SFE = shake flask extraction.

^(a) Includes duplicate fine processed kimberlite composite sample analyzed in 2010.

Table 8.III-4 Summary of Kinetic Test Program

Identifier	Rock Type	Pit	Status	Test Length (weeks)	Total Sulphur (wt%)	NP (kg CaCO ₃ /t)	AP (kg CaCO ₃ /t)
Kimberlites							
HC 1	kimberlite	5034	complete	36	0.03	228.50	0.70
HC 2	kimberlite	5034	complete	36	0.02	88.70	0.60
HC 3	hypabyssal kimberlite	5034	complete	36	0.02	3.13	0.60
HC 4	tuffisitic kimberlite breccias	Hearne	complete	36	0.03	4.93	1.03
HC 5	kimberlite	Hearne	complete	36	0.07	5.73	2.29
HC 6	kimberlite	Hearne	complete	36	0.02	2.53	0.60
HC 11	kimberlite	5034	complete	36	0.02	2.83	0.60
Column 5	kimberlite	5034	complete	30	0.04	118.45	0.30
Column 7	kimberlite	5034	complete	30	0.03	67.68	0.94
Column 8	kimberlite	Hearne	complete	30	0.03	47.31	0.96
Column 9	kimberlite	5034	complete	30	0.03	68.76	1.00
Column 10	kimberlite	5034	complete	30	0.03	119.13	0.78
Processed kimberlite							
HC 22	fine PK	Hearne	complete	165	0.040	73.8	0.8
HC 23	fine PK	5034	complete	165	0.050	121.8	1.3
HC 24	fine PK	5034	complete	165	0.020	127.0	0.6
HC 25	fine PK	Hearne	complete	165	0.080	81.5	2.0
HC 26	fine PK	Hearne	complete	165	0.040	75.0	0.8
HC 27	fine PK	5034	complete	165	0.060	100.5	1.5
PK fines composite (T1)	fine PK	composite	ongoing	70	0.07	70.3	2.2
PK coarse composite (HC1)	coarse PK	composite	ongoing	70	0.01	114	0.3
DGM 713 Coarse	coarse PK	composite	ongoing	33	0.05	29.6	1.6
DGM 713 Fine	fine PK	composite	ongoing	25	0.04	74.8	0.3
DGM 717 Coarse	coarse PK	composite	ongoing	33	0.04	65.6	1.3
DGM 717- Fine	fine PK	composite	ongoing	25	0.05	33.1	1.6
DGM 737 Coarse	coarse PK	composite	ongoing	33	0.04	148.6	1.3
DGM 737 Fine	fine PK	composite	ongoing	25	0.04	292.6	0.3
East Lobe Coarse (HGBR)	coarse PK	East Lobe	ongoing	25	0.03	139.5	0.3
East Lobe Fine (HGBR)	fine PK	East Lobe	ongoing	25	0.02	143.1	0.3
Tuzo & Hearne Coarse (HGBR)	coarse PK	Tuzo and Hearne	ongoing	25	0.03	52.8	0.3
Tuzo & Hearne Fine (HGBR)	fine PK	Tuzo and Hearne	ongoing	25	0.03	63.5	0.3

Table 8.III-4 Summary of Kinetic Test Program (continued)

Identifier	Rock Type	Pit	Status	Test Length (weeks)	Total Sulphur (wt%)	NP (kg CaCO ₃ /t)	AP (kg CaCO ₃ /t)
Mine rock							
HC 7	granite	Hearne	complete	36	0.05	6.0	1.5
HC 8	granite	Hearne	complete	207	0.03	4.9	1.0
HC 9	granite	Hearne	complete	207	0.07	5.7	2.3
HC 10	granite	Tuzo	complete	207	0.02	2.5	0.6
HC 12	granite	5034	complete	207	0.02	6.8	0.7
HC 13	granite	Hearne	complete	207	0.02	3.3	0.6
HC 14	diorite and granite	Hearne	complete	207	0.07	6.3	2.1
HC 15	granite	Hearne	complete	41	0.02	2.8	0.6
HC 16	granite	5034	complete	207	0.10	4.3	3.2
HC 17	granite	5034	complete	207	0.04	2.0	1.3
HC 18	granite	5034	complete	207	0.02	8.8	0.6
HC 2 [2011]	granite	Hearne	ongoing	25	0.04	7.3	1.3
HC 3 [2011]	granite	5034	ongoing	25	0.01	11.1	0.3
HC 4 [2011]	granite	5034	ongoing	25	0.09	7.1	2.2
HC 19	granite and granodiorite	Hearne	complete	207	0.03	6.3	0.8
HC 20	granite	Hearne	complete	207	0.02	7.2	0.6
HC 21	diabase	Tuzo	complete	207	0.09	11.3	0.3
Column 1	granite	Hearne	complete	42	0.02	2.1	0.6
Column 2	granite	5034	complete	36	0.06	12.3	2.0
Column 3	granite	Hearne	complete	36	0.08	49.3	2.6
Column 4	granite	Hearne	complete	42	0.02	4.3	0.6
Column 6	granite	5034	complete	42	0.02	7.0	0.6
HC 28	pre-leached granite	Hearne	complete	160	0.02	0.0	0.6
HC 29	pre-leached granite	5034	complete	160	0.06	0.0	1.6
HC 30	pre-leached granite	5034	complete	160	0.03	0.8	0.9
HC 31	pre-leached granite	5034	complete	160	0.02	0.3	0.6

Note: wt% = percent by weight; PK = processed kimberlite; NP = neutralization potential; AP = acid potential; kg CaCO₃/t = kilograms of calcium carbonate per tonne.

8.III.3.3 Testing Procedures

Samples were submitted for one or more of the following tests, as described in Attachment 8.III-2:

- general mineralogical analysis, including qualitative X-Ray Diffraction (XRD) and optical mineralogy of thin sections;
- detailed mineralogical analysis, including phosphorus department, association, and liberation;

- **whole** rock and bulk metal analysis, including aluminum, arsenic, barium, beryllium, boron, cadmium, calcium, lead, cobalt, copper, chromium, tin, iron, lithium, magnesium, manganese, mercury, nickel, potassium silver, selenium, silver, selenium, sodium, total sulfur, vanadium, and zinc;
- ABA including paste pH, sulphur species (including total sulphur, sulphate sulphur, pyritic sulphur, and non-extractable sulphur), acid potential (**AP**) and acid neutralization potential (**NP**), and carbonate content;
- **net acid generation** (NAG) testing;
- **shake flask extraction** (SFE) leach testing, including analysis of leachate for major parameters and metals including aluminum, arsenic, barium, beryllium, boron, cadmium, calcium, lead, cobalt, copper, chromium, tin, iron, lithium, magnesium, manganese, mercury, nickel, potassium, silver, selenium, sodium, total sulfur, vanadium, and zinc;
- **chemical** analysis of process water for major parameters and metals including aluminum, arsenic, barium, beryllium, boron, cadmium, calcium, lead, cobalt, copper, chromium, tin, iron, lithium, magnesium, manganese, mercury, nickel, potassium silver, selenium, silver, selenium, sodium, total sulfur, vanadium, and zinc; and
- **kinetic testing** including:
 - **humidity cell** tests (HCT) carried out using the standard humidity cell test approach described in ASTM D 5744-96-1996, including analysis of major parameters and metals; **and**
 - **column** testing as described by Price (1997), including analysis of major parameters and metals.
- **saturated** column testing, including analysis of major parameters and metals.

8.III.3.4 Quality Assurance and Quality Control

Protocols for quality assurance/quality control (QA/QC) were followed to validate the integrity of the results. The protocols included the use of internal laboratory standards, duplicates, and other QA samples.

Evaluation of the QA/QC results for the test work completed as part of the geochemistry program indicated that the data produced are of sufficient quality to be used for their intended purposes. Results of duplicate samples were evaluated using scatter plots and calculation of relative **percent** differences (RPD). Standards and blanks were graphically compared against expected values as an indication of analytical accuracy. **Quality assurance/quality control** analyses are reported in **Attachment 8.III-4** for ABA analysis, **Attachment 8.III-5** for whole rock analysis, **Attachment 8.III-7** for SFE, **Attachment 8.III-8** for humidity cell analysis, and **Attachment 8.III-9** for column testing.

8.III.4 RESULTS

8.III.4.1 Kimberlite

8.III.4.1.1 Static Testing

Mineralogy

In 2004, four kimberlite samples were submitted for optical mineralogy and XRD analysis (Petrascience 2004; Attachment 8.III-3). A detailed summary of the results of mineralogical analysis is reported in Table 8.III-5.

Results showed that the samples were dominated by kimberlitic material, typically pervasively altered to a very fine-grained assemblage of clays plus minus ($\pm$) chlorite $[(\text{Fe,Mg,Al})_6(\text{Si,Al})_4\text{O}_{10}(\text{OH})_8] \pm \text{talc } [\text{Mg}_3\text{Si}_4\text{O}_{10}] \pm \text{biotite } [\text{K}(\text{Mg,Fe})_3\text{AlSi}_3\text{O}_{10}(\text{F,OH})_2]$. The clays, as identified by Rietveld XRD, include vermiculite $[(\text{Mg,Fe,Al})_3(\text{Al,Si})_4\text{O}_{10}(\text{OH})]$, chlinochlore $[(\text{Mg}_5\text{Al})(\text{AlSi}_3)\text{O}_{10}(\text{OH})_8]$, phlogopite $[\text{KMg}_3\text{AlSi}_3\text{O}_{10}(\text{F,OH})_2]$ and actinolite $[\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2]$. Olivine $[(\text{Mg,Fe})_2\text{SiO}_4]$ is preserved in some samples, typically partly to totally pseudomorphosed by serpentine, itself variously replaced by the clay $\pm$ chlorite $\pm$ talc $\pm$ biotite assemblage. Quartz $[\text{SiO}_2]$, amphibole $[\text{Ca}_2(\text{Fe,Mg})_5\text{Si}_8\text{O}_{22}(\text{OH})_2]$ and K-feldspar $[\text{KAlSi}_3\text{O}_8]$ commonly occur in small amounts.

Trace unidentified carbonate minerals were identified in the tuffistic kimberlite breccia sample.

According the mineralogical report, sulphide minerals are extremely rare in the samples (less than 2%) and mostly consist of pyrite $[\text{FeS}_2]$ with lesser chalcopyrite $[\text{CuFeS}_2]$ and trace pyrrhotite $[\text{Fe}_{(1-x)}\text{S}]$.

Table 8.III-5 **Summary of Kimberlite Mineralogy**

	Mineral	Formula	Mineral Composition (%)			
			04-ARD-126-015	04-ARD-137-013	04-ARD-159-010	04-ARD-171-015
			Kimberlite	Hypabyssal Kimberlite	Tuffistic Kimberlite Breccia	Tuffistic Kimberlite
Semi-quantitative XRD	Vermiculite 2M	(Mg,Fe,Al) ₃ (Al,Si) ₄ O ₁₀ (OH)	27		19	
	Clinocllore II	(Mg ₅ Al)(AlSi ₃)O ₁₀ (OH) ₈	31	42	15	30
	Phlogopite 1M	KMg ₃ AlSi ₃ O ₁₀ (F,OH) ₂	7.0	32	7.6	20
	Actinolite	Ca ₂ (Mg,Fe) ₅ Si ₈ O ₂₂ (OH) ₂	3.5		3.7	
	Pectolite 1A	NaCa ₂ Si ₃ O ₈ (OH)		12		8.0
	Natrolite	Na ₂ Al ₂ Si ₃ O ₁₀	1.7			
	Talc 1A	Mg ₃ Si ₄ O ₁₀	25		21	
	Lizardite	Mg ₃ Si ₂ O ₅		13	2.2	8.0
	Monticellite	CaMgSiO ₄		0.5		1.9
	Forsterite	Mg ₂ SiO ₄		minor?		32
	Microcline intermediate	KAlSi ₃ O ₈	2.9		24	
	Orthoclase	KAlSi ₃ O ₈			3.7	
	Quartz	SiO ₂			3.7	
	Hematite	Fe ₂ O ₃			0.6	
	Perovskite	CaTiO ₃		0.6		0.5
	Rutile	TiO ₂	0.5			
	Titanite	CaTiSiO ₅	1.8			
TOTAL			100	100	100	100
Mineral Phases Observed in Optical Microscopy			Major: Biotite [K(Mg,Fe) ₃ AlSi ₃ O ₁₀ (F,OH) ₂], chlorite [(Fe,Mg,Al) ₆ (Si,Al) ₄ O ₁₀ (OH) ₈], olivine [(Mg,Fe) ₂ SiO ₄], serpentine [(Mg,Fe) ₃ Si ₂ O ₅ (OH) ₄] Minor: Titanite, Rutile	Major: Chlorite, biotite, serpentine, olivine, groundmass Minor: Titanite, rutile Trace: Magnetite [Fe ₃ O ₄], pyrite [FeS ₂]	Major: Groundmass, K- feldspar, biotite, chlorite Minor: Quartz, hematite [Fe ₂ O ₃], ilmenite [FeTiO ₃], rutile Trace: Magnetite, chalcopryrite [CuFeS ₂], pyrite, carbonate	Major: Groundmass, chlorite, serpentine, biotite Minor: Amphibole [Ca ₂ (Fe,Mg) ₅ Si ₈ O ₂₂ (OH) ₂], olivine Trace: Olivine, hematite [Fe ₂ O ₃], perovskite [CaTiO ₃], chalcopryrite [CuFeS ₂]

Acid Base Accounting

Results of ABA testing for the kimberlite are provided in Table 8.III-6 and Figures 8.III-1 to 8.III-3. Attachment 8.III-4 contains detailed ABA results.

Principal observations with respect to the ABA characteristics of kimberlite included:

- Paste pH values ranged from 7.1 to 11.0, with a median value of 8.64. Paste pH values were well above the screening criteria of pH 5.5 typically used to identify samples with a potential for acid generation (Price 1997). The average paste pH of the tuffisitic kimberlite breccia was the lowest of all the kimberlite facies (pH 8.22).
- The kimberlite samples contained between <0.01 and 0.75% total sulphur, with an average total sulphur concentration of 0.04%. Sulphur is primarily in the form of sulphide sulphur (Figure 8.III-1). Sulphide sulphur concentrations in the kimberlite ranged from <0.01 to 0.72%, with average concentrations of 0.03%. For the purpose of the evaluation in this report, AP was calculated using total sulphur.
- Of the 509 samples of kimberlite submitted for ABA, only three samples had sulphide sulphur concentrations in excess of 0.3%.
- The results of sulphur analysis were consistent with the mineralogical evaluation of kimberlite, which indicated that the sulphide mineral content of kimberlite is low.
- According to AMEC (unpublished), the presence of sulphide concentrations greater than 0.1 wt% in kimberlite samples did not appear to be related to proximity to mine rock contacts.
- The neutralization potential of the kimberlites ranged from 2.4 to 600 kilograms of calcium carbonate per tonne (kg CaCO₃/t), with an average value of 124 kg CaCO₃/t. Generally, the tuffisitic kimberlite samples reported lower neutralization potential values (averages of 57.8 and 73.2 kg CaCO₃/t) than the other kimberlite types (averages of 123, 125, and 168 kg CaCO₃/t).
- The NP was greater than the carbonate NP for all but seven samples (Figure 8.III-2). On average, the carbonate NP was about one-tenth of the NP. A carbonate NP significantly lower than the neutralization potential indicates most of the bulk NP is attributable to non-carbonate minerals.
- The NP/AP ratio of the kimberlite samples ranged from 0.84 to 3416. Of the 509 samples submitted for ABA, only four samples had NP/AP ratios less than 4. Three samples had an NP/AP ratio between 1 and 3, indicating an uncertain acid generating potential, including one tuffisitic kimberlite breccias and two undifferentiated kimberlite samples (Figure 8.III-3). One undifferentiated kimberlite sample had an NP/AP ratio less than one (0.84) and would therefore be classified as PAG according to the guidance in Price (1997).

Table 8.III-6 Summary of Kimberlite Acid Base Accounting Results

Sample ID	Paste pH	CO ₂ %	Total Sulphur wt%	Sulphate wt%	Sulphide wt%	AP kg CaCO ₃ /t	NP kg CaCO ₃ /t	NP/AP kg CaCO ₃ /t	CaNP kg CaCO ₃ /t
Hypabyssal Kimberlite, n=63									
Minimum	8.0	0.04	<0.01	<0.01	<0.01	<0.3	37	14	0.91
Maximum	10	8.5	0.21	0.082	0.14	4.4	420	1808	194
Mean	9.0	0.75	0.039	0.012	0.028	0.88	168	350	17
Median	8.8	0.36	0.03	0.0073	0.015	0.48	145	220	8.2
Standard Deviation	0.7	1.3	0.039	0.013	0.03	0.94	107	369	29
Hypabyssal Kimberlite Transitional Zone, n=9									
Minimum	8.3	0.12	<0.01	<0.01	<0.01	<0.3	39	42	2.7
Maximum	10	1.9	0.06	0.06	0.03	0.94	259	1712	44
Mean	9.3	0.51	0.022	0.014	0.013	0.38	126	591	12
Median	9.6	0.28	0.02	0.005	0.01	0.3	99	290	6.4
Standard Deviation	0.74	0.58	0.016	0.018	0.0079	0.26	82	637	13
Kimberlite, n=391									
Minimum	7.1	<0.01	<0.01	<0.01	<0.01	<0.3	2.4	0.84	0.11
Maximum	11	18	0.75	0.08	0.72	23	600	3416	414
Mean	9.0	0.89	0.036	0.0096	0.031	0.99	123	292	20
Median	8.7	0.28	0.02	0.005	0.02	0.62	89	140	6.4
Standard Deviation	0.73	2.2	0.061	0.0098	0.058	1.9	104	445	50
Tuffisitic Kimberlite, n=21									
Minimum	8.3	<0.01	<0.01	<0.01	<0.01	<0.3	37	59	0.11
Maximum	8.7	0.14	0.03	0.0053	0.03	0.94	119	396	3.2
Mean	8.6	0.07	0.013	0.005	0.013	0.41	73	208	1.6
Median	8.6	0.08	0.01	0.005	0.01	0.3	62	188	1.8
Standard Deviation	0.13	0.034	0.0058	0.000073	0.0058	0.19	26	101	0.78
Tuffisitic Kimberlite Breccia, n=25									
Minimum	7.5	0.04	<0.01	<0.01	<0.01	<0.3	28	1.5	0.91
Maximum	8.6	4.7	0.71	0.086	0.62	20	100	386	107
Mean	8.2	0.8	0.06	0.013	0.051	1.6	58	113	18
Median	8.2	0.26	0.03	0.01	0.02	0.62	65	104	5.9
Standard Deviation	0.27	1.3	0.14	0.016	0.12	3.8	22	95	29
All Kimberlite, n=509									
Minimum	7.1	<0.01	<0.01	<0.01	<0.01	<0.3	2.4	0.84	0.11
Maximum	11	18	0.75	0.09	0.72	23	600	3416	414
Mean	8.9	0.83	0.04	0.01	0.03	0.97	124	293	19
Median	8.7	0.27	0.02	0.01	0.02	0.63	90	147	6.1
Standard Deviation	0.7	2.0	0.06	0.01	0.06	1.90	102	424	46

Note: AP = acid potential (calculated using total sulphur); NP = neutralization potential; CaNP = calcium neutralization potential; wt% = percent by weight; kg CaCO₃/t = kilograms of calcium carbonate per tonne; CO₂ = carbon dioxide.

Figure 8.III-1 Total Sulphur Versus Sulphide Sulphur for Kimberlites

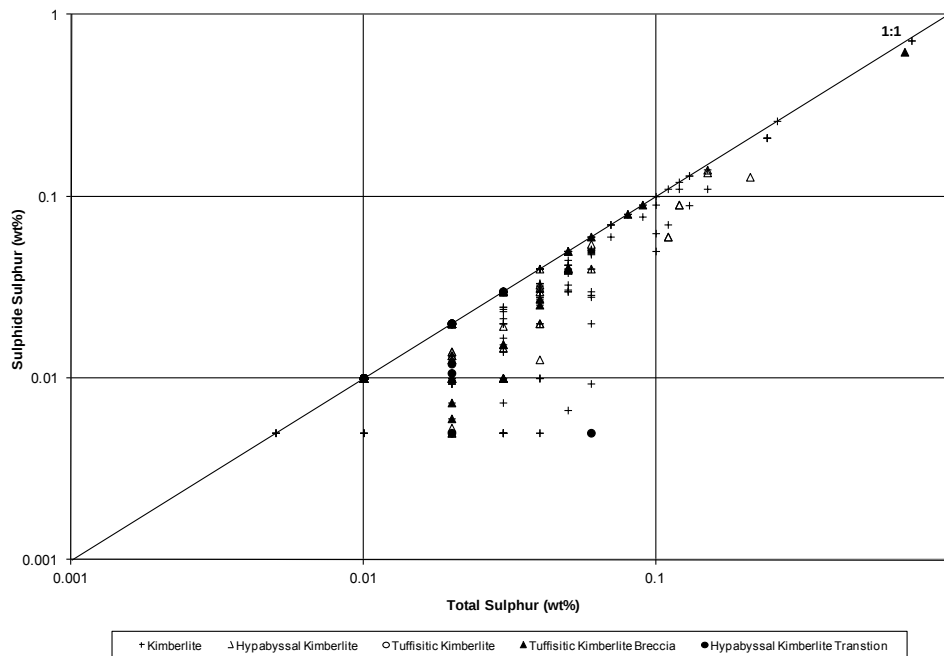


Figure 8.III-2 Total Neutralization Potential Versus Carbonate Neutralization Potential for Kimberlites

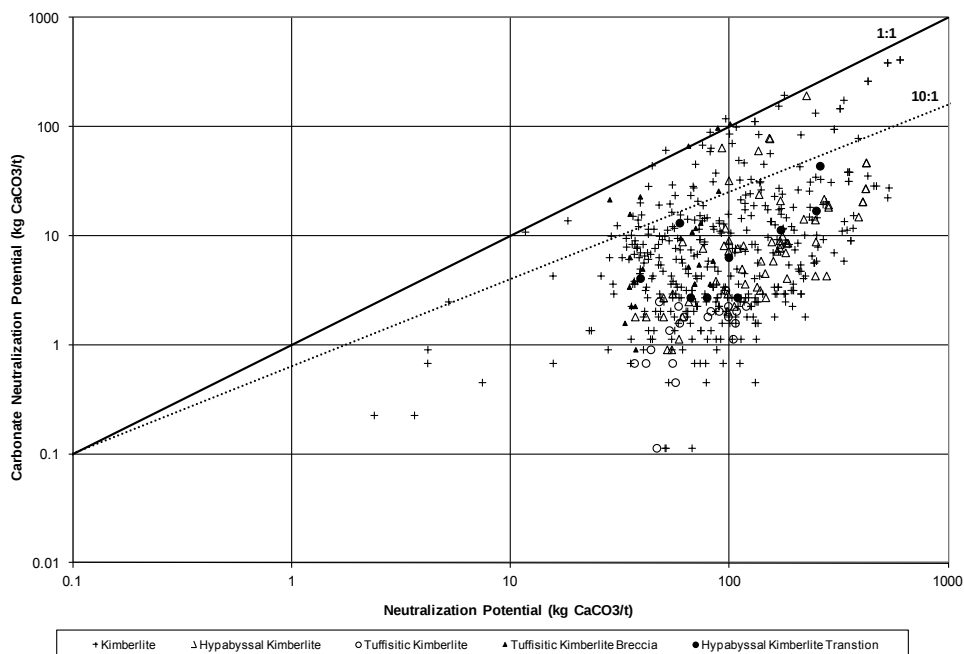
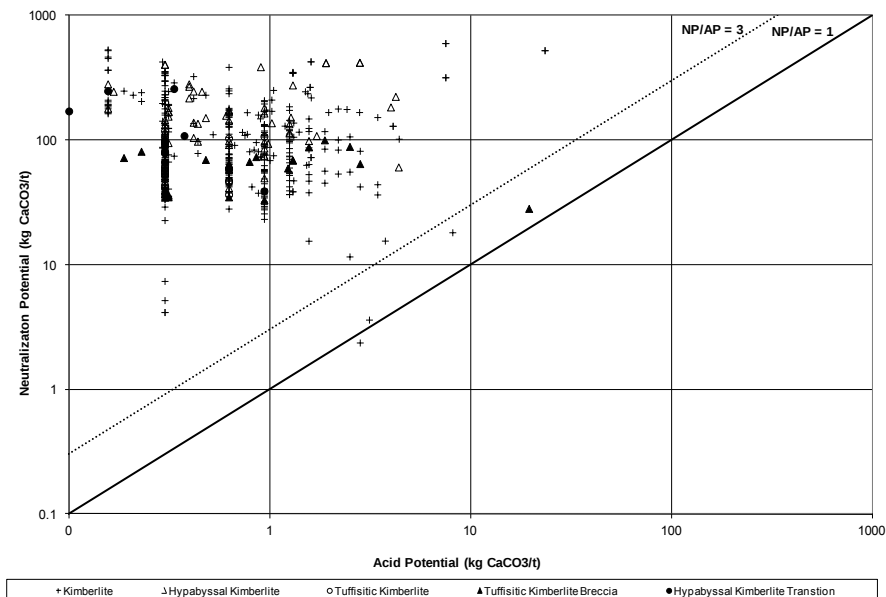


Figure 8.III-3 Acid Potential Versus Neutralization Potential for Kimberlites



8.III.4.1.2 Whole Rock and Trace Element Chemistry

A complete record of the analytical results and a summary of the chemistry of the individual kimberlite facies is provided in Attachment 8.III-5. A summary of the whole rock results is presented in Table 8.III-7 and bulk metal results are reported in Table 8.III-8. Trace metal concentrations were compared to the average crustal abundances of elements in Price (1997). The purpose of this comparison was to identify metals that occur at elevated concentrations in the solid phase.

Magnesium, iron, and aluminum are the major metals in kimberlite. For all kimberlite facies, the average silica concentration was less than 50%. Overall, the chemical composition of kimberlites was similar to the average crustal abundances of ultrabasic and basaltic rocks presented in Price (1997).

Results of the trace element chemistry analyses indicated average concentrations of nickel (886 milligrams per kilogram [mg/kg]), boron (103 mg/kg), cobalt (55 mg/kg), chromium (292 mg/kg), magnesium (12%), phosphorus (0.11 mg/kg), selenium (0.26 mg/kg), and strontium (394 mg/kg) were elevated compared to average background concentrations in continental crust rock (Price 1997). Relative to kimberlite, tuffisitic kimberlite, and tuffisitic kimberlite breccia, the hypabyssal kimberlite and transitional hypabyssal kimberlite are enriched in mafic minerals (Annex D, Bedrock Geology, Terrain, Soil, and Permafrost Baseline) and associated elements including chromium, copper, iron, manganese, nickel, and zinc.

Table 8.III-7 Summary of Kimberlite Whole Rock Results

Parameter	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Ba(F)	LOI	Total
Unit	%	%	%	%	%	%	%	%	%	%	%	%	%
Hypabyssal Kimberlite, n= 24													
Minimum	36	0.51	1.9	6.6	0.02	26	0.46	0.01	0.2	0.07	0.02	8.1	98
Maximum	44	0.74	4.8	9.0	0.14	36	6.4	1.2	1.6	0.56	0.15	16	100
Mean	39	0.6	3.5	7.7	0.1	30	3.2	0.24	0.89	0.33	0.097	12	99
Median	40	0.6	3.5	7.5	0.11	30	2.9	0.09	0.9	0.34	0.11	13	99
Standard Deviation	2.6	0.057	0.7	0.82	0.033	2.5	2.1	0.37	0.39	0.13	0.038	2.3	0.43
Kimberlite, n= 150													
Minimum	32	0.14	1.6	1.5	0.0059	0.5	0.15	0.01	0.07	0.02	0.01	0.62	98
Maximum	87	0.73	18	8.9	0.18	36	8.8	3.7	11	0.82	0.23	17	100
Mean	45	0.53	5.5	6.5	0.069	25	2.8	0.58	1.5	0.28	0.091	12	99
Median	43	0.56	4.5	6.8	0.07	28	1.8	0.3	0.95	0.28	0.09	13	99
Standard Deviation	8.9	0.12	3.0	1.7	0.043	8.4	2.1	0.74	1.5	0.13	0.039	3.5	0.4
Hypabyssal Kimberlite Transitional Zone, n = 4													
Minimum	37	0.62	3.1	7.9	0.12	28	2.1	0.03	0.8	0.37	0.1	8.7	98
Maximum	41	0.69	4.1	8.6	0.14	32	6.0	0.81	1.5	0.46	0.15	13	99
Mean	39	0.66	3.5	8.4	0.13	30	4.8	0.28	1.1	0.42	0.12	11	99
Median	38	0.67	3.5	8.5	0.13	30	5.4	0.15	1.1	0.43	0.12	11	99
Standard Deviation	2.0	0.031	0.43	0.35	0.012	2.0	1.8	0.36	0.29	0.038	0.021	1.8	0.34
Tuffisitic Kimberlite, n= 12													
Minimum	42	0.4	4.1	5.8	0.02	24	0.72	0.03	0.4	0.12	0.03	13	99
Maximum	45	0.61	7.5	7.1	0.07	30	1.6	0.58	1.3	0.4	0.1	15	100
Mean	44	0.5	5.8	6.5	0.049	27	1.2	0.28	0.75	0.22	0.058	14	99
Median	44	0.49	5.9	6.3	0.05	26	1.2	0.31	0.57	0.2	0.06	13	99
Standard Deviation	1.1	0.06	1.1	0.36	0.014	2.0	0.28	0.21	0.31	0.083	0.024	0.83	0.19
Tuffisitic Kimberlite Breccia, n= 10													
Minimum	47	0.37	7.1	4.3	0.01	13	1.4	0.15	1.5	0.15	0.05	9.1	99
Maximum	54	0.44	10	7.3	0.02	22	2.6	2.0	3.6	0.37	0.12	15	99
Mean	49	0.4	8.2	5.2	0.017	18	1.7	0.55	2.5	0.28	0.073	13	99
Median	49	0.41	8.2	5.2	0.02	19	1.6	0.42	2.5	0.27	0.075	13	99
Standard Deviation	2.2	0.028	1.0	0.86	0.0048	2.5	0.35	0.53	0.69	0.079	0.022	1.6	0.17
ALL KIMBERLITES, n=200													
Minimum	32	0.14	1.6	1.5	0.0059	0.5	0.15	0.01	0.07	0.02	0.01	0.62	98
Maximum	87	0.74	18	9.0	0.18	36	8.8	3.7	11	0.82	0.23	17	100
Mean	44	0.53	5.4	6.6	0.07	26	2.7	0.52	1.4	0.29	0.089	12	99
Median	43	0.56	4.4	6.9	0.07	28	1.7	0.27	0.96	0.28	0.09	13	99
Standard Deviation	8.0	0.11	2.8	1.6	0.044	7.8	2.0	0.68	1.4	0.12	0.039	3.2	0.4

Note: % = percent.

Table 8.III-8 Summary of Kimberlite Bulk Metal Results

Parameter	Ag	Al	As	B	Ba	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	La	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Sr	Ti	Tl	U	Zn
Unit	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	%	mg/kg	%	mg/kg	mg/kg	%	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg
PRICE CRUSTAL ABUNDANCE ^(a) (mg/kg)		82300	1.8	10		0.0085	41500	3.0	25	102	60	56300	20850	20	23300	950	1.2	23550	84	1050	14	0.2	0.05	370	5650	0.85	2.7	70
Hypabyssal Kimberlite, n= 24																												
Minimum	0.05	0.85	0.7	2.0	243	0.05	0.28	0.05	44	271	3.5	3.3	0.27	6.0	11	280	0.05	0.023	797	0.031	0.5	0.05	0.25	163	0.046	0.05	0.7	18
Maximum	0.1	2.1	10	573	1,295	0.05	4.1	0.2	107	608	93	5.7	1.9	90	18	1,277	4.4	0.83	1,391	0.24	14	0.2	0.5	609	0.13	0.8	1.8	236
Mean	0.085	1.6	2.3	167	795	0.05	1.9	0.06	70	406	49	4.5	1.1	44	15	883	0.44	0.17	1,114	0.13	6.3	0.083	0.28	353	0.085	0.16	1.2	47
Median	0.1	1.5	1.6	76	744	0.05	1.8	0.05	71	396	49	4.4	1.1	40	15	934	0.25	0.047	1,110	0.14	7.8	0.075	0.25	318	0.087	0.1	1.2	42
Standard Deviation	0.023	0.31	2.2	179	325	1.4E-17	1.4	0.033	14	97	18	0.73	0.5	29	2.0	272	0.89	0.25	180	0.053	4.9	0.043	0.084	130	0.024	0.18	0.25	42
Kimberlite, n= 150																												
Minimum	0.05	0.33	0.25	0.5	10	0.05	0.06	0.05	2.4	29	0.6	0.74	0.04	4.0	0.28	55	0.05	0.005	2.1	0.011	0.5	0.05	0.25	4.0	0.002	0.05	0.3	10
Maximum	0.7	4.0	10	1,747	1,434	0.2	5.8	0.5	104	821	148	5.6	2.0	88	19	1,556	88	2.3	1,521	0.3	99	3.3	0.5	10,000	0.23	4.0	4.8	226
Mean	0.08	1.7	1.6	103	617	0.054	1.5	0.058	54	281	38	3.6	0.75	49	12	612	1.4	0.18	872	0.11	6.6	0.12	0.26	422	0.075	0.13	1.1	37
Median	0.05	1.7	1.3	27	624	0.05	0.9	0.05	57	274	40	3.7	0.65	50	12	600	0.3	0.071	935	0.11	2.8	0.05	0.25	289	0.075	0.1	1.0	32
Standard Deviation	0.059	0.6	1.2	191	389	0.017	1.2	0.039	20	145	24	1.1	0.47	22	4.2	351	7.3	0.28	335	0.047	10	0.29	0.035	899	0.036	0.33	0.48	24
Hypabyssal Kimberlite Transitional Zone, n = 4																												
Minimum	0.1	1.4	1.0	7.0	820	0.05	1.0	0.05	73	355	45	4.8	0.92	7.0	13	1,034	0.2	0.047	1,137	0.15	1.8	0.05	0.25	357	0.056	0.05	1.3	38
Maximum	0.1	1.8	4.6	461	1,387	0.05	4.2	0.1	81	452	71	5.7	2.0	68	15	1,243	0.4	0.64	1,374	0.2	14	0.1	0.5	710	0.12	0.2	1.8	56
Mean	0.1	1.6	2.0	154	1,072	0.05	3.2	0.075	79	413	57	5.3	1.4	32	14	1,157	0.3	0.24	1,282	0.18	11	0.075	0.31	547	0.096	0.14	1.5	49
Median	0.1	1.6	1.3	74	1,040	0.05	3.8	0.075	80	423	56	5.5	1.4	27	14	1,176	0.3	0.14	1,309	0.18	13	0.075	0.25	560	0.11	0.15	1.4	50
Standard Deviation	0	0.13	1.7	209	255	0	1.5	0.029	4.1	44	11	0.43	0.45	26	0.92	103	0.12	0.28	102	0.023	5.9	0.029	0.13	153	0.028	0.075	0.22	7.5
Tuffisitic Kimberlite, n= 12																												
Minimum	0.05	1.8	0.25	20	201	0.05	0.45	0.05	37	207	23	2.8	0.31	55	9.8	261	0.05	0.044	639	0.032	0.6	0.05	0.25	158	0.031	0.05	0.7	18
Maximum	0.1	3.1	3.5	106	576	0.05	0.87	0.05	68	354	55	4.0	1.2	73	14	618	0.2	0.24	833	0.14	9.5	0.1	0.25	393	0.088	0.1	1.5	37
Mean	0.054	2.5	0.88	40	387	0.05	0.64	0.05	46	272	36	3.2	0.56	63	12	350	0.13	0.076	717	0.077	1.8	0.054	0.25	248	0.053	0.054	1.1	27
Median	0.05	2.5	0.65	30	384	0.05	0.67	0.05	45	277	36	3.2	0.48	62	11	311	0.1	0.06	712	0.067	1.2	0.05	0.25	248	0.05	0.05	1.2	28
Standard Deviation	0.014	0.4	0.86	27	150	7.2E-18	0.12	7.2E-18	9.5	50	9.0	0.33	0.22	5.2	1.3	104	0.054	0.053	57	0.032	2.4	0.014	0	76	0.015	0.014	0.22	5.2
Tuffisitic Kimberlite Breccia, n= 10																												
Minimum	0.05	1.3	0.7	9.0	120	0.05	0.59	0.05	29	89	3.8	2.2	0.31	44	6.0	143	0.5	0.047	428	0.063	1.7	0.05	0.25	114	0.025	0.05	0.8	13
Maximum	0.1	2.7	1.5	23	438	0.1	1.3	0.3	45	222	46	4.4	0.54	78	9.3	258	4.2	0.11	692	0.15	32	0.05	0.5	254	0.048	0.1	1.6	27
Mean	0.055	2.1	1.0	14	228	0.055	0.97	0.075	36	145	22	2.8	0.41	60	8.1	184	1.1	0.078	582	0.11	6.1	0.05	0.3	179	0.036	0.09	1.1	19
Median	0.05	2.1	1.0	13	214	0.05	0.97	0.05	36	138	23	2.5	0.39	58	8.4	173	0.9	0.081	609	0.11	2.3	0.05	0.25	177	0.035	0.1	1.0	19
Standard Deviation	0.016	0.42	0.29	3.7	90	0.016	0.2	0.079	5.7	37	14	0.66	0.083	10	1.0	35	1.1	0.02	91	0.031	9.4	7.3E-18	0.11	46	0.0086	0.021	0.23	4.2
ALL KIMBERLITE n=200																												
Minimum	0.05	0.33	0.25	0.5	10	0.05	0.06	0.05	2.4	29	0.6	0.74	0.04	4.0	0.28	55	0.05	0.005	2.1	0.011	0.5	0.05	0.25	4.0	0.002	0.05	0.3	10
Maximum	0.7	4.0	10	1,747	1,434	0.2	5.8	0.5	107	821	148	5.7	2.0	90	19	1,556	88	2.3	1,521	0.3	99	3.3	0.5	10,000	0.23	4.0	4.8	236
Mean	0.078	1.8	1.6	103	614	0.054	1.5	0.059	55	292	38	3.7	0.78	49	12	618	1.2	0.17	886	0.11	6.3	0.11	0.26	394	0.074	0.12	1.1	37
Median	0.05	1.8	1.3	32	603	0.05	0.89	0.05	57	279	40	3.7	0.65	55	12	596	0.3	0.065	920	0.12	2.5	0.05	0.25	285	0.073	0.1	1.1	31
Standard Deviation	0.053	0.59	1.4	181	383	0.015	1.2	0.04	20	142	23	1.1	0.48	22	4.0	360	6.3	0.26	323	0.048	9.3	0.26	0.052	783	0.034	0.29	0.43	26

Notes: mg/kg = milligrams per kilogram; % = percent.

^(a) Typical crustal abundance for continental rocks taken from Price (1997).

>1 x	- Concentration greater than typical crustal abundance.
>5 x	- Concentration greater than <u>5 x</u> the typical crustal abundance.
>10 x	- Concentration greater than <u>10 x</u> the typical crustal abundance.

8.III.4.1.3 Shake Flask Extraction Testing

Attachment 8.III-7 presents detailed results of SFE of kimberlite samples. All SFE leachates had neutral to alkaline pH values, ranging from 7.95 to 10.6. There are no established guidelines for comparison of SFE leachate results. Table 8.III-9 provides the mean, median, standard deviation, and range of select parameters in kimberlite SFE leachates.

8.III.4.1.4 Kinetic Testing

Humidity Cells

Tables 8.III-10a and 8.III-10b contain a summary of the average leachate chemistry for selected parameters from the standard humidity cells. Results are presented for both the first flush (the first five weeks) in Table 8.III-10a and steady state conditions (the last five weeks) in Table 8.III-10b. Figures 8.III-4a and 8.III-4b presents the concentrations of key parameters and pH values of the kimberlite humidity cells. Attachment 8.III-8 provides the weekly results and calculated parameters. The kimberlite material used to construct the humidity cells had sulphide concentrations that fell between the median and 90th percentile of all kimberlite ABA sulphide values and between the 25th percentile and median of all kimberlite ABA NP values.

The principal observations with respect to the kimberlite humidity cells are as follows:

- Neutral to alkaline pH values were maintained through the duration of the kimberlite kinetic tests. Kinetic test pH decreased very slightly over the duration of the test. Given the low total sulphur content of the humidity cell test samples, it is unlikely that the slight decrease in pH is a result of sulphide oxidation.
- The sulphate concentrations decreased with time in all kimberlite humidity cells. Concentrations were typically less than 5 milligrams per litre per week (mg/L/wk) after week 20 for all humidity cells with the exception of HC 6. HC 6 sulphate concentrations were less than 10 mg/L each week since week 19. The low sulphate concentrations support the conclusion that the decreasing pH is likely unrelated to sulphide oxidation.
- Concentrations of major ions including sodium, magnesium, and calcium generally decreased over time after five weeks.
- Key metal concentrations including selenium, zinc, and iron were below the detection limits in many samples. Arsenic concentrations peaked between weeks 18 and 30 in all samples, with maximum concentrations ranging from 0.005 to 0.014 mg/L.

- As presented in Table 8.III-10a and 8.III-10b, trace metal concentrations in humidity cell test leachates were generally low. Copper, mercury, and lead concentrations were less than the lower detection limit at steady state. Steady state concentrations of nickel and molybdenum were less than or equal to the detection limit in all but one humidity cell.
- Table 8.III-11 summarizes the expected NP, CaNP and sulphide depletion times in humidity cells assuming leaching rates remain constant. In all cells except HC 11, the rate of NP consumption was greater than the rate of sulphate production, indicating that it is unlikely that acid generation would occur in the long-term. However, given the low sulphide content in HC 11 even upon complete depletion of NP, the rate of acid production is expected to be insufficient to produce appreciable amounts of acidity.

Table 8.III-9 Average and Range of Values for Kimberlite Shake Flask Extraction Tests

Parameter Unit	pH s.u.	SO ₄ mg/L	Al mg/L	As mg/L	Ca mg/L	Cr mg/L	Co mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Ni mg/L	P mg/L	K mg/L	Se mg/L	Na mg/L	Sr mg/L	U mg/L	Zn mg/L
Hypabyssal Kimberlite, n = 2																					
04-ARD-137-011	10	3.0	0.007	<0.001	14	<0.001	<0.001	<0.001	< 0.05	<0.001	0.06	<0.001	<0.0005	<0.001	<0.15	14	<0.001	19	0.24	<0.0005	<0.005
04-ARD-164-015	11	<1	0.006	<0.001	73	<0.001	<0.001	<0.001	0.08	<0.001	0.35	<0.001	<0.0005	<0.001	<0.15	44	<0.001	1.6	1.3	<0.0005	<0.005
Hypabyssal Kimberlite Transitional Zone, n = 1																					
04-ARD-171-001	9.0	6.0	0.007	0.001	5.7	<0.001	<0.001	<0.001	< 0.05	<0.001	5.5	<0.001	0.0006	<0.001	<0.15	11	<0.001	7.9	0.071	<0.0005	<0.005
Kimberlite, n = 21																					
Mean	9.1	25	2.0	0.0059	15	0.017	0.0051	0.0016	2.8	0.001	15	0.021	0.016	0.11	0.16	13	<0.001	18	0.17	0.00053	0.0069
Median	9.0	9.0	0.067	0.001	8.0	0.001	0.001	0.001	0.22	0.001	9.0	0.004	0.0012	0.009	0.15	7.0	<0.001	16	0.093	0.0005	0.005
Standard Deviation	0.59	40	5.0	0.027	16	0.043	0.015	0.0033	6.6	0.00071	23	0.062	0.044	0.33	0.071	12	---	14	0.15	0.00035	0.0062
Minimum	8.0	<1	<0.005	<0.001	1.3	<0.001	<0.001	<0.001	<0.05	<0.001	0.23	<0.001	<0.0005	<0.001	<0.15	2.6	<0.001	0.81	0.018	<0.0005	<0.005
Maximum	10	163	19	0.087	57	0.15	0.046	0.01	27	0.002	103	0.22	0.17	1.2	0.3	41	<0.001	44	0.58	0.0011	0.022
Tuffisitic Kimberlite, n = 1																					
04-ARD-171-017	8.5	5.0	13	0.001	7.3	0.11	0.027	0.003	19	<0.001	71	0.14	0.0039	0.77	0.2	5.0	<0.001	17	0.099	<0.0005	0.019
Tuffisitic Kimberlite Breccia, n = 2																					
04-ARD-157-006	8.9	54	3.1	0.002	9.0	0.017	0.009	0.002	3.3	<0.001	20	0.02	0.035	0.13	<0.15	5.1	<0.001	27	0.098	<0.0005	0.005
04-ARD-159-012	8.6	104	0.014	<0.001	19	<0.001	<0.001	<0.001	0.06	<0.001	9.5	0.002	0.036	0.004	<0.15	6.0	<0.001	35	0.25	<0.0005	<0.005

Note: s.u. = standard units; mg/L = milligrams per litre; ARD = acid rock drainage.

Table 8.III-10a First Flush Concentrations of Select Parameters in Kimberlite Humidity Cell Leachates

	pH	SO ₄	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
First Flush																					
HC 1 - Kimberlite: Dec 14 - Jan 11, 2005																					
Minimum	7.8	<1	<0.005	<0.001	14	<0.001	<0.001	<0.001	<0.05	<0.001	5.5	<0.001	<0.0005	0.0013	<0.15	12	<0.001	<0.05	0.079	<0.0005	<0.005
Maximum	8.3	1.0	0.048	<0.001	30	<0.001	<0.001	<0.001	<0.05	<0.001	12	0.0021	<0.0005	0.002	<0.15	20	<0.001	5.3	0.21	<0.0005	<0.005
Average	8.1	1.0	0.019	<0.001	20	<0.001	<0.001	<0.001	<0.05	<0.001	8.5	0.0017	<0.0005	0.0018	<0.15	15	<0.001	2.9	0.13	<0.0005	<0.005
Median	8.1	1.0	0.005	<0.001	16	<0.001	<0.001	<0.001	<0.05	<0.001	8.4	0.002	<0.0005	0.002	<0.15	14	<0.001	3.4	0.09	<0.0005	<0.005
HC 2 - Kimberlite: Dec 14 - Jan 11, 2005																					
Minimum	8.4	6.0	0.016	0.001	4.7	<0.001	<0.001	<0.001	<0.05	<0.001	2.4	<0.001	0.0035	0.0011	<0.15	3.4	0.0011	2.5	0.048	<0.0005	<0.005
Maximum	8.8	14	0.076	0.002	7.5	<0.001	<0.001	<0.001	0.08	<0.001	4.0	<0.001	0.011	0.002	<0.15	6.1	0.003	12	0.075	<0.0005	<0.005
Average	8.5	8.8	0.048	0.0013	6.1	<0.001	<0.001	<0.001	0.067	<0.001	3.2	<0.001	0.0072	0.0017	<0.15	4.5	0.0024	7.7	0.063	<0.0005	<0.005
Median	8.5	8.0	0.051	0.001	6.2	<0.001	<0.001	<0.001	0.07	<0.001	3.2	<0.001	0.007	0.002	<0.15	3.9	0.003	9.3	0.065	<0.0005	<0.005
HC 3 - Hypabyssal Kimberlite: Dec 14 - Jan 11, 2005																					
Minimum	8.7	6.0	<0.005	<0.001	4.5	<0.001	<0.001	<0.001	<0.05	<0.001	0.45	<0.001	<0.0005	<0.001	<0.15	9.5	<0.001	15	0.087	<0.0005	<0.005
Maximum	8.9	12	0.061	0.002	10.0	0.002	<0.001	<0.001	<0.05	<0.001	0.56	<0.001	<0.0005	0.001	<0.15	12	0.001	19	0.16	<0.0005	<0.005
Average	8.8	8.6	0.024	0.0013	6.3	0.0013	<0.001	<0.001	<0.05	<0.001	0.49	<0.001	<0.0005	0.001	<0.15	11	0.001	18	0.11	<0.0005	<0.005
Median	8.8	8.0	0.005	0.001	4.5	0.001	<0.001	<0.001	<0.05	<0.001	0.47	<0.001	<0.0005	0.001	<0.15	11	0.001	19	0.089	<0.0005	<0.005
HC 4 - Tuffistic Kimberlite Breccia: Dec 14 - Jan 11, 2005																					
Minimum	8.3	9.0	0.037	<0.001	4.1	<0.001	<0.001	<0.001	0.01	<0.001	1.8	<0.001	0.025	0.0012	<0.15	2.2	<0.001	6.9	0.048	<0.0005	<0.005
Maximum	8.6	45	0.12	0.001	9.3	<0.001	<0.001	<0.001	0.07	<0.001	4.0	<0.001	0.073	0.006	<0.15	4.4	0.003	25	0.1	0.0005	<0.005
Average	8.4	21	0.067	0.001	6.1	<0.001	<0.001	<0.001	0.043	<0.001	2.6	<0.001	0.041	0.0034	<0.15	3.4	0.0017	15	0.067	0.0005	<0.005
Median	8.4	18	0.043	0.001	4.8	<0.001	<0.001	<0.001	0.05	<0.001	2.1	<0.001	0.025	0.003	<0.15	3.6	0.001	14	0.054	0.0005	<0.005
HC 5 - Kimberlite: Dec 14 - Jan 11, 2005																					
Minimum	8.5	17	<0.005	<0.001	6.0	<0.001	<0.001	<0.001	<0.05	<0.001	4.1	<0.001	0.0013	<0.001	<0.15	5.4	<0.001	14	0.08	<0.0005	<0.005
Maximum	8.8	36	0.05	<0.001	14	<0.001	<0.001	<0.001	<0.05	<0.001	7.8	<0.001	0.0025	<0.001	<0.15	9.6	<0.001	31	0.16	<0.0005	<0.005
Average	8.6	24	0.02	<0.001	8.7	<0.001	<0.001	<0.001	<0.05	<0.001	5.5	<0.001	0.0021	<0.001	<0.15	7.3	<0.001	20	0.11	<0.0005	<0.005
Median	8.6	20	0.005	<0.001	6.6	<0.001	<0.001	<0.001	<0.05	<0.001	4.5	<0.001	0.0024	<0.001	<0.15	7.0	<0.001	14	0.091	<0.0005	<0.005
HC 6 - Kimberlite: Dec 14 - Jan 11, 2005																					
Minimum	7.8	18	0.024	<0.001	8.6	<0.001	<0.001	<0.001	<0.05	<0.001	3.5	0.002	0.0066	0.0021	<0.15	2.2	<0.001	1.3	0.076	<0.0005	<0.005
Maximum	8.3	34	0.077	<0.001	16	0.003	0.001	<0.001	0.14	<0.001	6.8	0.0043	0.024	0.005	<0.15	3.4	0.001	9.3	0.14	<0.0005	<0.005
Average	8.0	26	0.056	<0.001	11	0.0017	0.001	<0.001	0.1	<0.001	4.9	0.0031	0.015	0.0034	<0.15	2.8	0.001	5.4	0.1	<0.0005	<0.005
Median	8.1	25	0.068	<0.001	10	0.001	0.001	<0.001	0.12	<0.001	4.4	0.003	0.015	0.003	<0.15	2.9	0.001	5.7	0.097	<0.0005	<0.005
HC 11 - Kimberlite: Dec 14 - Jan 11, 2005																					
Minimum	7.6	1.0	0.063	<0.001	3.7	<0.001	<0.001	<0.001	<0.05	<0.001	0.4	0.006	0.0014	<0.001	<0.15	1.1	<0.001	<0.05	0.043	0.0005	<0.005
Maximum	8.0	5.0	0.099	0.001	4.8	<0.001	<0.001	0.002	<0.05	<0.001	0.6	0.042	0.0026	<0.001	<0.15	2.1	<0.001	2.4	0.049	0.026	<0.005
Average	7.8	3.8	0.081	0.001	4.2	<0.001	<0.001	0.0013	<0.05	<0.001	0.51	0.029	0.0021	<0.001	<0.15	1.7	<0.001	1.1	0.046	0.017	<0.005
Median	7.7	5.0	0.08	0.001	4.0	<0.001	<0.001	0.001	<0.05	<0.001	0.54	0.04	0.0023	<0.001	<0.15	2.0	<0.001	0.96	0.047	0.024	<0.005

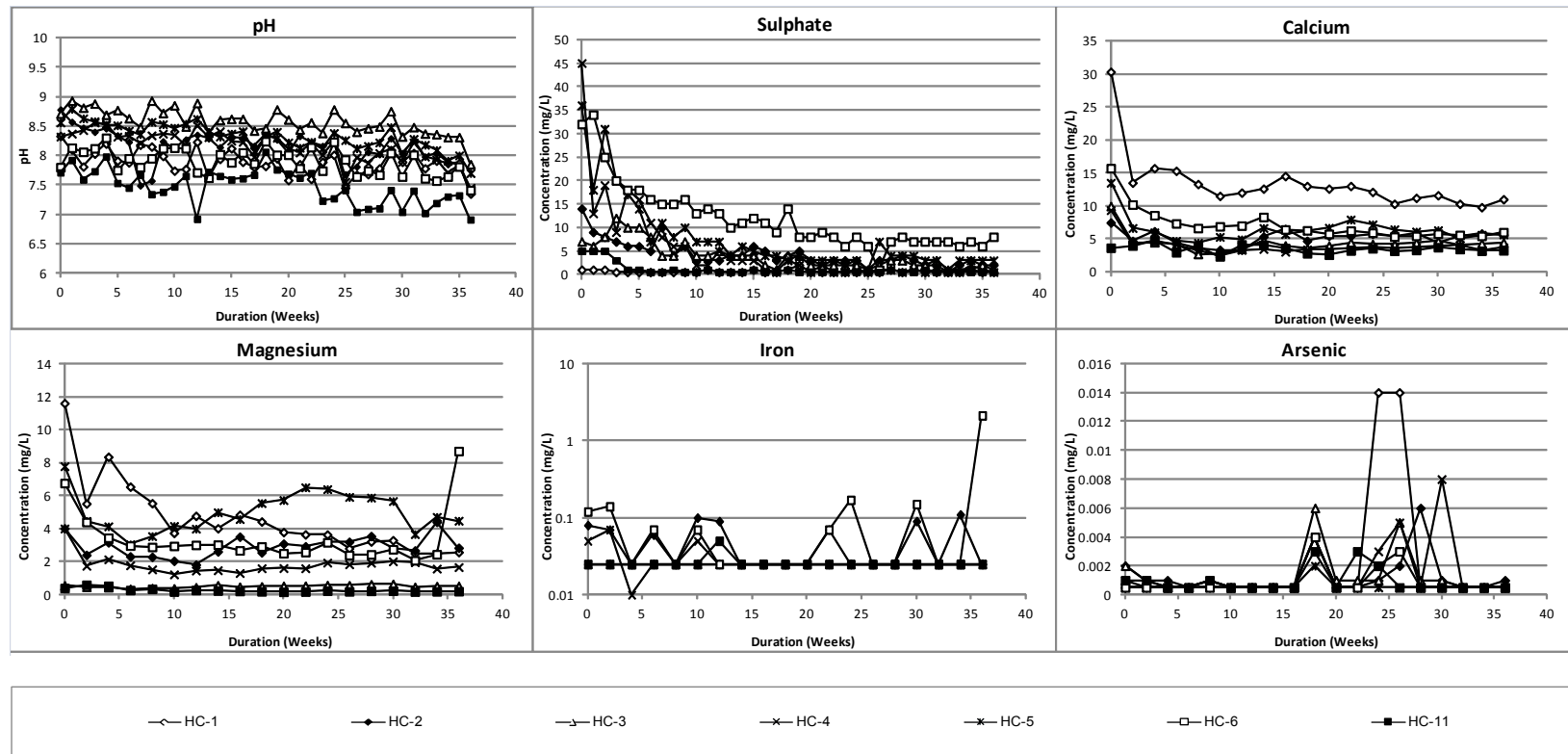
Note: s.u. = standard units; mg/L = milligrams per litre.

Table 8.III-10b Steady State Concentrations of Select Parameters in Kimberlite Humidity Cell Leachates

	pH	SO ₄	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Steady State																					
HC 1 - Kimberlite: Jul 26 - Aug 23, 2005																					
<i>Minimum</i>	7.4	<1	<0.005	<0.001	9.8	<0.001	<0.001	<0.001	<0.05	<0.001	2.5	<0.001	<0.0005	<0.001	<0.15	5.7	<0.001	1.9	0.042	<0.0005	<0.005
<i>Maximum</i>	7.9	1.0	<0.005	<0.001	11	<0.001	<0.001	<0.001	<0.05	<0.001	2.6	0.001	<0.0005	<0.001	<0.15	6.7	<0.001	2.1	0.047	<0.0005	<0.005
<i>Average</i>	7.7	1.0	<0.005	<0.001	10	<0.001	<0.001	<0.001	<0.05	<0.001	2.5	0.001	<0.0005	<0.001	<0.15	6.4	<0.001	2.0	0.045	<0.0005	<0.005
<i>Median</i>	7.9	1.0	<0.005	<0.001	10	<0.001	<0.001	<0.001	<0.05	<0.001	2.5	0.001	<0.0005	<0.001	<0.15	6.7	<0.001	2.0	0.045	<0.0005	<0.005
HC 2 - Kimberlite: Jul 26 - Aug 23, 2005																					
<i>Minimum</i>	7.4	<1	0.006	<0.001	5.3	<0.001	<0.001	<0.001	<0.05	<0.001	2.7	<0.001	<0.0005	<0.001	<0.15	2.0	<0.001	3.3	0.055	<0.0005	<0.005
<i>Maximum</i>	8.0	3.0	0.26	0.001	5.8	0.001	<0.001	<0.001	0.11	<0.001	4.4	0.003	<0.0005	0.012	<0.15	2.1	<0.001	4.0	0.064	<0.0005	<0.005
<i>Average</i>	7.8	2.0	0.092	0.001	5.6	0.001	<0.001	<0.001	0.07	<0.001	3.3	0.0017	<0.0005	0.0047	<0.15	2.0	<0.001	3.7	0.059	<0.0005	<0.005
<i>Median</i>	7.9	2.0	0.011	0.001	5.6	0.001	<0.001	<0.001	0.05	<0.001	2.8	0.001	<0.0005	0.001	<0.15	2.0	<0.001	3.7	0.059	<0.0005	<0.005
HC 3 - Hypabyssal Kimberlite: Jul 26 - Aug 23, 2005																					
<i>Minimum</i>	7.9	1.0	<0.005	<0.001	4.1	<0.001	<0.001	<0.001	<0.05	<0.001	0.47	<0.001	<0.0005	<0.001	<0.15	7.8	<0.001	10	0.07	<0.0005	<0.005
<i>Maximum</i>	8.4	2.0	<0.005	<0.001	4.5	<0.001	<0.001	<0.001	<0.05	<0.001	0.53	<0.001	<0.0005	<0.001	<0.15	7.8	<0.001	11	0.077	<0.0005	<0.005
<i>Average</i>	8.2	1.2	<0.005	<0.001	4.3	<0.001	<0.001	<0.001	<0.05	<0.001	0.51	<0.001	<0.0005	<0.001	<0.15	7.8	<0.001	11	0.074	<0.0005	<0.005
<i>Median</i>	8.3	1.0	<0.005	<0.001	4.3	<0.001	<0.001	<0.001	<0.05	<0.001	0.52	<0.001	<0.0005	<0.001	<0.15	7.8	<0.001	10	0.074	<0.0005	<0.005
HC 4 - Tuffistic Kimberlite Breccia: Jul 26 - Aug 23, 2005																					
<i>Minimum</i>	7.5	<1	0.025	<0.001	3.3	<0.001	<0.001	<0.001	<0.05	<0.001	1.6	<0.001	0.0008	<0.001	<0.15	1.4	<0.001	4.0	0.036	<0.0005	<0.005
<i>Maximum</i>	8.0	2.0	0.081	<0.001	4.1	<0.001	<0.001	<0.001	<0.05	<0.001	2.0	0.001	0.0011	0.002	<0.15	1.7	<0.001	5.0	0.043	<0.0005	<0.005
<i>Average</i>	7.7	1.2	0.047	<0.001	3.7	<0.001	<0.001	<0.001	<0.05	<0.001	1.7	0.001	0.00097	0.0013	<0.15	1.5	<0.001	4.5	0.04	<0.0005	<0.005
<i>Median</i>	7.8	1.0	0.035	<0.001	3.7	<0.001	<0.001	<0.001	<0.05	<0.001	1.7	0.001	0.001	0.001	<0.15	1.5	<0.001	4.4	0.04	<0.0005	<0.005
HC 5 - Kimberlite: Jul 26 - Aug 23, 2005																					
<i>Minimum</i>	7.7	1.0	<0.005	<0.001	5.1	<0.001	<0.001	<0.001	<0.05	<0.001	3.7	<0.001	<0.0005	<0.001	<0.15	3.8	<0.001	1.3	0.063	<0.0005	<0.005
<i>Maximum</i>	8.2	3.0	0.013	<0.001	5.7	<0.001	<0.001	<0.001	<0.05	<0.001	4.7	<0.001	<0.0005	<0.001	<0.15	4.3	<0.001	1.6	0.078	<0.0005	<0.005
<i>Average</i>	7.9	2.6	0.0077	<0.001	5.5	<0.001	<0.001	<0.001	<0.05	<0.001	4.3	<0.001	<0.0005	<0.001	<0.15	4.1	<0.001	1.4	0.072	<0.0005	<0.005
<i>Median</i>	8.0	3.0	0.005	<0.001	5.6	<0.001	<0.001	<0.001	<0.05	<0.001	4.5	<0.001	<0.0005	<0.001	<0.15	4.2	<0.001	1.3	0.075	<0.0005	<0.005
HC 6 - Kimberlite: Jul 26 - Aug 23, 2005																					
<i>Minimum</i>	7.4	6.0	0.011	<0.001	5.5	<0.001	<0.001	<0.001	<0.05	<0.001	2.1	0.001	<0.0005	<0.001	<0.15	2.8	<0.001	0.92	0.048	<0.0005	<0.005
<i>Maximum</i>	7.8	8.0	1.7	<0.001	6.0	0.02	0.008	<0.001	2.1	<0.001	8.7	0.016	<0.0005	0.078	<0.15	2.9	<0.001	1.3	0.056	<0.0005	<0.005
<i>Average</i>	7.6	6.8	0.57	<0.001	5.7	0.0073	0.0033	<0.001	0.74	<0.001	4.4	0.0063	<0.0005	0.027	<0.15	2.8	<0.001	1.1	0.051	<0.0005	<0.005
<i>Median</i>	7.6	7.0	0.039	<0.001	5.6	0.001	0.001	<0.001	0.05	<0.001	2.5	0.002	<0.0005	0.003	<0.15	2.8	<0.001	1.2	0.05	<0.0005	<0.005
HC 11 - Kimberlite: Jul 26 - Aug 23, 2005																					
<i>Minimum</i>	6.9	<1	0.059	<0.001	3.2	<0.001	<0.001	<0.001	<0.05	<0.001	0.19	0.004	<0.0005	<0.001	<0.15	0.3	<0.001	<0.05	0.013	0.004	<0.005
<i>Maximum</i>	7.3	<1	0.065	<0.001	3.5	<0.001	<0.001	<0.001	<0.05	<0.001	0.21	0.008	<0.0005	<0.001	<0.15	0.4	<0.001	0.09	0.014	0.0047	<0.005
<i>Average</i>	7.1	<1	0.062	<0.001	3.3	<0.001	<0.001	<0.001	<0.05	<0.001	0.2	0.006	<0.0005	<0.001	<0.15	0.37	<0.001	0.073	0.013	0.0044	<0.005
<i>Median</i>	7.2	<1	0.063	<0.001	3.3	<0.001	<0.001	<0.001	<0.05	<0.001	0.2	0.006	<0.0005	<0.001	<0.15	0.4	<0.001	0.08	0.013	0.0046	<0.005

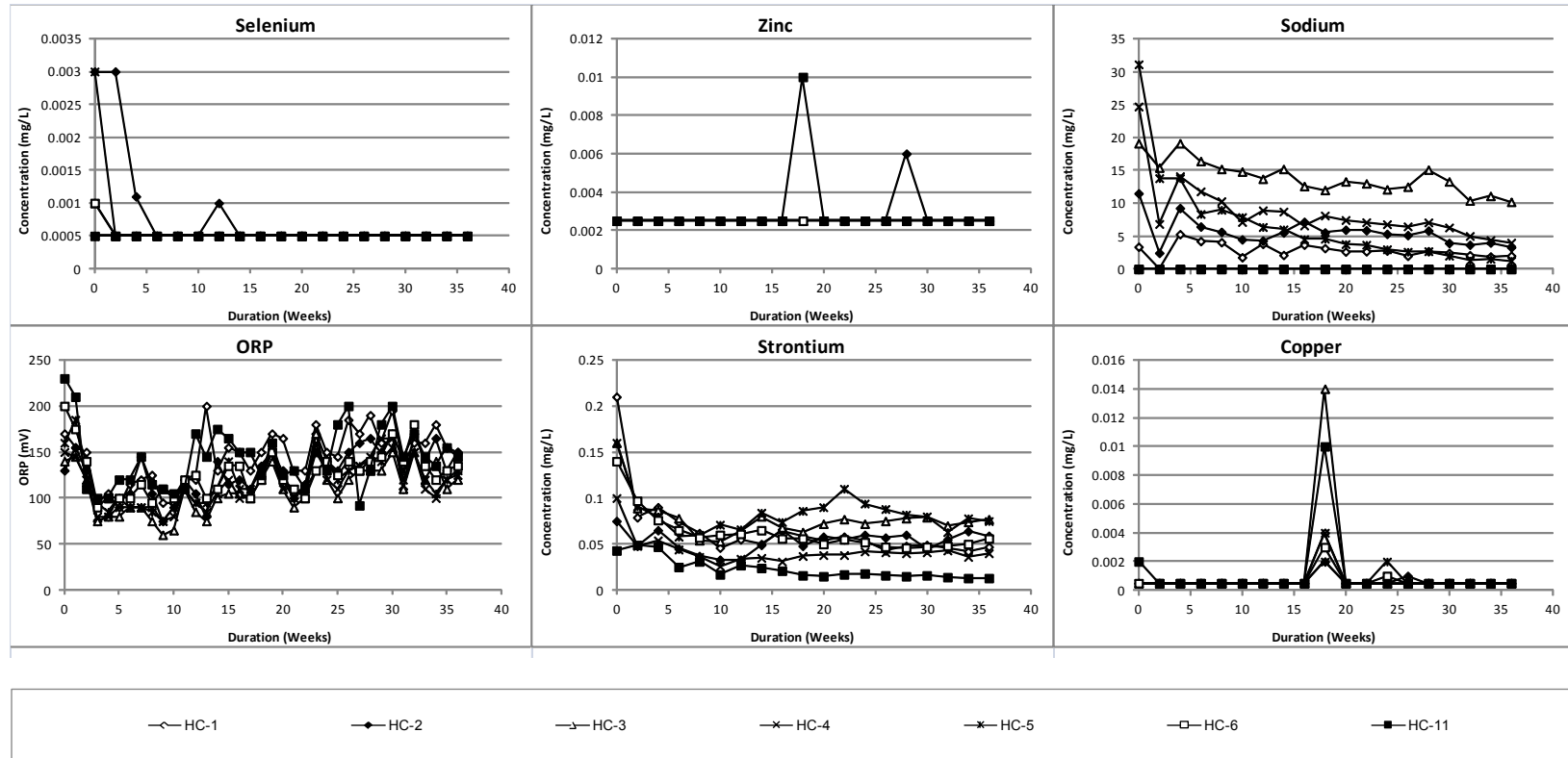
Note: s.u. = standard units; mg/L = milligrams per litre; <= less than.

Figure 8.III-4a Leachate Concentrations in Kimberlite Humidity Cells



Note: Total dissolved solids and fluoride not measured in humidity cell test leachates. Phosphorus concentrations were below detection limits throughout testing.

Figure 8.III-4b Leachate Concentrations in Kimberlite Humidity Cells



Note: Total dissolved solids and fluoride not measured in humidity cell test leachates. Phosphorus concentrations were below detection limits throughout testing.

Table 8.III-11 Estimated Acid Potential and Neutralization Potential Depletion Times for Kimberlite Humidity Cells

Humidity Cell ID	Lithology	Sulphide Sulphur (wt%)	NP (kg CaCO ₃ /t)	Time to Depletion (Years)				
				Sulphide Sulphur	NP (emp)	CaNP (emp)	NP (SO ₄)	CaNP (SO ₄)
HC 1	Kimberlite	0.02	326	40	331	20	14954	909
HC 2	Kimberlite	0.02	188	11	151	5.0	2716	102
HC 3	Hypabyssal Kimberlite	0.01	442	7.8	192	4.6	7119	194
HC 4	Tuffistic Kimberlite Breccia	0.02	148	23	131	3.9	3940	138
HC 5	Kimberlite	0.01	422	2.5	168	2.1	2483	42
HC 6	Kimberlite	0.04	52	6.2	111	16	406	60
HC 11	Kimberlite	0.05	4.1	120	34	3.2	464	52

Note: ID = identification; emp = empirical; NP = neutralization potential; CaNP = calcium neutralization potential; wt% = percent by weight; kg CaCO₃/t = kilograms of calcium carbonate per tonne; SO₄ = sulphate.

8.III.4.1.5 Column Tests

Tables 8.III-12a and 8.III-12b contain a summary of the column leachate concentrations for selected parameters. Results are presented for both the first flush (the first five weeks) in Table 8.III-12a and steady state conditions (the last five weeks) in Table 8.III-12b. Figure 8.III-5a, 8.III-5b, and 8.III-5c presents the concentrations of key parameters, pH values and ORP values in the column leachates. Attachment 8.III-9 provides the detailed results.

The principal observations with respect to the kimberlite columns are as follows:

- Neutral to alkaline pH values were maintained through the duration of the kimberlite kinetic tests and pH values remained generally stable over time.
- The sulphate concentrations decreased after the first five weeks in kimberlite column leachates. Concentrations were typically less than 20 milligrams per litre (mg/L) after week 10.
- Concentrations of major ions including magnesium and calcium generally decreased over time after five weeks. Sodium concentrations in leachates decreased gradually over time during testing.
- Key metal concentrations including selenium, zinc, and iron were below the detection limits in many samples. Arsenic concentrations generally increased over time.

Table 8.III-12a First Flush Concentrations of Select Parameters in Kimberlite Column Leachates

	pH	SO ₄	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Column 5 - Kimberlite: Jan 31, 2005 - Feb 28, 2005																					
<i>Minimum</i>	7.3	122	<0.005	0.002	34	<0.001	<0.001	<0.001	<0.05	<0.001	15	0.004	0.049	0.013	<0.15	11	0.002	50	0.41	0.021	<0.005
<i>Maximum</i>	8.5	1252	0.019	0.005	422	<0.001	0.009	0.003	0.15	<0.001	148	0.078	0.25	0.087	<0.15	29	0.017	146	4.6	0.026	<0.005
<i>Average</i>	7.7	531	0.01	0.003	170	<0.001	0.004	0.0017	0.083	<0.001	62	0.03	0.14	0.04	<0.15	18	0.0073	86	1.9	0.023	<0.005
<i>Median</i>	8.3	218	0.006	0.002	54	<0.001	0.002	0.001	0.05	<0.001	22	0.007	0.13	0.019	<0.15	14	0.003	63	0.65	0.021	<0.005
Column 7 - Kimberlite: Jan 31, 2005 - Feb 28, 2005																					
<i>Minimum</i>	7.9	100	<0.005	0.013	25	<0.001	<0.001	<0.001	<0.05	<0.001	14	<0.001	0.023	0.004	<0.15	17	<0.001	28	0.28	<0.0005	<0.005
<i>Maximum</i>	8.0	308	0.029	0.022	74	0.001	<0.001	0.001	0.11	<0.001	43	0.004	0.044	0.012	<0.15	23	0.003	45	0.81	<0.0005	<0.005
<i>Average</i>	8.0	181	0.013	0.017	45	0.001	<0.001	0.001	0.07	<0.001	25	0.002	0.032	0.0073	<0.15	20	0.0017	35	0.49	<0.0005	<0.005
<i>Median</i>	8.0	134	0.005	0.017	35	0.001	<0.001	0.001	0.05	<0.001	19	0.001	0.029	0.006	<0.15	19	0.001	32	0.38	<0.0005	<0.005
Column 8 - Kimberlite: Jan 31, 2005 - Feb 28, 2005																					
<i>Minimum</i>	7.8	310	<0.005	0.002	34	<0.001	<0.001	<0.001	<0.05	<0.001	13	0.005	0.54	0.005	<0.15	6.6	0.002	80	0.52	0.0008	<0.005
<i>Maximum</i>	7.9	1647	0.009	0.003	334	<0.001	0.001	0.002	0.2	<0.001	115	0.021	2.2	0.019	<0.15	18	0.019	242	5.2	0.0071	<0.005
<i>Average</i>	7.9	858	0.0063	0.0023	157	<0.001	0.001	0.0013	0.1	<0.001	54	0.012	1.3	0.013	<0.15	12	0.0083	153	2.4	0.0031	<0.005
<i>Median</i>	7.8	617	0.005	0.002	104	<0.001	0.001	0.001	0.06	<0.001	36	0.009	1.1	0.014	<0.15	12	0.004	138	1.6	0.0014	<0.005
Column 9 - Kimberlite: Jan 31, 2005 - Feb 28, 2005																					
<i>Minimum</i>	8.2	72	<0.005	0.016	14	<0.001	<0.001	<0.001	<0.05	<0.001	2.9	<0.001	0.012	<0.001	<0.15	18	0.003	38	0.21	<0.0005	<0.005
<i>Maximum</i>	8.2	273	0.008	0.044	78	0.003	<0.001	<0.001	<0.05	<0.001	17	0.002	0.043	0.002	<0.15	36	0.016	80	1.3	<0.0005	<0.005
<i>Average</i>	8.2	157	0.006	0.031	39	0.002	<0.001	<0.001	<0.05	<0.001	8.4	0.0013	0.027	0.0013	<0.15	26	0.0077	55	0.61	<0.0005	<0.005
<i>Median</i>	8.2	125	0.005	0.032	24	0.002	<0.001	<0.001	<0.05	<0.001	4.8	0.001	0.027	0.001	<0.15	24	0.004	48	0.38	<0.0005	<0.005
Column 10 - Kimberlite: Jan 31, 2005 - Feb 28, 2005																					
<i>Minimum</i>	8.4	3.0	0.009	0.001	2.7	0.001	<0.001	<0.001	<0.05	<0.001	0.06	<0.001	0.0005	<0.001	<0.15	20	<0.001	125	1.9	<0.0005	<0.005
<i>Maximum</i>	8.9	4.0	0.009	0.002	6.6	0.001	<0.001	<0.001	<0.05	<0.001	0.18	<0.001	0.001	<0.001	<0.15	35	<0.001	238	3.4	<0.0005	<0.005
<i>Average</i>	8.6	3.3	0.009	0.0013	4.4	0.001	<0.001	<0.001	<0.05	<0.001	0.12	<0.001	0.0007	<0.001	<0.15	27	<0.001	175	2.5	<0.0005	<0.005
<i>Median</i>	8.7	3.0	0.009	0.001	3.9	0.001	<0.001	<0.001	<0.05	<0.001	0.13	<0.001	0.0006	<0.001	<0.15	26	<0.001	161	2.2	<0.0005	<0.005

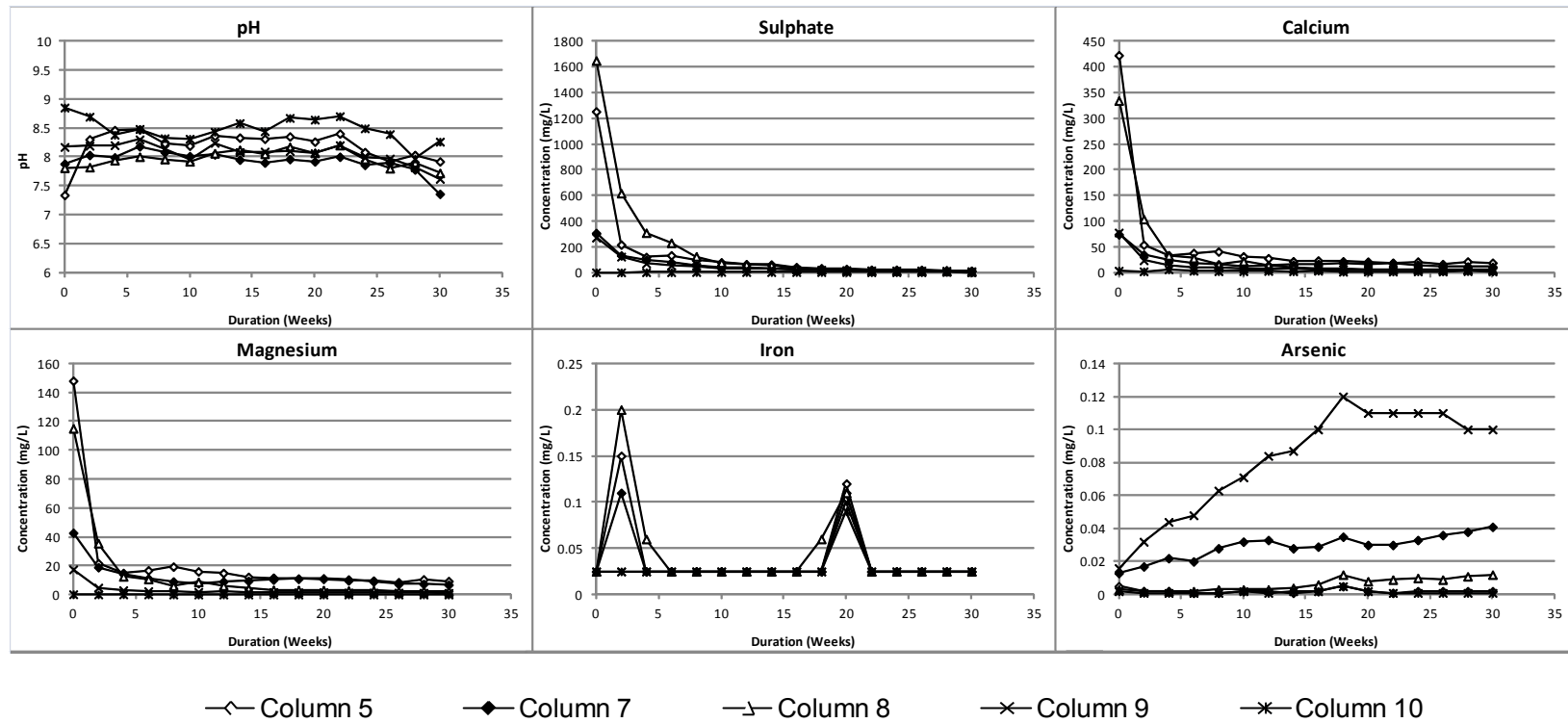
Note: **s.u.** = standard units; mg/L = milligrams per litre; <= less than.

Table 8.III-12b Steady State Concentrations of Select Parameters in Kimberlite Column Leachates

	pH	SO ₄	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Column 5 - Kimberlite: Aug 1, 1005 - Aug 29, 2005																					
<i>Minimum</i>	7.9	15	<0.005	0.002	17	<0.001	<0.001	<0.001	<0.05	<0.001	8.5	<0.001	0.0073	0.004	<0.15	8.4	0.002	20	0.22	0.015	<0.005
<i>Maximum</i>	8.0	22	0.011	0.002	22	<0.001	<0.001	<0.001	<0.05	<0.001	11	<0.001	0.0091	0.006	<0.15	9.7	0.002	24	0.25	0.021	<0.005
<i>Average</i>	8.0	19	0.007	0.002	19	<0.001	<0.001	<0.001	<0.05	<0.001	9.4	<0.001	0.0083	0.005	<0.15	9.2	0.002	22	0.24	0.018	<0.005
<i>Median</i>	7.9	19	0.005	0.002	19	<0.001	<0.001	<0.001	<0.05	<0.001	9.3	<0.001	0.0085	0.005	<0.15	9.6	0.002	23	0.25	0.018	<0.005
Column 7 - Kimberlite: Aug 1, 1005 - Aug 29, 2005																					
<i>Minimum</i>	7.4	13	<0.005	0.036	12	<0.001	<0.001	<0.001	<0.05	<0.001	6.8	<0.001	0.0014	<0.001	<0.15	17	0.001	7.3	0.12	<0.0005	<0.005
<i>Maximum</i>	7.9	17	<0.005	0.041	12	<0.001	<0.001	<0.001	<0.05	<0.001	7.3	<0.001	0.0019	<0.001	<0.15	19	0.002	9.4	0.14	<0.0005	<0.005
<i>Average</i>	7.6	15	<0.005	0.038	12	<0.001	<0.001	<0.001	<0.05	<0.001	7.1	<0.001	0.0017	<0.001	<0.15	18	0.0017	8.2	0.13	<0.0005	<0.005
<i>Median</i>	7.8	15	<0.005	0.038	12	<0.001	<0.001	<0.001	<0.05	<0.001	7.3	<0.001	0.0017	<0.001	<0.15	18	0.002	7.9	0.13	<0.0005	<0.005
Column 8 - Kimberlite: Aug 1, 1005 - Aug 29, 2005																					
<i>Minimum</i>	7.7	10	0.025	0.009	5.9	<0.001	<0.001	<0.001	<0.05	<0.001	2.4	<0.001	0.11	<0.001	<0.15	3.3	<0.001	37	0.084	0.0007	<0.005
<i>Maximum</i>	7.9	14	0.06	0.012	6.3	<0.001	<0.001	<0.001	<0.05	<0.001	2.6	<0.001	0.12	0.002	<0.15	3.6	0.002	41	0.094	0.001	0.006
<i>Average</i>	7.8	12	0.039	0.011	6.0	<0.001	<0.001	<0.001	<0.05	<0.001	2.5	<0.001	0.12	0.0013	<0.15	3.5	0.0017	39	0.089	0.0008	0.0053
<i>Median</i>	7.8	12	0.033	0.011	5.9	<0.001	<0.001	<0.001	<0.05	<0.001	2.4	<0.001	0.12	0.001	<0.15	3.6	0.002	38	0.09	0.0007	0.005
Column 9 - Kimberlite: Aug 1, 1005 - Aug 29, 2005																					
<i>Minimum</i>	7.6	12	<0.005	0.1	5.1	0.002	<0.001	<0.001	<0.05	<0.001	1.1	<0.001	0.0007	<0.001	<0.15	11	<0.001	22	0.077	<0.0005	<0.005
<i>Maximum</i>	8.0	17	<0.005	0.11	5.6	0.003	<0.001	<0.001	<0.05	<0.001	1.3	<0.001	0.001	<0.001	<0.15	12	0.002	24	0.091	<0.0005	<0.005
<i>Average</i>	7.8	15	<0.005	0.1	5.3	0.0023	<0.001	<0.001	<0.05	<0.001	1.2	<0.001	0.00083	<0.001	<0.15	12	0.0013	23	0.083	<0.0005	<0.005
<i>Median</i>	7.8	15	<0.005	0.1	5.2	0.002	<0.001	<0.001	<0.05	<0.001	1.3	<0.001	0.0008	<0.001	<0.15	11	0.001	23	0.082	<0.0005	<0.005
Column 10 - Kimberlite: Aug 1, 1005 - Aug 29, 2005																					
<i>Minimum</i>	8.0	3.0	0.006	0.001	2.4	<0.001	<0.001	<0.001	<0.05	<0.001	<0.05	<0.001	<0.0005	<0.001	<0.15	13	<0.001	30	1.1	<0.0005	<0.005
<i>Maximum</i>	8.4	6.0	0.007	0.001	3.0	<0.001	<0.001	<0.001	<0.05	<0.001	<0.05	<0.001	<0.0005	<0.001	<0.15	13	<0.001	40	1.1	<0.0005	0.005
<i>Average</i>	8.2	4.3	0.0067	0.001	2.6	<0.001	<0.001	<0.001	<0.05	<0.001	<0.05	<0.001	<0.0005	<0.001	<0.15	13	<0.001	36	1.1	<0.0005	0.005
<i>Median</i>	8.3	4.0	0.007	0.001	2.4	<0.001	<0.001	<0.001	<0.05	<0.001	<0.05	<0.001	<0.0005	<0.001	<0.15	13	<0.001	37	1.1	<0.0005	0.005

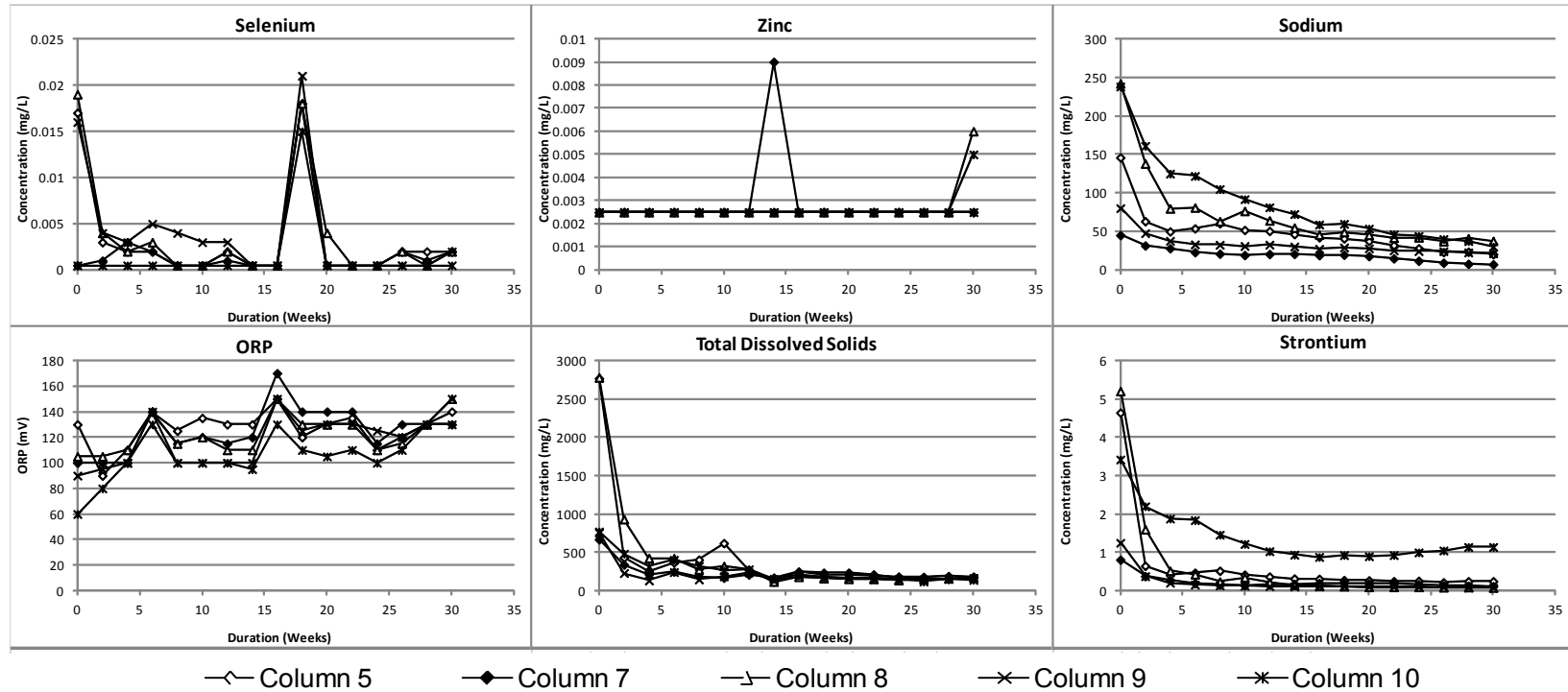
Note: **s.u.** = standard units; mg/L = milligrams per litre.

Figure 8.III-5a Leachate Concentrations in Kimberlite Columns



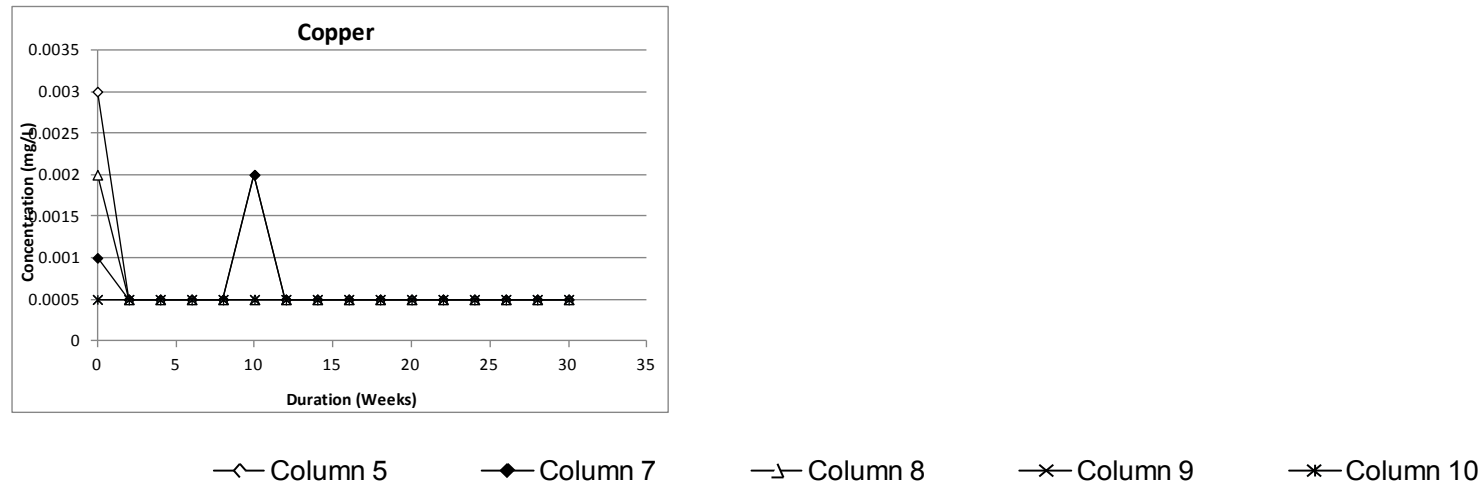
Note: Fluoride not measured in column test leachates. Phosphorus concentrations were below detection limits throughout testing.

Figure 8.III-5b Leachate Concentrations in Kimberlite Columns



Note: Fluoride not measured in column test leachates. Phosphorus concentrations were below detection limits throughout testing.

Figure 8.III-5c Leachate Concentrations in Kimberlite Columns



Note: Fluoride not measured in column test leachates. Phosphorus concentrations were below detection limits throughout testing.

8.III.4.1.6 Comparison with Other Kimberlites

Table 8.III-13 presents a range of kimberlite kinetic test results from the seven Gahcho Kué Project (Project) kimberlite humidity cells, two Diavik Diamond Mine kimberlite humidity cell samples, five Snap Lake Mine humidity cell samples, and five Ekati Mine kimberlite humidity cell samples (Golder 2002).

The first Diavik Diamond Mine sample is a volcanoclastic kimberlite representative of the bulk of the kimberlite material at the Diavik Diamond Mine site. The second Diavik Diamond Mine sample represents a kimberlite rich material with mudstone xenoliths. The five Ekati Mine samples represent kimberlites from a number of different pipes. Results presented for the Project, Snap Lake Mine and Ekati Mine are the minimum and maximum (i.e., range) of the average values from the numerous humidity cells. The average was calculated using the long-term steady state (last five measurements) concentrations.

The results suggest that the Project kimberlite kinetic leaching results are most similar to Snap Lake Mine samples and somewhat similar to Ekati Diamond Mine. The Project kimberlite results are the least similar to Diavik Diamond Mine kimberlite. Leachate pH values from all the projects were neutral to alkaline with the exception of mudstone rich kimberlite at Diavik Diamond Mine. Concentrations of aluminum, cobalt, chromium, and iron were similar between the current project and Ekati Mine; both of which were greater relative to Snap Lake Mine and less than Diavik Diamond Mine. Nickel and molybdenum concentrations were greater at Ekati Mine and Snap Lake Mine compared to the Project. Copper and zinc concentrations measured at the detection limit hinders comparison with Snap Lake Mine.

Table 8.III-13 Comparison of Selected Parameters at Steady State for Kimberlite Humidity Cells

Parameter	Units	Gahcho Kué Project (n=7)	Snap Lake Mine (n=5)	Diavik Diamond Mine		Range in Ekati Mine Samples (n=5)
				Stage 1 Kimberlite (n=1)	Stage 1 Mudstone (n=1)	
Total sulphur	wt %	0.02 to 0.05	0.05 to 0.15	0.42	3.5	0.001 to 0.7
NP/AP		4.1 to 442	8.2 to 363	6.5	0.38	7.7 to 14,496
pH		6.91 to 8.37	8.0 to 8.02	8.38	3.5	8.0 to 10.8
Sulphate	mg/L	<1 to 8.0	3.8 to 27.2	691	8,765	3.2 to 48.0
Aluminum	mg/L	<0.005 to 1.7	0.003 to 0.016	<0.001	69.7	0.009 to 0.22
Cobalt	µg/L	<1 to 8.0	0.19 to 0.54	3.1	2,713	0.12 to 0.54
Chromium	µg/L	<1 to 2.82	0.33 to 1.5	1	27.3	1.7 to 3.9
Copper	µg/L	<1-20	0.3 to 1.7	4.2	217	3.5 to 9.5
Iron	mg/L	<0.05 to 2.12	<0.01 to 0.05	<0.01	0.39	0.0023 to 0.3
Potassium	µg/L	30 to 780	3.9 to 837	-	-	4.4 to 15.6
Manganese	µg/L	<1 to 16	1.6 to 5.0	9.3	23,700	0.62 to 8.2
Molybdenum	µg/L	<0.5 to 1.1	2.8 to 13.3	131	0.2	1.1 to 13.7
Nickel	µg/L	<1 to 78	1.7 to 51	3.7	19,500	1.6 to 15
Zinc	µg/L	<5	0.25 to 1.58	3.4	11,600	4.6 to 22

Source: Golder 2002.

8.III.4.2 Processed Kimberlite

The processing of kimberlite material is largely a mechanical process with few reagents. Processing of kimberlite involves four principle steps (De Beers 2010):

- multiple stages of crushing;
- scrubbing and screening;
- diamond recovery; and
- disposal of reject material.

PK is the residual material that remains after processing of the raw kimberlite ore. Samples of PK and process water were provided for geochemical testing by De Beers.

8.III.4.2.1 Static Testing

General Mineralogical Analysis

In 2004, 12 coarse PK samples were submitted for optical mineralogy and XRD analysis (Petrascience 2004 – Attachment 8.III.3). Results showed that the samples were dominated by kimberlitic material, typically pervasively altered to a very fine-grained assemblage of clays, including vermiculite, chlinochlore, phlogopite and talc with minor (1% – 10%) actinolite, orthoclase [KAlSi₃O₈], quartz, hematite [Fe₂O₃] and lizardite [Mg₃Si₂O₅]. Carbonate concentrations range from 1.3 to 3.1%, consisting primarily of calcite [CaCO₃]. According to the mineralogical report, sulphide minerals are extremely rare in the samples (less

than 2%) and mostly consist of pyrite with lesser chalcopyrite and trace pyrrhotite. A detailed mineralogy summary is reported in Table 8.III-14a and 8.III-14b.

In 2010, two PK samples (fine and coarse) were submitted for XRD analysis (CEMI 2010 – Attachment 8.III.3). Similar to 2004 results, 2010 results showed that the coarse PK sample was dominated by clays, including montmorillonite (27%) $[(\text{Na,Ca})_{0.3}(\text{Al,Mg})_2\text{Si}_4\text{O}_{10}(\text{OH})_2 \cdot n\text{H}_2\text{O}]$, talc (12%) and biotite (13%), with 11% quartz, 13% plagioclase $[\text{NaAlSi}_3\text{O}_8 - \text{CaAl}_2\text{Si}_2\text{O}_8]$ and minor (1% - 10%) lizardite, potassium feldspar, diopside $[\text{CaMgSi}_2\text{O}_6]$, magnetite $[\text{Fe}_3\text{O}_4]$ and forsterite $[\text{Mg}_2\text{SiO}_4]$ (Table 8.III-14a and 8.III-14b). The coarse PK contains 1.3% carbonates, including 0.4% calcite, and 0.9% dolomite. The presence of sulphide minerals was not observed.

The fine PK sample was dominated by montmorillonite (50%) with 11% talc, and minor (1% - 10%) biotite, lizardite, potassium feldspar, plagioclase, quartz, diopside, magnetite, and forsterite (Table 8.III-14a and 8.III-14b). Carbonate mineral concentrations are higher than those reported in the coarse PK in the same year, and include calcite (0.8%) and dolomite (1.4%) $[(\text{Ca,Mg})\text{CO}_3]$. The presence of sulphide minerals was not observed.

In 2011, seven additional samples were submitted for mineralogical analysis to determine the general mineralogical composition, and identify the source minerals and associations of phosphorus in the PK (SGS Lakefield – Attachment 8.III-3). Samples submitted included three coarse PK samples generated in 2010, three fine PK samples generated by crushing the coarse PK samples, and one fine composite sample from 2010 testing. The mineralogical composition of the PK samples submitted for kinetic testing was dominated by silicate minerals, including serpentine (16% to 37%) $[(\text{Mg,Fe})_3\text{Si}_2\text{O}_5(\text{OH})_4]$, undifferentiated magnesium-bearing clays (7% to 19%), chlorite (8% to 14%) $[(\text{Mg,Fe})_3(\text{Si,Al})_4\text{O}_{10}(\text{OH})_2 \cdot (\text{Mg,Fe})_3(\text{OH})_6]$, quartz (0.4% to 15%) $[\text{SiO}_2]$, potassium feldspar (2% to 18%) $[\text{KAlSi}_3\text{O}_8]$ and olivine (1% to 26%) $[(\text{Fe,Mg})_2\text{SiO}_4]$ with minor (1% to 10%) diopside $[\text{CaMgSi}_2\text{O}_6]$, amphibole $[(\text{Mg,Fe,Ca,Na})_{2-3}(\text{Mg,Fe,Al})_5(\text{Si,Al})_8\text{O}_{22}\text{OH}_2]$, plagioclase $[\text{NaAlSi}_3\text{O}_8 - \text{CaAl}_2\text{Si}_2\text{O}_8]$, talc $[\text{Mg}_3\text{Si}_4\text{O}_{10}]$ and biotite $[\text{K}(\text{Mg,Fe})_3\text{AlSi}_3\text{O}_{10}(\text{F,OH})_2]$.

Carbonate minerals included calcite (0.26% to 0.95%) $[\text{CaCO}_3]$, dolomite (0.15% to 1.3%) $[(\text{Ca,Mg})\text{CO}_3]$, and other carbonate (0.01% to 0.11%). Sulphide concentrations were consistent with those reported in ABA analysis, ranging from 0.03% to 0.36% sulphide minerals and generally higher sulphide concentrations were reported in the fine PK fractions, which could have been the result of the samples used, or preferential liberation of sulphide minerals through grinding.

With the exception of sulphide concentrations, no trends in general composition were reported to differentiate the fine PK from the coarse PK. Generally, sample composition varied between the DGM samples, but remained similar between the coarse and fine PK fractions for each sample.

Table 8.III-14a Summary of Processed Kimberlite Mineralogy

Mineral		Formula	Mineral Composition (%)																				
			Coarse Processed Kimberlite														Fine Processed Kimberlite						
			2004	2004	2004	2004	2004	2004	2004	2004	2004	2004	2004	2004	2010	2011			2010	2011			
		I-3	I-4	II-10	II-12	II-13	II-17	II-18	III-1	IV1+ IV2	V1+V2	VI-1	VIII-1	PK-Coarse Composite	DGM 717 -1280/+ 200 µm	DGM 717 - 212 µm	DGM 713 -1280/+ 200 µm	PK-Fines Comp	DGM 713 - 212 µm	DGM 737 - 1280/+200 µm	DGM 737 - 212	PK Comp - 200 µm	
Semi-quantitative XRD	Montmorillonite model	(Na,Ca) _{0.3} (Al,Mg) ₂ Si ₄ O ₁₀ (OH) ₂ ·nH ₂ O												27				50					
	Vermiculite 2M	(Mg,Fe,Al) ₃ (Al,Si) ₄ O ₁₀ (OH)	26	25	28	29	26	27	24	20	19	17	20	20									
	Chlorite	(Mg,Fe) ₃ (Si,Al) ₄ O ₁₀ (OH) ₂ ·(Mg,Fe) ₃ (OH) ₆														13.71	10.88	7.90		7.52	9.55	7.72	8.80
	Clinocllore II	(Mg ₅ Al)(AlSi ₃)O ₁₀ (OH) ₈	26	25	31	27	34	21	25	28	30	31	24	31									
	Phlogopite 1M	KMg ₃ AlSi ₃ O ₁₀ (F,OH) ₂	5.9	6.1	8.9	5.4	8.8	8.1	13	11	11	11	9.5	13									
	Biotite	K(Mg,Fe) ₃ (AlSi ₃ O ₁₀)(OH) ₂													13	3.85	4.70	10.84	9.3	11.08	4.66	3.26	5.24
	Actinolite	Ca ₂ (Mg,Fe) ₅ Si ₈ O ₂₂ (OH) ₂	4.9	4.2		2.2				2.7			4.7										
	Amphibole	(Mg,Fe,Ca,Na) ₂₋₃ (Mg,Fe,Al) ₅ (Si,Al) ₈ O ₂₂ OH ₂														2.82	2.47	1.40		1.98	9.32	7.44	2.81
	Pectolite 1A	NaCa ₂ Si ₃ O ₈ (OH)												0.8									
	Natrolite	Na ₂ Al ₂ Si ₃ O ₁₀																					
	Talc 1A	Mg ₃ Si ₄ O ₁₀	28	28	19	22	26	22	22	19	16	17	19	11	12	6.77	8.01	6.94	11	6.58	2.84	3.26	7.08
	Lizardite	Mg ₃ Si ₂ O ₅	?	?	5.4			15	10	9.2	11	11	8.9	13	5.4				4.1				
	Serpentine	(Mg,Fe) ₃ Si ₂ O ₅ (OH) ₄														34.87	36.96	25.17		15.66	23.82	28.64	31.76
	Mg-Clays															18.78	17.56	10.54		6.59	10.71	12.01	11.76
	Diopside	CaMgSi ₂ O ₆													1.9	2.83	3.18	0.25	1.7	0.47	6.26	4.20	1.61
	Orthopyroxene	(Mg,Fe) ₂ Si ₂ O ₆														1.59	1.42	1.69		1.44	1.13	1.18	1.34
	Monticellite	CaMgSiO ₄							97														
	Forsterite	Mg ₂ SiO ₄							1.0	2.5	4.1	4.0	2.2	4.8	4.2				2.4				
	Olivine	(Fe,Mg) ₂ SiO ₄														3.81	3.04	1.48		0.74	19.92	26.39	7.17
	Garnite - Pyrope	Mg ₃ Al ₂ (SiO ₄)														0.03	0.05	0.11		0.13	0.34	0.13	0.08
	Plagioclase	NaAlSi ₃ O ₈ – CaAl ₂ Si ₂ O ₈													13	0.43	0.71	6.29	6.4	10.27	0.82	0.28	2.69
	K-Feldspar	KAlSi ₃ O ₈													8.8	5.98	4.80	17.77	6.6	17.04	5.90	1.76	8.68
	Microcline intermediate	KAlSi ₃ O ₈				7.7																	
	Orthoclase	KAlSi ₃ O ₈	4.5	4.5	4.7		3.1	3.1	1.7	2.6	3.0	3.9	3.7	2.8									
	Quartz	SiO ₂	3.3	4.2	1.6	2.9		1.3		2.0	2.5	2.3	4.3	1.0	11	0.32	2.15	5.30	5.1	14.73	1.43	0.44	5.69
	Other Silicates															0.08	0.09	0.42		0.43	0.28	0.14	0.18
	Fe-Oxides															0.11	0.75	0.72		1.91	0.20	0.45	1.25
	Magnetite	Fe ₃ O ₄													1.3				1.1				
	Hematite	Fe ₂ O ₃				3.5					0.5	0.4	0.3										
	Chromite	FeCr ₂ O ₄														0.35	0.36	0.17		0.10	0.52	0.39	0.32
	Ilmenite	FeTiO ₃														0.03	0.29	1.21		0.90	0.54	0.74	0.51
	Rutile	TiO ₂					1.0		0.5	0.6		0.4	0.8	0.6									
	Anatase	TiO ₂							0.7														
	Other Oxides															0.02	0.14	0.05		0.03	0.02	0.01	0.19
	Apatite	Ca ₅ (PO ₄) ₃ (F,Cl,OH)														1.26	0.96	0.36		0.34	0.96	0.91	0.83
	Monazite	(Ce,La)PO ₄														0.01	0.03	0.02		0.03	0.01	0.00	0.01
	Fe-Ti-P (Low_Si)															0.00	0.00	0.00		0.00	0.00	0.00	0.12
	Dolomite	(Ca,Mg)CO ₃	0.9	1.1	0.2	0.3	0.3	2.1	0	0.4	1.2	0.4	0.9		0.9	1.29	0.68	0.60	1.4	0.89	0.15	0.22	1.03
	Calcite	CaCO ₃	1.8	1.8	1.4	1.0	1.0	0.8	1.9	2.0	1.9	2.3	2.1	2.1	0.4	0.95	0.44	0.58	0.8	0.58	0.41	0.26	0.71
	Other Carbonates															0.00	0.00	0.01		0.01	0.09	0.11	0.01
	Sulphides															0.06	0.18	0.07		0.36	0.04	0.03	0.05
	Jarosite	K ₂ Fe ₆ ³⁺ (SO ₄) ₄ (OH) ₁₂													0.4				0.5				
	Other															0.05	0.15	0.09		0.19	0.08	0.05	0.05
	TOTAL		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: Titanite CaTiSiO₅ and Perovskite CaTiO₃ not found.

Table 8.III-14b Summary of Processed Kimberlite Mineralogy

	Mineral Composition for Coarse Processed Kimberlite (%)											
	2004	2004	2004	2004	2004	2004	2004	2004	2004	2004	2004	2004
	I-3	I-4	II-10	II-12	II-13	II-17	II-18	III-1	IV1+ IV2	V1+V2	VI-1	VIII-1
Mineral Phases Observed in Optical Microscopy	Major: Groundmass, chlorite [(Fe,Mg,Al) ₆ (Si,Al) ₄ O ₁₀ (OH) ₆], talc, K-feldspar, biotite Minor: Carbonate Trace: Quartz, magnetite, pyrrhotite [FeS _(1-x)], rutile, hematite	Major: Groundmass, chlorite, serpentine, K- feldspar, biotite Minor: Carbonate, hematite Trace: Amphibole [Ca ₂ (Fe,Mg) ₅ Si ₈ O ₂₂ (OH) ₂], quartz, magnetite, rutile, chalcopyrite [CuFeS ₂]	Major: Groundmass, biotite, serpentine, chlorite Minor: K-feldspar Trace: Magnetite, hematite, carbonate, quartz, pyrrhotite, rutile, chalcopyrite	Major: Groundmass, chlorite, serpentine Minor: Biotite, amphibole, hematite Trace: Magnetite, pyrite [FeS ₂], rutile	Major: Groundmass, chlorite, biotite Minor: K-feldspar, serpentine Trace: Quartz, hematite, magnetite, pyrite	Major: Groundmass, serpentine, biotite, chlorite Minor: K-feldspar, rutile, talc Trace: Carbonate, hematite, pyrite	Optical mineralogy was not analyzed on this sample.	Major: Groundmass, chlorite, serpentine, biotite Minor: Olivine, hematite, rutile, K- feldspar, carbonate, quartz, amphibole, magnetite Trace: Pyrrhotite, chalcopyrite, ilmenite [FeTiO ₃]	Major: Groundmass, serpentine, biotite, olivine, K-feldspar, chlorite Minor: Rutile, carbonate Trace: Pyrrhotite, quartz, hematite, magnetite	Major: Groundmass, biotite, chlorite, serpentine, olivine, talc Minor: Rutile, K- feldspar, pyrite Trace: Carbonate, hematite, magnetite, plagioclase	Major: Groundmass, serpentine, biotite, chlorite, olivine Minor: Rutile, carbonate, talc, pyrrhotite Trace: Magnetite, chalcopyrite, hematite, quartz, amphibole, enargite [Cu ₃ AsS ₄]	Major: Groundmass, serpentine, biotite, chlorite, olivine Minor: Rutile, pyrite Trace: Carbonate, magnetite, chalcopyrite, hematite, quartz, K- feldspar

Note: Optical mineralogy was not analyzed on course or fine PK composite in 2010-2011.

Detailed Mineralogical Analysis

The seven PK samples submitted for general mineralogical analysis in 2011 were also submitted for more detailed mineralogical analysis to determine the liberation, deportation, and association of phosphorus (SGS Lakefield – Attachment 8.III-3). Phosphorus occurs in three minerals in the PK samples: apatite; (0.36% to 1.3%) $[\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})]$, monazite (0.002% to 0.03%) $[(\text{Ce}, \text{La})\text{PO}_4]$ and an unnamed Fe-Ti-P mineral (<0.001% to 0.12%). Apatite is the main source of phosphorus in all samples; however, sample “PK Comp Fine” is the only sample that contains appreciable concentrations of the Fe-Ti-P mineral phase (0.12%). Generally, the coarse PK samples host higher concentrations of apatite than the corresponding fine PK fractions of the same DGM sample. Monazite concentrations reported no correlation with particle size.

Apatite liberation is defined in terms of the surface area that is exposed at the mineral surface. Liberation has been described further with respect to association of apatite with other mineral classes. All samples contain apatite; however, a proportion of the apatite in each sample is “locked” in the core of mineral grains. The percent liberation describes the proportion of the mineral surface area that is exposed at surface of a grain, rather than locked within other mineral grains. “PK Comp Fine” has a higher percentage of available or “free” apatite (>95% area) that occurs at the surface of the mineral grain than any of the samples that are currently undergoing testing. Generally, the fine fractions of the DGM samples host higher concentrations of free, liberated (80% to 95% area), middling (50% to 80 % area exposed) and sub-middling (20% to 50% area exposed) apatite in comparison to the coarse fractions which host primarily locked apatite (<20% area).

As with the results of the liberation analysis, the concentrations of free and liberated apatite are highest in “PK Comp Fine”, and generally higher in the DGM fine PK samples than the corresponding coarse PK samples. Apatite that is neither free nor liberated is primarily associated with silicate minerals, with a minor fraction associated with ‘complex’ particles, including any combination of mineral associations.

The grain size of the apatite grains was also reported as part of the mineralogical study, to determine the influence of grain size on phosphorus mobility. Generally, apatite grains were smaller than the average grain size in the samples, and the fine PK samples reported smaller apatite grains than those reported in the coarse PK samples.

Acid Base Accounting

Results of ABA testing for the processed kimberlite are provided in Table 8.III-15 and Figures 8.III-6 to 8.III-8. Attachment 8.III-4 contains detailed ABA results.

The principal observations with respect to the ABA characteristics of processed kimberlites are as follows:

- The paste pH values of coarse PK samples ranged from 7.4 to 8.9 with an average of 8.1. The paste pH values of the fine PK were slightly higher than those in the coarse PK, ranging from 7.8 to 9.0, with an average value of 8.4.
- The coarse PK samples contained between <0.01% and 0.06% total sulphur, with an average total sulphur concentration of 0.03%, lower than the average reported in the kimberlites. The fine PK samples reported higher sulphur concentrations, ranging from 0.01% to 0.09%. Sulphur was primarily in the form of sulphide sulphur for both the coarse PK and fine PK (Figure 8.III-6). Sulphide sulphur concentrations in the coarse PK ranged from <0.01% to 0.06%, with average concentrations of 0.03%. Sulphide sulphur concentrations in the fine PK were similar to those in the coarse PK, ranging from 0.01% to 0.09%, with an average of 0.04%. The low sulphide sulphur concentrations in both the coarse and fine PK are supported by mineralogical results. AP was calculated using total sulphur.
- The neutralization potential of the coarse PK ranged from 6.5 to 171 kg CaCO₃/t, with an average value of 65 kg CaCO₃/t. Generally, the fine PK samples reported higher neutralization potential values, ranging from 23 to 293 kg CaCO₃/t, with an average value of 104 kg CaCO₃/t.
- Similar to kimberlite, NP was greater than the carbonate NP for all coarse and fine PK samples (Figure 8.III-7). On average, the carbonate NP was about one-tenth of the NP. A carbonate NP significantly lower than the neutralization potential indicates most of the neutralization potential is attributable to non-carbonate minerals.
- The NP/AP ratio for coarse PK ranged from 19 to 750, while the ratio ranged from 21 to 976 for fine PK. All fine and coarse PK samples are classified as not potentially acid generating (Figure 8.III-8).
- The NAG-pH values of the coarse PK ranged from 5.13 to 8.72, and from 5.9 to 8.2 for the fine PK. All NAG-pH values exceeded 4.5, indicating the presence of sufficient NP to buffer the acidity generated by the complete oxidation of sulphide minerals. The results of NAG testing confirm the results of ABA, indicating both coarse PK and fine PK are non-acid generating.

Table 8.III-15 Summary of Acid Base Accounting Results from Processed Kimberlite

Sample ID	Paste pH	CO ₂	Total Sulphur	Sulphate	Sulphide	AP	NP	NP/AP	CaNP	NAG-pH
		%	wt%	wt%	wt%	kg CaCO ₃ /t	kg CaCO ₃ /t	kg CaCO ₃ /t	kg CaCO ₃ /t	
Fine Processed Kimberlite, n=27										
Minimum	7.80	0.42	<0.01	<0.01	<0.01	<0.3	23	21	7.5	5.1
Maximum	9.03	0.65	0.09	0.04	0.09	2.81	293	976	40.0	8.7
Mean	8.43	0.50	0.05	0.01	0.04	1.07	104	186	16.3	7.3
Median	8.49	0.45	0.04	0.01	0.03	0.84	84	89	14.8	7.4
Standard Deviation	0.33	0.09	0.02	0.009	0.02	0.75	57	235	7.7	1.1
Coarse Processed Kimberlite, n=49										
Minimum	7.41	0.11	<0.01	<0.01	<0.01	0.15	6.5	19	2.5	5.9
Maximum	8.96	0.44	0.06	0.04	0.06	1.88	171	750	15.0	8.2
Mean	8.13	0.22	0.03	0.01	0.03	0.88	65	131	7.0	7.1
Median	8.09	0.21	0.03	0.01	0.03	0.94	55	63	5.2	7.0
Standard Deviation	0.38	0.07	0.01	0.009	0.01	0.47	35	166	3.5	0.71

Note: ID = identification; CO₂ = carbon dioxide; % = percent; wt% = percent by weight; kg/CaCO₃/t = kilograms of calcium carbonate per tonne; AP = acid potential (calculated using total sulphur); NP = neutralization potential; CaNP = calcium neutralization potential; NAG = net- acid generation.

Figure 8.III-6 Total Sulphur Versus Sulphide Sulphur for Processed Kimberlites

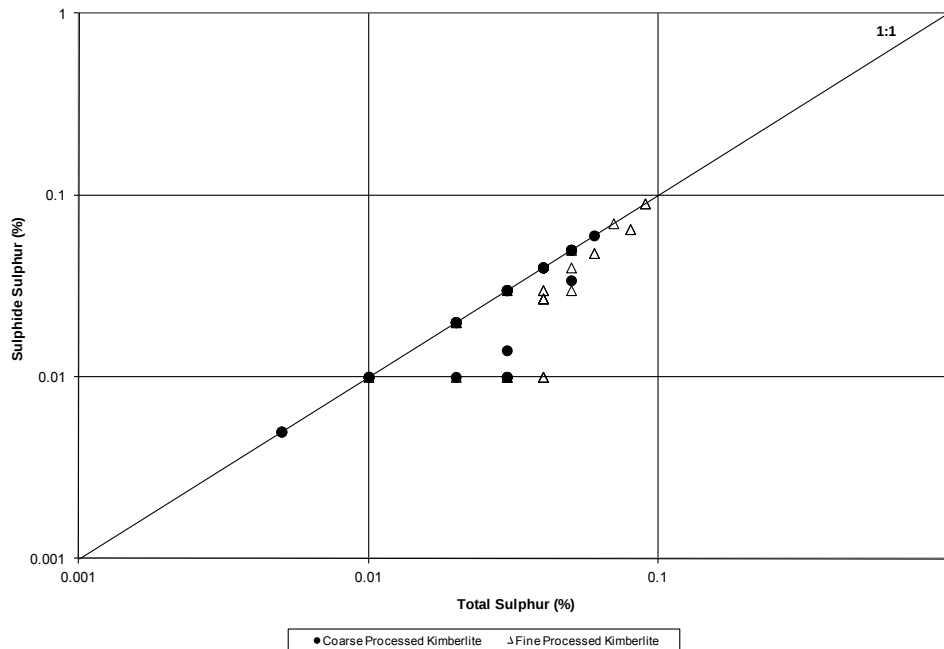


Figure 8.III-7 Total **Neutralization** Potential Versus Carbonate **Neutralization** Potential for Processed Kimberlites

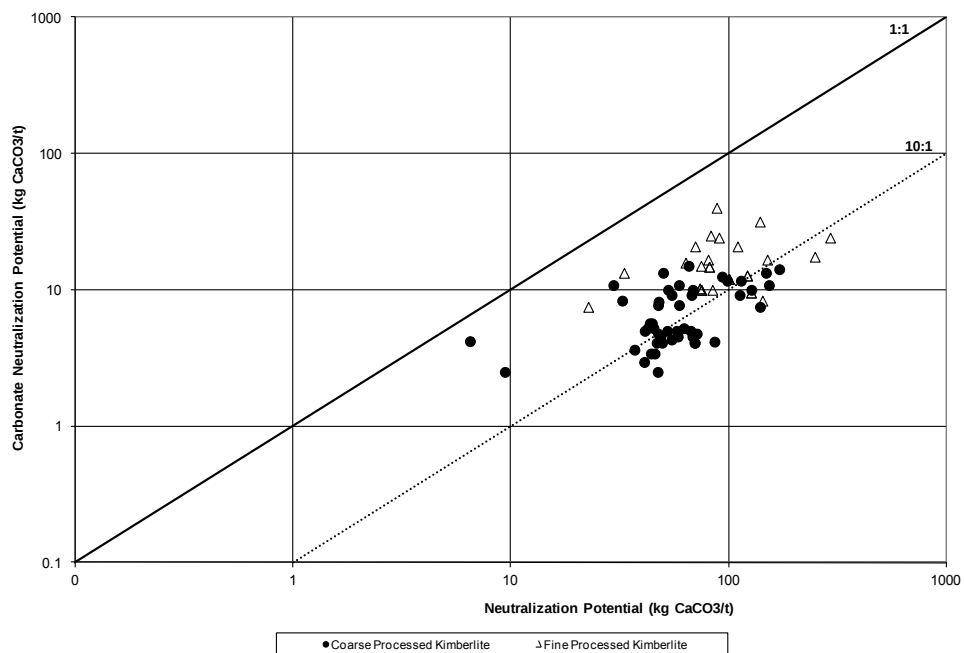
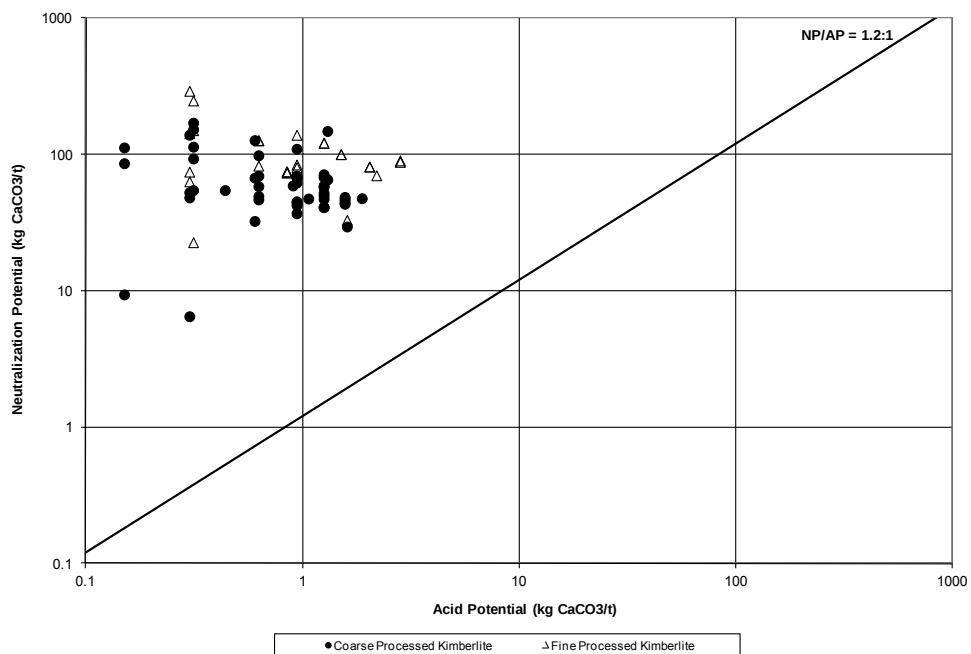


Figure 8.III-8 Acid Potential Versus **Neutralization** Potential for Processed Kimberlites



8.III.4.2.2 Trace Element Chemistry

A complete record of the analytical results and a summary of the chemistry of the coarse and fine processed kimberlite are provided in Attachment 8.III-5. A summary of the bulk metal results are reported in Table 8.III-16.

Results of the trace element chemistry analyses conducted on coarse PK samples indicate average concentrations of nickel (731 mg/kg), cobalt (47 mg/kg), chromium (292 mg/kg), boron (94 mg/kg), phosphorus (556 mg/kg) and bismuth (0.18 mg/kg) are higher when compared to average background concentrations in continental crust rock as provided in Price (1997). Bulk metal results of trace element chemistry conducted on fine PK samples indicate average concentrations of nickel (898 mg/kg), cobalt (56 mg/kg), chromium (338 mg/kg), boron (143 mg/kg), phosphorus (335 mg/kg) and bismuth (0.09 mg/kg), along with arsenic (6.3 mg/kg), copper (92 mg/kg), magnesium (10.3 mg/kg), molybdenum (7.4 mg/kg) and antimony (0.5 mg/kg) are higher when compared to average background concentrations in continental crust rock as provided in Price (1997).

8.III.4.2.3 Shake Flask Extraction Testing

Table 8.III-17 provides the mean, median, standard deviation, and range of values in the SFE testing of PK. Complete results are in Attachment 8.III-7. The results indicate that the pH of all leachates is alkaline (minimum value of 7.38). Mean concentrations of metals, sulphate, and pH were generally similar in fine PK and coarse PK leachates. Mean phosphorus concentrations were marginally higher in the fine PK (0.03 mg/L) than those reported in the coarse PK (0.02 mg/L). There are no established guidelines for comparison of SFE leachate results.

8.III.4.2.4 Process Water Analysis

Table 8.III-18 provides the mean, median, standard deviation, and range of values measured in process water. Process water consists of the water that was recycled through the pilot plant during the metallurgical tests conducted on each sample of kimberlite in 2010. The results of process water analysis are used to evaluate the mass load that is contributed to the Fine PK slurry in water that has been recycled during processing. Complete results are in Attachment 8.III-6. Process water leachates were alkaline (minimum value of pH 7.9), with low metal and sulphate concentrations.

Table 8.III-16 Summary of Processed Kimberlite Bulk Metal Results

Parameter	Ag	Al	As	B	Ba	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	La	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Sr	Ti	Tl	U	Zn
Unit	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	%	mg/kg	%	mg/kg	mg/kg	%	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg
PRICE CRUSTAL ABUNDANCE ^(a)	---	8.23	1.80	10.00	---	0.01	4.15	3.00	25.00	102.00	60.00	5.63	2.09	20.00	2.33	950.00	1.20	2.36	84.00	0.11	14.00	0.20	0.05	370.00	0.57	0.85	2.70	70.00
5x	---	41.15	9.00	50.00	---	0.04	20.75	15.00	125.00	510.00	300.00	28.15	10.43	100.00	11.65	4750.00	6.00	11.78	420.00	0.53	70.00	1.00	0.25	1850.00	2.83	4.25	13.50	350.00
10x	---	82.30	18.00	100.00	---	0.09	41.50	30.00	250.00	1020.00	600.00	56.30	20.85	200.00	23.30	9500.00	12.00	23.55	840.00	1.05	140.00	2.00	0.50	3700.00	5.65	8.50	27.00	700.00
Fine Processed Kimberlite, n = 25																												
Minimum	0.07	0.73	1.0	40	96	<0.02	0.44	<0.01	13	131	36	3.1	0.22	15	1.4	255	0.3	0.03	162	0.071	3.4	<0.05	<0.5	34	0.061	0.08	0.9	30
Maximum	0.9	2.3	23	350	1,402	0.2	3.3	0.4	83	768	192	9.0	12,600	88	17	1,050	32	0.43	1,369	1,620	37	1.6	<0.5	540	0.37	0.2	2.1	94
Mean	0.28	1.8	6.3	143	693	0.09	1.5	0.1	56	338	92	5.1	2,096	48	10.3	569	7.4	0.094	898	335	13	0.5	<0.5	261	0.18	0.13	1.3	59
Median	0.3	1.9	3.6	122	717	0.1	1.4	0.1	59	322	75	4.9	0.54	44	9.1	554	7.3	0.06	905	0.10	9.9	0.3	<0.5	223	0.13	0.1	1.3	57
Standard Deviation	0.19	0.39	5.9	95	345	0.035	0.62	0.071	17	122	48	1.2	3,961	26	3.7	215	7.1	0.084	307	596	9	0.48	0	129	0.1	0.048	0.23	17
Coarse Processed Kimberlite, n = 22																												
Minimum	0.01	0.65	<0.5	30	42	<0.02	0.19	<0.01	<0.1	94	5.2	1.3	0.2	9.8	0.68	136	<0.05	0.04	21	0.046	0.2	<0.05	<0.5	14	0.042	0.02	<0.05	25
Maximum	0.40	2.78	1.3	200	1,380	1.5	4.1	<0.1	87	713	57	6.8	1.8	91	18	1,060	2.3	0.34	1,302	1,570	12	2.15	<1	566	0.15	0.26	2.1	55
Mean	0.12	2.0	0.92	94	588	0.18	1.4	0.06	47	292	35	4.0	0.86	49	11	533	0.63	0.13	731	556	4.1	0.2	<0.73	279	0.093	0.12	1.1	39
Median	0.1	2.0	1.0	90	605	0.08	1.0	0.08	49	283	34	4.0	0.83	61	12	502	0.45	0.1	771	220	3.0	0.1	<0.5	277	0.092	0.1	1.0	37
Standard Deviation	0.118	0.61	0.21	57	367	0.36	1.03	0.04	22	163	14	1.22	0.38	28	4.8	287	0.55	0.089	380	623	3.2	0.44	0.26	148	0.028	0.064	0.4	7.9

Notes: % = percent; mg/kg = milligrams per kilogram; <= less than

^(a) Typical crustal abundance for continental rocks taken from Price (1997).

>1 x	- Concentration greater than typical crustal abundance.
>5 x	- Concentration greater than 5 x the typical crustal abundance.
>10 x	- Concentration greater than 10 x the typical crustal abundance.

Table 8.III-17 Average and Range of Values for Processed Kimberlite Shake Flask Extraction Tests

Parameter	pH	F	Cl	SO ₄	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
Unit	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Fine Processed Kimberlite, n = 10																							
Minimum	7.7	<0.06	2.1	2.0	0.0009	0.0006	8.9	0.001	0.000046	<0.0005	<0.002	0.00002	4.0	0.0006	0.0025	0.001	<0.009	7.4	<0.00004	5.0	0.12	<0.000001	<0.001
Maximum	8.4	1.0	180.0	110	0.076	0.0062	44	0.002	0.00035	0.0069	0.12	0.00018	16	0.014	0.245	0.01	0.059	55	0.00159	56	0.99	0.0024	0.006
Mean	8.1	0.55	70	22	0.022	0.0018	26	0.00107	0.00012	0.0021	0.031	0.000071	8.3	0.003	0.037	0.0034	0.03	20	0.00033	14.3	0.34	0.00037	0.0019
Median	8.1	0.54	11	17	0.0072	0.0015	24	0.0010	0.000079	0.0017	0.02	0.00006	8.6	0.0019	0.02	0.0024	0.032	14	0.00019	9.7	0.28	0.00014	0.001
Standard Deviation	0.21	0.37	87	26.4	0.025	0.0014	9.1	0.00052	0.00009	0.0018	0.037	0.000044	2.9	0.0032	0.06	0.0025	0.018	13.8	0.00041	13.1	0.23	0.00064	0.0014
Coarse Processed Kimberlite, n = 10																							
Minimum	7.38	<0.06	0.5	1	0.0008	0.0005	3.34	0.0005	0.000015	0.0006	<0.002	<0.00002	0.814	0.0002	0.00018	0.0003	<0.009	0.946	<0.00004	1.01	0.0305	<0.000001	<0.001
Maximum	8.36	1.14	140	68	0.2	0.0039	50.4	0.0023	0.000562	0.013	0.306	0.00023	24.6	0.0041	0.18	0.0098	0.075	42.6	0.00132	44.3	0.882	0.00109	0.003
Mean	8.0	0.51	26.9	16.4	0.034	0.0016	15	0.0007	0.00016	0.0023	0.042	0.000049	5.7	0.0016	0.0155	0.003	0.02	11	0.00043	20	0.23	0.00025	0.0015
Median	8.1	0.47	7.2	10.0	0.022	0.0013	12	0.0005	0.000129	0.0014	0.019	0.00003	5.0	0.0013	0.005	0.0023	0.011	8.1	0.0003	21	0.17	0.000051	0.001
Standard Deviation	0.26	0.36	43.62	19	0.045	0.0011	11	0.00041	0.00014	0.0027	0.07	0.000054	5.1	0.00106	0.0384	0.002	0.0163	9.4	0.00038	13	0.21	0.00035	0

Note: s.u. = standard units; mg/L = milligrams per litre.

Table 8.III-18 Average and Range of Values for Process Water Quality

Parameter	pH	SO ₄	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
Units	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Process Water Quality, n=9																					
Minimum	7.9	16	0.005	0.0011	23	0.0021	0.00004	0.0014	0.001	<0.00002	3.0	0.0001	0.0033	0.0004	0.034	5.0	0.00014	3.9	0.13	0.00004	<0.001
Maximum	8.8	23	0.043	0.0016	30	0.0041	0.00011	0.0024	<0.002	0.00008	4.0	0.0075	0.0038	0.0021	0.089	7.8	0.00019	6.1	0.16	0.00023	<0.001
Average	8.4	20	0.013	0.0014	26	0.0027	0.00006	0.0018	0.0058	0.00003	3.6	0.0012	0.0036	0.0008	0.072	6.0	0.00016	4.9	0.14	0.00016	<0.001
Median	8.5	20	0.008	0.0014	27	0.0026	0.00005	0.0016	0.005	0.00003	3.7	0.0005	0.0036	0.0006	0.078	5.7	0.00016	4.7	0.14	0.00017	<0.001
Standard Deviation	0.28	2.7	0.012	0.0001	2.3	0.0007	0.00002	0.0003	0.0035	0.00002	0.30	0.0024	0.0002	0.0006	0.018	0.95	0.00002	0.62	0.010	0.00007	0

Note: s.u. = standard units; mg/L = milligrams per litre.

8.III.4.2.5 Kinetic Testing

Humidity Cells

Attachment 8.III-8 provides detailed results of PK humidity cell tests. The concentrations of key parameters and pH values of the PK humidity cells are presented in Figure 8.III-9a, 8.III-9b, and 8.III-9c. Tables 8.III-19a and 8.III-19b contain a summary of the average leachate chemistry for selected parameters from the standard humidity cells. Results are presented for both the first flush (the first five weeks) in Table 8.III-19a and steady state conditions (the last five weeks) in Table 8.III-19b. PK humidity cell testing was conducted on five cells in 2005. Two PK humidity cell tests initiated in 2010 and ten cells initiated in 2011 are ongoing. The principal observations with respect to the PK humidity cell tests are:

- PK humidity cell leachates were neutral to alkaline (Figure 8.III-9a, 8.III-9b, and 8.III-9c), ranging from 7.3 to 9.3. The pH values of the 2005 fine PK humidity cells 23, 24, 25, 26, and 27 and the 2011 cell DGM 737 Fine were more alkaline than the pH values from the other humidity cells, potentially due to the different carbonate and silicate minerals contributing to the buffering capacity. Generally, the coarse PK cells reported lower pH values (7.3 to 8.4) than those reported in leachates from the fine PK cells (7.4 to 9.3). PK humidity cell leachates generally reported stable pH values after the first flush.
- Sulphide oxidation, as measured by the amount of sulphate in leachate, is very low with stable concentrations less than 5 mg/L (Table 8.III-19b) in the coarse PK and less than 16 mg/L in the fine PK.
- Based on concentration trends of major ions that are typically associated with readily-soluble materials, it appears that readily-soluble materials were flushed from the humidity cell tests during the initial weeks of testing. Generally, concentrations of major ions, including fluoride, were higher in the fine PK HCTs during the initial weeks of testing. Sample DGM 737 Fine reported elevated fluoride concentrations (1.3 to 1.9) in comparison to the other cells throughout testing.
- Metal concentrations in PK humidity cell test leachates were generally low; concentrations were similar to those measured in kimberlite humidity cell tests.
- Concentrations of key metals including arsenic and selenium generally decreased after the first flush (five weeks) to steady state conditions in PK humidity cell tests undertaken in 2005, 2010, and the coarse PK cells initiated in 2011. The fine PK humidity cells initiated in 2011 have not reached steady state conditions for arsenic concentrations. These cells, show decreasing arsenic concentrations to the 20th week, after reaching a maximum of 0.42 mg/L in week two leachates from Tuzo and Hearne

Fine. Selenium concentrations from leachates of fine PK cells initiated in 2011 have remained stable throughout testing.

- Concentrations for several metals, including iron and zinc, were generally low or below the detection limit after the first flush, ranging from 0.0005 to 0.007 mg/L. Iron and molybdenum concentrations were generally higher in the leachates from the fine PK HCTs (0.001 to 5.6 mg/L and 0.00038 to 1.6 mg/L, respectively) compared to the coarse PK HCTs (0.001 to 0.26 mg/L and 0.00016 to 1.5 mg/L, respectively). Similarly, several other trace metals reported higher concentrations in fine PK HCT leachates than coarse PK HCT leachates, including boron, antimony, lithium, chromium, lead, and tin.
- Phosphorus concentrations in the cells initiated in 2005 were below the detection limit of 0.15 mg/L throughout testing. Phosphorus was measured at lower detection limits in 2010 and 2011 and the measured concentrations in the 2010 and 2011 HCT leachates were generally below 0.1 mg/L for all samples, with the exception of one sample collected at week 4 from DGM 713 Coarse reporting 0.88 mg/L total phosphorus. Concentrations of phosphorus in the leachates were generally higher in the coarse PK during the initial weeks of testing. The 2011 fine PK HCT leachates reported similar phosphorus concentrations to those reported in the 2010 sample PK Comp Fine during the initial weeks of testing.
- Table 8.III-20 summarizes the predicted depletion NP, sulphide, and CaNP depletion times in PK humidity cells completed in 2005, 2010, and 2011. In all cells except humidity cell 25, there are sufficient neutralizing minerals to buffer potential acid generation over the long term.

Table 8.III-19a First Flush Concentrations in Leachate from Processed Kimberlite Humidity Cells

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
First Flush																							
HC 22 - Processed Kimberlite Fines: Oct 11, 2005 - Nov 8, 2005																							
Minimum	7.8	4.0	3.5	0.05	0.009	0.001	6.8	0.001	0.001	0.001	0.05	0.001	1.5	0.001	0.0009	0.002	0.15	9.7	0.001	7.1	0.071	0.0005	0.005
Maximum	8.4	10	8.5	0.26	0.12	0.001	10.0	0.002	0.001	0.002	0.15	0.001	2.0	0.002	0.0033	0.005	0.15	11	0.001	12	0.097	0.0005	0.013
Average	8.1	5.4	6.0	0.15	0.065	0.001	8.4	0.0015	0.001	0.0015	0.1	0.001	1.8	0.0015	0.0021	0.0035	0.15	10	0.001	9.4	0.084	0.0005	0.009
HC 23 - Processed Kimberlite Fines: Oct 11, 2005 - Nov 8, 2005																							
Minimum	7.9	13	6.3	0.14	0.01	0.002	7.4	0.002	0.001	0.001	0.05	0.001	1.8	0.001	0.0038	0.004	0.15	7.1	0.001	11	0.09	0.0005	0.005
Maximum	8.8	25	145	0.28	0.029	0.01	59	0.003	0.001	0.002	0.05	0.001	13	0.002	0.0065	0.006	0.15	30	0.001	59	1.0	0.0005	0.008
Average	8.4	18	76	0.21	0.02	0.006	33	0.0025	0.001	0.0015	0.05	0.001	7.4	0.0015	0.0052	0.005	0.15	18	0.001	35	0.55	0.0005	0.0065
HC 24 - Processed Kimberlite Fines: Oct 11, 2005 - Nov 8, 2005																							
Minimum	8.3	2.0	20	0.14	0.005	0.001	6.3	0.001	0.001	0.001	0.05	0.001	0.41	0.001	0.0005	0.001	0.15	11	0.001	13	0.18	0.0005	0.005
Maximum	9.3	3.0	126	0.24	0.005	0.002	29	0.001	0.001	0.003	0.05	0.001	2.6	0.001	0.0005	0.003	0.15	32	0.001	57	0.98	0.0005	0.005
Average	8.7	2.6	73	0.19	0.005	0.0015	18	0.001	0.001	0.002	0.05	0.001	1.5	0.001	0.0005	0.002	0.15	21	0.001	35	0.58	0.0005	0.005
HC 25 - Processed Kimberlite Fines: Oct 11, 2005 - Nov 8, 2005																							
Minimum	8.1	28	10	0.53	0.005	0.002	12	0.001	0.001	0.001	0.05	0.001	3.6	0.001	0.0095	0.003	0.15	7.7	0.001	16	0.11	0.0005	0.005
Maximum	8.6	41	110	0.66	0.006	0.009	55	0.001	0.001	0.005	0.05	0.001	15	0.003	0.013	0.008	0.15	18	0.001	43	0.59	0.0005	0.005
Average	8.3	32	60	0.59	0.0055	0.0055	33	0.001	0.001	0.003	0.05	0.001	9.1	0.002	0.011	0.0055	0.15	13	0.001	29	0.35	0.0005	0.005
HC 26 - Processed Kimberlite Fines: Oct 11, 2005 - Nov 8, 2005																							
Minimum	8.3	3.0	37	0.22	0.005	0.001	14	0.001	0.001	0.001	0.05	0.001	1.8	0.001	0.0009	0.002	0.15	10	0.001	13	0.13	0.0005	0.005
Maximum	8.8	10	40	0.24	0.01	0.001	19	0.001	0.001	0.002	0.05	0.001	1.8	0.001	0.0018	0.002	0.15	11	0.001	14	0.18	0.0005	0.005
Average	8.5	5.2	38	0.23	0.0075	0.001	16	0.001	0.001	0.0015	0.05	0.001	1.8	0.001	0.0014	0.002	0.15	11	0.001	13	0.16	0.0005	0.005
HC 27 - Processed Kimberlite Fines: Oct 11, 2005 - Nov 8, 2005																							
Minimum	8.4	3.0	0.37	0.12	0.005	0.001	8.0	0.001	0.001	0.001	0.05	0.001	1.2	0.001	0.0005	0.001	0.15	9.2	0.001	15	0.12	0.0005	0.005
Maximum	9.0	17	23	0.43	0.006	0.003	13	0.001	0.001	0.002	0.05	0.001	1.2	0.001	0.002	0.002	0.15	13	0.001	25	0.18	0.0005	0.005
Average	8.7	8.6	12	0.27	0.0055	0.002	10	0.001	0.001	0.0015	0.05	0.001	1.2	0.001	0.0013	0.0015	0.15	11	0.001	20	0.15	0.0005	0.005
T-1: PK - Fines Composite - Processed Kimberlite Fines: July 29, 2010 - Aug 26, 2010																							
Minimum	7.9	31	3.5	0.72	0.0037	0.0013	20	0.0011	0.000089	0.001	0.002	0.00002	6.7	0.0018	0.043	0.0029	0.02	15	0.00053	12	0.23	0.000066	0.001
Maximum	8.1	137	27	0.82	0.044	0.0025	45	0.0024	0.0002	0.0041	0.062	0.00011	13	0.0082	0.074	0.0052	0.036	17	0.00092	19	0.5	0.00031	0.001
Average	8.0	65	11	0.78	0.015	0.0018	29	0.0016	0.00013	0.002	0.021	0.00005	9.3	0.0041	0.056	0.0039	0.025	16	0.00075	14	0.34	0.00017	0.001
HC1: PK - Coarse Composite - Processed Kimberlite Coarse: July 29, 2010 - Aug 26, 2010																							
Minimum	7.7	5.0	27	0.29	0.0027	0.0006	8.0	0.0008	0.000034	0.0005	0.002	0.00002	3.4	0.0012	0.0021	0.0009	0.009	7.6	0.00004	17	0.11	0.000002	0.001
Maximum	7.9	36	94	0.34	0.014	0.0013	19	0.0042	0.00019	0.004	0.012	0.00014	8.2	0.0084	0.0056	0.0022	0.014	12	0.002	36	0.27	0.00006	0.002
Average	7.8	12	62	0.31	0.0071	0.00094	14	0.002	0.000078	0.0015	0.0056	0.00006	5.8	0.0028	0.0031	0.0015	0.01	9.5	0.00067	26	0.19	0.000028	0.0012
HC 5: PK - DGM 713 Coarse - Processed Kimberlite Coarse: May 5, 2011 - June 2, 2011																							
Minimum	7.3	8.0	0.1	0.69	0.0054	0.0004	5.7	0.00025	0.000001	0.0009	0.003	0.00001	1.9	0.001	0.0082	0.002	0.015	2.8	0.00018	5.8	0.046	0.0000005	0.001
Maximum	7.7	150	2.5	1.1	0.027	0.0037	35	0.0018	0.00034	0.024	0.071	0.00008	12	0.008	0.032	0.0066	0.88	6.3	0.059	15	0.33	0.00073	0.083
Average	7.5	65	1.1	0.95	0.013	0.0011	17	0.00056	0.0002	0.0058	0.021	0.00004	5.9	0.0035	0.021	0.004	0.2	4.2	0.012	10	0.16	0.00047	0.02
HC 6: PK - DGM 717 Coarse - Processed Kimberlite Coarse: May 5, 2011 - June 2, 2011																							
Minimum	7.7	8.0	1.6	0.2	0.0048	0.002	4.4	0.00025	0.000042	0.0016	0.001	0.00001	2.3	0.0007	0.0053	0.0012	0.0045	5.8	0.00033	13	0.063	0.00015	0.002
Maximum	8.0	88	22	0.26	0.022	0.0028	16	0.0008	0.00018	0.0029	0.034	0.00006	8.3	0.0034	0.021	0.0033	0.078	11	0.0011	28	0.24	0.00023	0.005
Average	7.8	42	9.8	0.24	0.0096	0.0025	9.0	0.00041	0.00011	0.0022	0.013	0.000034	4.8	0.0016	0.012	0.0021	0.031	8.3	0.00067	20	0.14	0.00018	0.0028
HC 7: PK - DGM 737 Coarse - Processed Kimberlite Coarse: May 5, 2011 - June 2, 2011																							
Minimum	7.3	1.0	51	0.11	0.0015	0.0006	15	0.00025	0.000072	0.00025	0.001	0.00001	7.2	0.0012	0.00016	0.0019	0.0045	6.7	0.00002	1.8	0.23	0.0000005	0.001
Maximum	7.5	5.0	160	0.19	0.0056	0.0023	42	0.00025	0.00032	0.0011	0.001	0.00007	19	0.0044	0.00072	0.0049	0.068	14	0.0036	9.6	0.68	0.000008	0.008
Average	7.4	3.4	102	0.15	0.0026	0.0014	28	0.00025	0.00018	0.00075	0.001	0.000034	12	0.0024	0.00034	0.0032	0.023	11	0.0011	5.9	0.44	0.0000023	0.0042
T-2: PK - DGM 713 Fine - Processed Kimberlite Fines: June 23, 2011 -July 21, 2011																							
Minimum	7.9	13	0.6	1.3	0.0061	0.04	20	0.00025	0.00012	0.0017	0.004	0.00003	6.8	0.0026	0.0038	0.0018	0.0045	18	0.00026	11	0.18	0.0023	0.003
Maximum	8.2	148	17	2.4	0.04	0.29	62	0.0013	0.00026	0.004	0.042	0.00017	19	0.0062	0.16	0.0059	0.017	37	0.0021	35	0.56	0.0082	0.01
Average	8.0	47	4.6	1.8	0.015	0.21	29	0.00067	0.00017	0.003	0.013	0.000074	9.5	0.0036	0.047	0.003	0.0089	24	0.00082	19	0.26	0.0035	0.0058
T-3: PK - DGM 717 Fine - Processed Kimberlite Fines: June 23, 2011 -July 21, 2011																							
Minimum	8.0	22	2.0	0.37	0.0052	0.037	11	0.00025	0.000052	0.0007	0.001	0.00004	6.6	0.0009	0.011	0.0012	0.0045	23	0.00031	25	0.17	0.000057	0.002
Maximum	8.3	205	76	0.44	0.078	0.28	47	0.0079	0.00026	0.0042	0.14	0.00012	26	0.0034	0.23	0.0046	0.013	61	0.0033	91	0.73	0.00079	0.01
Average	8.1	79	19	0.4	0.023	0.17	19	0.0021	0.00012	0.0021	0.032	0.000082	11	0.0021	0.083	0.0028	0.0073	36	0.0011	46	0.3	0.00027	0.0064

Table 8.III-19a First Flush Concentrations in Leachate from Processed Kimberlite Humidity Cells (continued)

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
T-4: PK - DGM 737 Fine - Processed Kimberlite Fines: June 23, 2011 -July 21, 2011																							
Minimum	7.6	5.0	72	0.37	0.003	0.035	34	0.00025	0.000091	0.0006	0.001	0.00004	1.8	0.0001	0.0027	0.0015	0.0045	39	0.00002	8.3	0.81	0.0000005	0.004
Maximum	8.0	22	680	1.7	0.015	0.27	152	0.0009	0.00036	0.0029	0.004	0.00006	53	0.0042	0.0063	0.006	0.014	158	0.0033	74	4.1	0.000012	0.011
Average	7.8	14	264	1.2	0.0072	0.19	77	0.00038	0.00018	0.0014	0.0018	0.00005	15	0.0012	0.0045	0.0029	0.0064	78	0.00088	26	1.9	0.0000055	0.007
HC 11: Tuzo and Hearne Coarse - Processed Kimberlite Coarse: June 23, 2011 -July 21, 2011																							
Minimum	8.1	15	0.4	1.6	0.0059	0.0023	7.9	0.0015	0.00031	0.0005	0.002	0.00004	3.4	0.0016	0.046	0.0045	0.0045	18	0.00054	50	0.1	0.0022	0.001
Maximum	8.3	585	64	2.6	0.17	0.0071	171	0.0035	0.00093	0.005	0.26	0.00014	66	0.013	1.5	0.053	0.012	72	0.011	214	2.1	0.024	0.008
Average	8.2	148	14	2.3	0.085	0.0047	42	0.0023	0.00056	0.0022	0.12	0.000074	17	0.0048	0.45	0.017	0.006	31	0.003	91	0.52	0.007	0.003
HC 12: East Lobe Coarse - Processed Kimberlite Coarse: June 23, 2011 -July 21, 2011																							
Minimum	7.7	1.0	74	0.09	0.0012	0.0011	23	0.00025	0.000053	0.00025	0.001	0.00002	0.86	0.0001	0.00027	0.0006	0.0045	35	0.00002	13	0.5	0.000001	0.002
Maximum	8.3	3.0	540	0.17	0.049	0.0036	98	0.0012	0.00045	0.0017	0.19	0.00013	14	0.004	0.019	0.0069	0.0045	152	0.001	122	2.0	0.00017	0.004
Average	7.9	2.0	243	0.12	0.011	0.0022	60	0.00044	0.00018	0.00076	0.04	0.000062	4.5	0.001	0.006	0.0025	0.0045	78	0.00053	47	1.2	0.000048	0.0028
T-5: Tuzo and Hearne Fine - Processed Kimberlite Fines: June 23, 2011 -July 21, 2011																							
Minimum	8.1	21	0.4	0.99	0.0065	0.068	9.7	0.0006	0.00014	0.0012	0.017	0.00003	5.1	0.0014	0.026	0.0032	0.0045	18	0.0011	33	0.13	0.0010	0.002
Maximum	8.3	703	73	1.4	0.19	0.42	155	0.0068	0.0007	0.0069	0.3	0.00011	72	0.013	1.6	0.031	0.032	75	0.011	187	1.9	0.0082	0.006
Average	8.2	187	16	1.2	0.063	0.25	41	0.0024	0.00044	0.0041	0.11	0.000062	19	0.0047	0.47	0.011	0.010	36	0.0033	80	0.52	0.003	0.0042
T-6: East Lobe Fine - Processed Kimberlite Fines: June 23, 2011 -July 21, 2011																							
Minimum	7.8	1.0	59	0.12	0.0016	0.032	22	0.00025	0.000059	0.0008	0.001	0.00003	0.3	0.0001	0.00038	0.0008	0.0045	37	0.00023	10	0.4	0.0000005	0.003
Maximum	8.5	4.0	810	0.26	0.004	0.17	128	0.0009	0.00023	0.0027	0.006	0.00005	42	0.0014	0.0079	0.0028	0.013	196	0.00058	151	2.4	0.0003	0.013
Average	8.2	2.4	297	0.19	0.0022	0.13	67	0.0005	0.00013	0.0015	0.0032	0.000036	10.0	0.00042	0.0026	0.0016	0.0075	92	0.0004	49	1.2	0.000077	0.0062

Note: s.u. = standard units; µs/cm = microSiemens per centimetre; mg/L = milligrams per litre.

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Steady State																							
HC 22 - Processed Kimberlite Fines: Nov 4, 2008 - Dec 2, 2008																							
Minimum	7.4	1.0	0.2	0.025	0.022	0.0002	1.8	0.0004	0.0002	0.0009	0.03	0.0002	0.9	0.0007	0.0006	0.0015	0.03	3.3	0.0002	2.0	0.019	0.0001	0.001
Maximum	7.6	2.0	0.25	0.08	0.068	0.0002	2.6	0.0008	0.0002	0.0046	0.1	0.0002	1.5	0.0014	0.0008	0.0035	0.03	4.1	0.0002	2.5	0.028	0.0001	0.001
Median	7.5	1.0	0.23	0.053	0.045	0.0002	2.2	0.0006	0.0002	0.0028	0.065	0.0002	1.2	0.0011	0.0007	0.0025	0.03	3.7	0.0002	2.3	0.024	0.0001	0.001
HC 23 - Processed Kimberlite Fines: Nov 4, 2008 - Dec 2, 2008																							
Minimum	8.1	1.0	0.2	0.13	0.014	0.0009	5.3	0.0003	0.0002	0.0011	0.03	0.0002	1.3	0.0005	0.0007	0.001	0.03	5.6	0.0002	1.6	0.079	0.0001	0.001
Maximum	7.9	2.0	0.2	0.25	0.027	0.001	6.1	0.0004	0.0002	0.0014	0.04	0.0002	1.4	0.0006	0.0008	0.0017	0.03	6.1	0.0002	1.9	0.092	0.0001	0.001
Average	8.4	1.4	0.2	0.19	0.021	0.00095	5.7	0.00035	0.0002	0.0013	0.035	0.0002	1.3	0.00055	0.00075	0.0014	0.03	5.8	0.0002	1.7	0.086	0.0001	0.001
HC 24 - Processed Kimberlite Fines: Nov 4, 2008 - Dec 2, 2008																							
Minimum	8.5	1.0	0.33	0.07	0.004	0.0009	9.8	0.0002	0.0002	0.0012	0.01	0.0002	1.6	0.0003	0.0001	0.0002	0.03	7.3	0.0002	5.2	0.24	0.0001	0.001
Maximum	8.3	2.0	0.42	0.17	0.007	0.0011	11	0.0002	0.0002	0.0018	0.01	0.0002	2.0	0.0005	0.0001	0.0004	0.03	7.8	0.0002	6.2	0.27	0.0001	0.001
Average	8.7	1.2	0.38	0.12	0.0055	0.001	10	0.0002	0.0002	0.0015	0.01	0.0002	1.8	0.0004	0.0001	0.0003	0.03	7.5	0.0002	5.7	0.25	0.0001	0.001
HC 25 - Processed Kimberlite Fines: Nov 4, 2008 - Dec 2, 2008																							
Minimum	8.1	1.0	0.39	0.08	0.017	0.0004	13	0.0002	0.0002	0.001	0.02	0.0002	4.8	0.0003	0.0008	0.0019	0.03	5.7	0.0002	1.1	0.14	0.0001	0.001
Maximum	8.1	2.0	0.54	0.2	0.02	0.0005	16	0.0003	0.0002	0.0021	0.03	0.0002	6.3	0.0009	0.0009	0.0024	0.03	6.4	0.0002	1.3	0.18	0.0001	0.001
Average	8.2	1.2	0.47	0.14	0.019	0.00045	14	0.00025	0.0002	0.0016	0.025	0.0002	5.6	0.0006	0.00085	0.0022	0.03	6.1	0.0002	1.2	0.16	0.0001	0.001
HC 26 - Processed Kimberlite Fines: Nov 4, 2008 - Dec 2, 2008																							
Minimum	7.5	1.0	0.2	0.06	0.029	0.0003	3.1	0.0003	0.0002	0.0005	0.04	0.0002	0.82	0.0006	0.0002	0.0016	0.03	3.2	0.0002	0.94	0.03	0.0001	0.001
Maximum	7.5	2.0	0.2	0.08	0.037	0.0003	3.3	0.0004	0.0002	0.0023	0.05	0.0002	0.86	0.0006	0.0003	0.002	0.03	3.4	0.0002	0.95	0.031	0.0001	0.001
Average	7.7	1.2	0.2	0.07	0.033	0.0003	3.2	0.00035	0.0002	0.0014	0.045	0.0002	0.84	0.0006	0.00025	0.0018	0.03	3.3	0.0002	0.95	0.031	0.0001	0.001
HC 27 - Processed Kimberlite Fines: Nov 4, 2008 - Dec 2, 2008																							

Table 8.III-19b Steady State Concentrations in Leachate from Processed Kimberlite Humidity Cells (continued)

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
T-4: DGM 737 Fine - Processed Kimberlite Fines: Sept 29, 2011 - Nov 3, 2011																							
Minimum	8.7	10	1.2	1.4	0.0007	0.031	12	0.00025	0.000024	0.00025	0.002	0.00004	0.22	0.0001	0.0042	0.0001	0.0045	15	0.00002	2.9	0.27	0.000001	0.0005
Maximum	9.0	16	1.6	1.6	0.001	0.055	13	0.0009	0.000031	0.00025	0.026	0.00008	0.33	0.0004	0.0055	0.0003	0.0045	18	0.00009	3.7	0.3	0.000007	0.001
Average	8.9	13	1.4	1.5	0.00085	0.043	13	0.00058	0.000028	0.00025	0.014	0.00006	0.27	0.00025	0.0049	0.0002	0.0045	17	0.000055	3.3	0.29	0.000004	0.00075
HC 11: Tuzo and Hearne Coarse - Processed Kimberlite Coarse: Sept 29, 2011 - Nov 3, 2011																							
Minimum	7.8	2.0	0.1	0.49	0.061	0.0023	7.0	0.0006	0.00019	0.00025	0.058	0.00003	2.8	0.0001	0.019	0.0025	0.0045	13	0.00009	8.0	0.092	0.00057	0.001
Maximum	8.0	4.0	0.1	0.54	0.065	0.003	7.4	0.0018	0.00021	0.00025	0.064	0.00006	3.0	0.0008	0.023	0.0027	0.0045	14	0.00038	19	0.099	0.001	0.003
Average	7.9	2.6	0.1	0.52	0.063	0.0027	7.2	0.0012	0.0002	0.00025	0.061	0.000045	2.9	0.00045	0.021	0.0026	0.0045	14	0.00024	13	0.095	0.0008	0.002
HC 12: East Lobe Coarse - Processed Kimberlite Coarse: Sept 29, 2011 - Nov 3, 2011																							
Minimum	8.1	1.0	2.6	0.09	0.0011	0.001	8.2	0.00025	0.000016	0.00025	0.0015	0.00001	1.0	0.0001	0.0003	0.0002	0.0045	17	0.00002	6.4	0.19	0.000008	0.003
Maximum	8.4	3.0	3.6	0.11	0.0024	0.0014	8.9	0.0013	0.000022	0.00025	0.003	0.00012	1.2	0.0001	0.00066	0.0003	0.0045	22	0.00023	7.5	0.21	0.000016	0.006
Average	8.2	2.0	3.1	0.098	0.0018	0.0012	8.6	0.00078	0.000019	0.00025	0.0023	0.000065	1.1	0.0001	0.00048	0.00025	0.0045	19	0.00013	6.9	0.2	0.000012	0.0045
T-5: Tuzo and Hearne Fine - Processed Kimberlite Fines: June 23, 2011 - July 21, 2011																							
Minimum																							
Maximum																							
Average																							
Insufficient sample volume for metal analysis beyond week 9																							
T-6: East Lobe Fine - Processed Kimberlite Fines: Sept 29, 2011 - Nov 3, 2011																							
Minimum	9.0	3.0	0.9	0.17	0.0004	0.04	7.9	0.0009	0.000019	0.00025	0.003	0.00002	0.11	0.0001	0.00047	0.0001	0.009	19	0.00002	4.7	0.14	0.000005	0.002
Maximum	9.1	5.0	1.1	0.29	0.0018	0.063	8.2	0.0019	0.000029	0.0006	0.015	0.00014	0.13	0.0001	0.00071	0.0002	0.01	27	0.00016	5.3	0.14	0.00001	0.006
Average	9.1	4.2	1.0	0.22	0.0011	0.052	8.1	0.0014	0.000024	0.00043	0.009	0.00008	0.12	0.0001	0.00059	0.00015	0.0095	23	0.00009	5.0	0.14	0.0000075	0.004

Note: s.u. = standard units; µs/cm = microSiemens per centimetre; mg/L = milligrams per litre.

Figure 8.III-9a Leachate Concentrations in Processed Kimberlite Humidity Cells

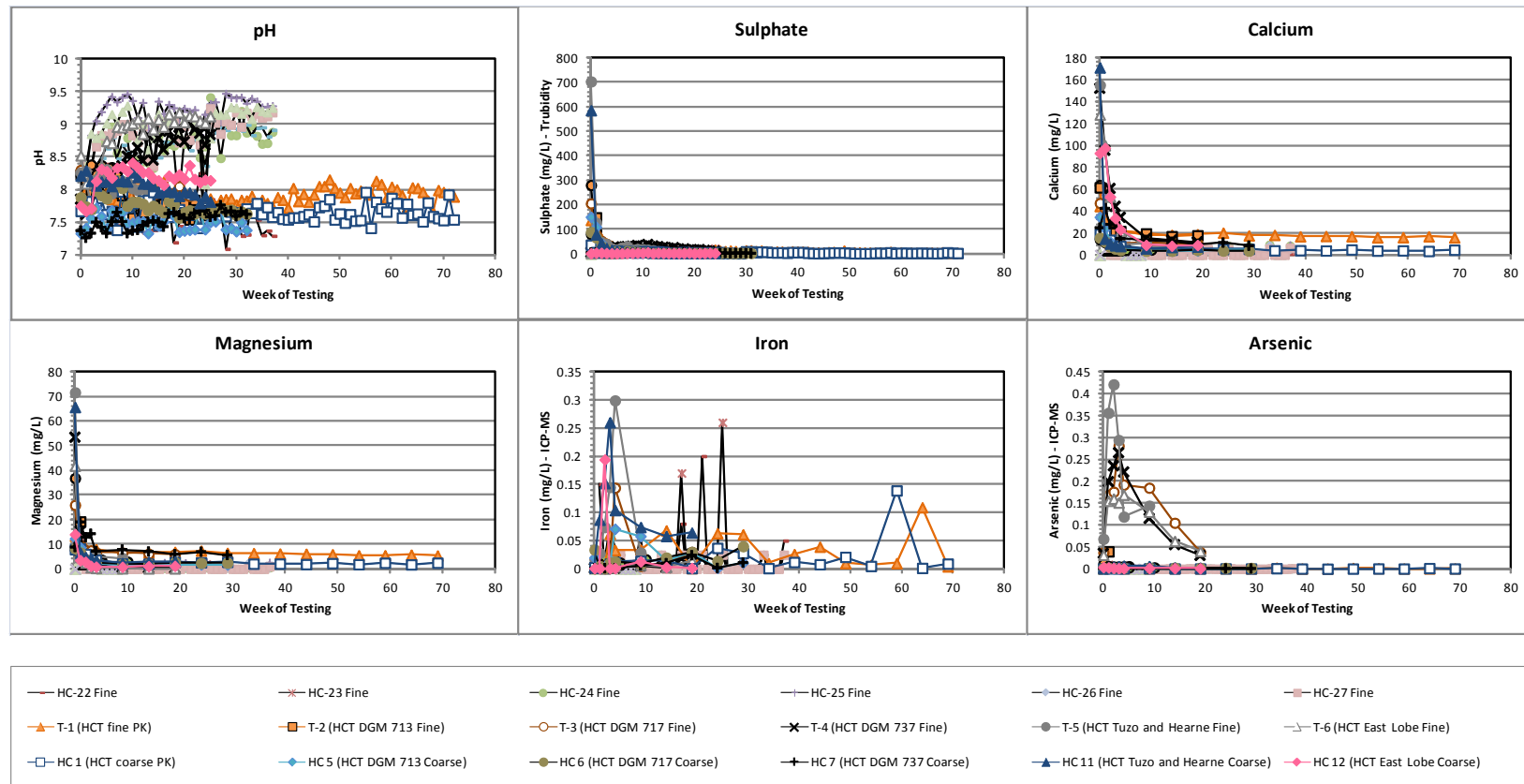


Figure 8.III-9b Leachate Concentrations in Processed Kimberlite Humidity Cells

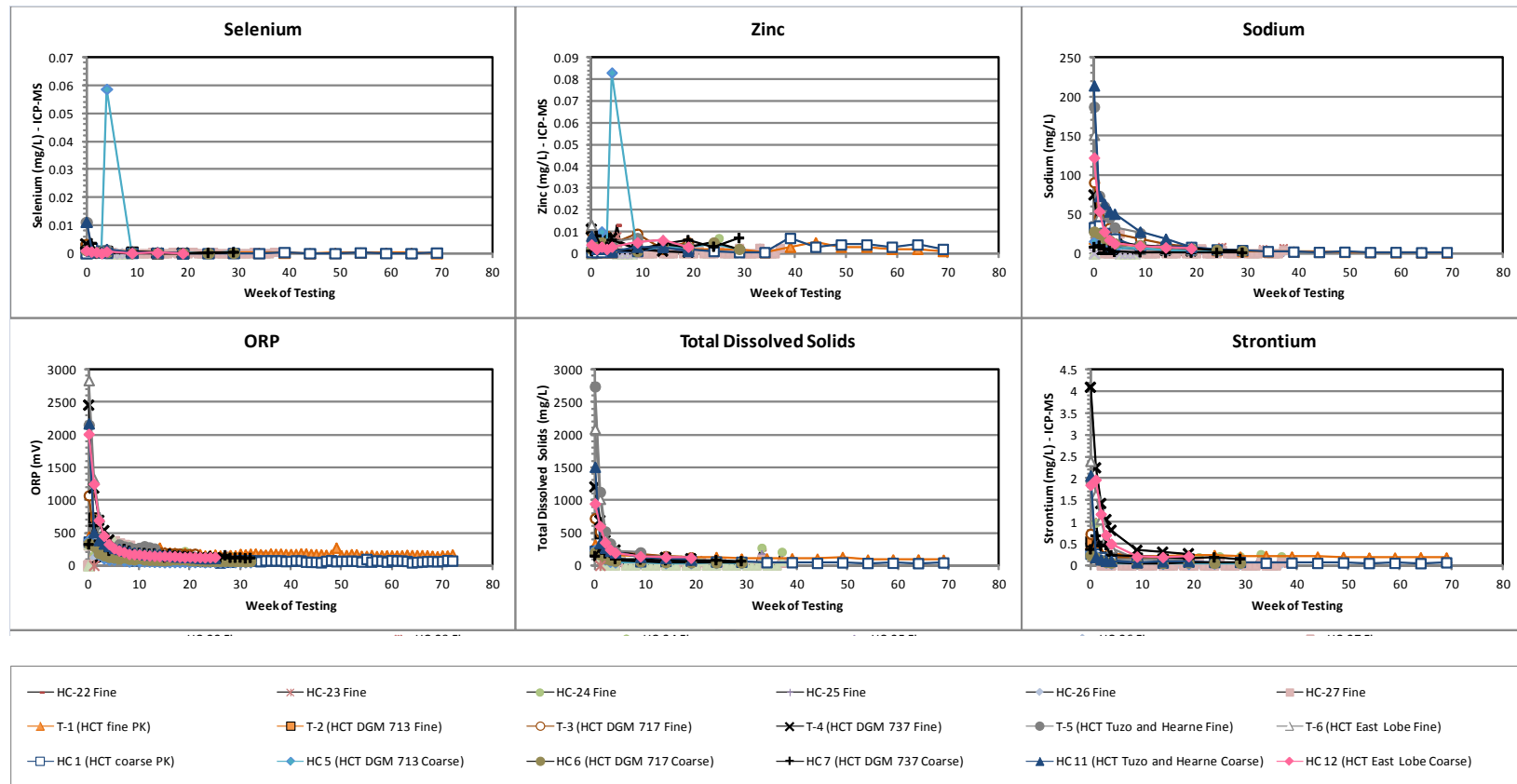


Figure 8.III-9c Leachate Concentrations in Processed Kimberlite Humidity Cells

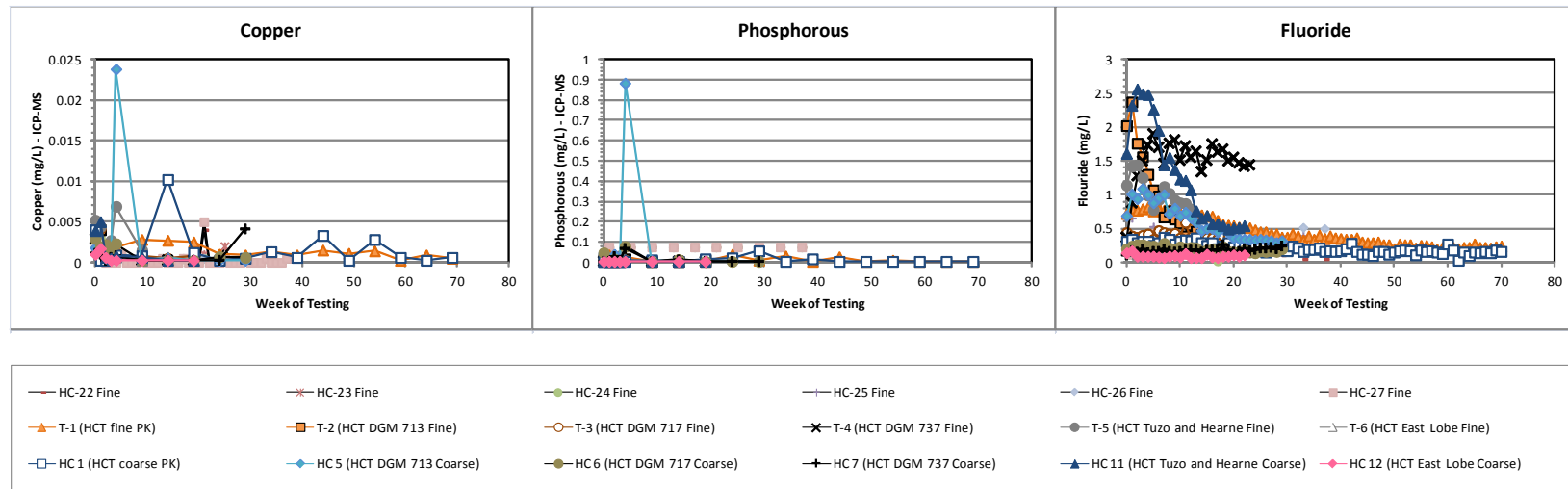


Table 8.III-20 Estimated Acid Potential and Neutralization Potential Depletion Times for Processed Kimberlite Humidity Cells

Humidity Cell ID	Lithology	Sulphide Sulphur (wt%)	NP (kg CaCO ₃ /t)	Time to Depletion (Years)				
				Sulphide Sulphur	NP (emp)	CaNP (emp)	NP (SO ₄)	CaNP (SO ₄)
HC 22	Fine Processed Kimberlite	0.027	87	49	261	34	4532	621
HC 23	Fine Processed Kimberlite	0.04	97	26	147	13	3465	354
HC 24	Fine Processed Kimberlite	0.02	203	19	85	3.8	4726	352
HC 25	Fine Processed Kimberlite	0.065	40	69	47	6.3	3088	548
HC 26	Fine Processed Kimberlite	0.027	89	29	171	19	3067	401
HC 27	Fine Processed Kimberlite	0.048	67	55	147	14	4219	496
T-1	Fine Processed Kimberlite	0.03	110	15	108	19	2348	445
T-2	Fine Processed Kimberlite	0.01	75	0.6	37	6.9	345	68
T-3	Fine Processed Kimberlite	0.05	33	7.7	14	5.2	191	74
T-4	Fine Processed Kimberlite	<0.01	293	0.19	211	17.0	576	47
T-5	Fine Processed Kimberlite	0.01	64	-0.46	20	4.7	152	37
T-6	Fine Processed Kimberlite	<0.01	143	2.2	91	5	1212	70
HC 1	Coarse Processed Kimberlite	0.01	114	6.8	251	24	3313	339
HC 5	Coarse Processed Kimberlite	0.05	30	25	45	16	543	196
HC 6	Coarse Processed Kimberlite	0.04	66	16	77	14.6	959	188
HC 7	Coarse Processed Kimberlite	0.04	149	27	155	14.1	3139	293
HC 11	Coarse Processed Kimberlite	0.01	53	-0.6	33	5	692	127
HC 12	Coarse Processed Kimberlite	<0.01	140	5.4	95	5	2631	141

Note: ID = identification; wt% = percent by weight; NP = neutralization potential; CaNP = calcium neutralization potential; kg CaCO₃/t = kilograms of calcium carbonate per tonne; emp = empirical SO₄ = sulphate.

Depletion calculations are unavailable for humidity cells constructed in 2010 for 'T-1: PK - Fines Composite' and 'HC1: PK - Coarse Composite', due to the short time period the HCTs have been running (4 weeks).

8.III.4.2.6 Submerged Column Tests

Submerged PK column tests (SCTs) were initiated in 2010 and 2011, and were ongoing at the date of preparation of this report. The objective of the submerged column tests is to evaluate the effect of submerging fine and coarse PK, respectively, under a column of water. Leachate samples are collected from the top and bottom of the test column, and results are discussed in the context of the "top" and "bottom" samples.

Tables 8.III-21a and 8.III-21b contain a summary of the column leachate concentrations for selected parameters. Results are presented for both the first flush (the first five weeks) in Table 8.III-21a and steady state conditions (the last five weeks) in Table 8.III-21b. Figures 8.III-10a and 8.III-10b present the results

of the top and bottom water collected from the columns, respectively. Attachment 8.III-9 provides detailed results. The principal observations with respect to the submerged PK columns are:

- Water collected from the SCTs had near-neutral pH values during the initial weeks of testing. In general, the pH of water collected from the top of the SCTs was lower than the pore water collected from the bottom. The pH of water from the top of the coarse PK SCTs varied from 7.0 to 8.0, and the bottom water (i.e., pore water) pH varied from 7.2 to 9.4. The pH of water from the fine PK SCTs varied from 7.1 to 7.8 at the top of the SCT, and 7.1 to 9.4 at the bottom.
- Redox potentials at the top of the column varied from approximately 400 mV at the beginning of the test to approximately 250 mV after 10 weeks of testing for both the fine and coarse PK. Water collected from the bottom of the fine PK SCTs generally reported a wider range in redox potential, ranging from 130 to 425 mV, while the bottom of the coarse PK SCTs reported values within the range reported at the top.
- Sulphate concentrations decreased to steady state conditions after the first flush. No concentration trends with grain size (i.e., coarse PK versus fine PK) were evident.
- Concentrations of major parameters including sodium, magnesium, and calcium were highest in leachates collected during the first flush from the bottom of the fine PK columns. Based on concentration trends of major ions that are typically associated with readily-soluble materials, it appears that readily-soluble materials were flushed during the initial weeks of testing.
- Arsenic concentrations were highest in leachates collected from the bottom of the PK columns (0.0003 to 0.014 mg/L) and were increasing over time in both the top and bottom of several of the 2011 coarse PK SCTs. Selenium concentrations were stable and low after the first flush (0.00002 to 0.00006 mg/L) in the bottom water collected from both the coarse and fine PK. Both the coarse and fine PK columns initiated in 2010 reported an increase in selenium concentrations after 35 weeks of testing.
- Iron and molybdenum concentrations were generally higher in the leachates from the bottom of the submerged columns relative to the samples collected from the top.
- Fluoride concentrations are generally similar between the coarse and fine fractions of each sample at the bottom of the columns. Generally, fluoride concentrations increased after the first flush and have remained stable in the supplemental column tests in the top of the saturated columns. The 2010 PK Comp Fine sample reported a decrease in fluoride concentrations to steady state conditions after week 40 of

testing. Fluoride concentrations in bottom column water generally stabilize near 20 weeks, with the exception of the 2011 cell DGM 737 Fine, which reports increasing fluoride concentrations throughout testing.

- Phosphorus concentrations in the SCT top water leachates were generally stable throughout sampling for both the coarse and fine PK. Water collected from the bottom water of the SCTs reported increasing phosphorus values from the 2010 sample PK Comp Fine until week 25. This trend has not been observed in any of the supplemental samples at the time of sampling. The cells initiated in 2011 reported similar phosphorus concentrations in both the top and bottom waters of the SCTs.

Table 8.III-21a First Flush Concentrations in Leachate from Processed Kimberlite Submerged Column Tests

		pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
First Flush																								
Col 1: PK - Fines Composite - Processed Kimberlite Fines: Aug 5, 2010 - Sept 2, 2010																								
TOP	Minimum	7.5	15.0	7.1	0.07	0.0031	0.0004	17.6	0.0012	0.000103	0.0010	0.001	0.00003	5.81	0.0001	0.00662	0.00130	0.0045	5.5	0.00002	3.17	0.194	0.0000240	0.0020
	Maximum	7.8	36	14	0.2	0.004	0.0007	35	0.002	0.00025	0.0088	0.0	0.0002	10	0.025	0.011	0.0045	0.16	5.9	0.0009	4.66	0.37	0.00047	0.005
	Average	7.7	21.4	9.8	0.152	0.0037	0.0005	23.5	0.0014	0.000167	0.0036	0.005	0.0001	7.4	0.0106	0.0081	0.003	0.036	5.7	0.00029	3.7	0.258	0.000134	0.0034
BOTTOM	Minimum	7.6	1.0	2.1	0.34	0.0031	0.0006	10.3	0.0012	0.000032	0.0008	0.001	0.00004	2.72	0.0015	0.0085	0.00030	0.0045	2.5	0.00002	0.64	0.107	0.0000080	0.0005
	Maximum	8.1	11	26	0.8	0.0	0.0009	35	0.0022	0.00014	0.003	0.06	0.0001	10.0	0.014	0.019	0.0036	0.15	14	0.0006	15	0.41	0.0003	0.002
	Average	7.9	5.0	13.9	0.6	0.02	0.00072	23.4	0.0018	0.00007	0.0018	0.024	0.00009	7.0	0.0057	0.013	0.0015	0.09	10.4	0.00026	8	0.28	0.000088	0.001
Col 2: PK - Coarse Composite - Processed Kimberlite Coarse: Aug 5, 2010 - Sept 2, 2010																								
TOP	Minimum	7.3	2.0	23.0	0.11	0.0022	0.0002	8.2	0.0011	0.000108	0.0011	0.001	0.00004	3.51	0.0001	0.00081	0.0027	0.0045	3.8	0.00002	8.5	0.112	0.0000200	0.002
	Maximum	7.7	10	40	0.2	0.005	0.0008	13	0.0027	0.00017	0.0033	0.01	0.0001	5.9	0.012	0.0015	0.0038	0.005	6.2	0.0006	13	0.2	0.00019	0.003
	Average	7.5	4.8	32	0.17	0.0038	0.00054	10.0	0.0018	0.000131	0.0021	0.0046	0.00008	4.4	0.0051	0.00112	0.0031	0.005	5.2	0.00028	10.4	0.143	0.000067	0.0024
BOTTOM	Minimum	7.7	7.0	190.0	0.49	0.0027	0.0005	30.7	0.0013	0.000047	0.0007	0.001	0.00002	11.8	0.0001	0.0037	0.00080	0.0045	19.3	0.00002	52	0.455	0.0000080	0.0010
	Maximum	7.9	30	390	0.6	0.007	0.0033	93	0.009	0.00013	0.0038	0.009	0.0006	36	0.0091	0.0059	0.0025	0.025	34	0.0076	92	1.2	0.0001	0.004
	Average	7.8	15.0	286	0.56	0.0041	0.00226	57	0.0031	0.000082	0.0018	0.0026	0.00017	22.5	0.0038	0.0044	0.00166	0.012	26.0	0.00314	73	0.78	0.00004	0.002
Col 3: PK - DGM 713 Coarse - Processed Kimberlite Coarse: May 26, 2011 - June 23, 2011																								
TOP	Minimum	7.3	1.0	0.1	0.13	0.0016	0.0004	1.5	0.00025	0.00004	0.00025	0.001	0.00002	0.48	0.0004	0.00036	0.0008	0.0045	0.65	0.00002	0.83	0.015	0.0000005	0.003
	Maximum	7.6	5.0	0.2	0.21	0.004	0.0028	3.7	0.0007	0.00007	0.0035	0.011	0.00017	1.2	0.003	0.0035	0.0018	0.023	1.2	0.0003	1.4	0.035	0.000062	0.007
	Average	7.5	2.4	0.12	0.18	0.0024	0.0013	2.8	0.00034	0.00006	0.0017	0.0038	0.00007	0.9	0.0013	0.00115	0.0013	0.0107	0.95	0.00011	1.2	0.026	0.00003	0.004
BOTTOM	Minimum	7.6	2.0	0.3	1.5	0.0038	0.0012	11	0.00025	0.000119	0.0011	0.001	0.00009	4.0	0.001	0.0063	0.0032	0.0045	4.7	0.00002	10.8	0.11	0.000308	0.006
	Maximum	8.0	22	0.8	2.7	0.008	0.0073	19	0.0011	0.00028	0.0018	0.021	0.00029	7.0	0.005	0.022	0.0061	0.031	6.5	0.00084	15	0.18	0.002	0.014
	Average	7.8	11.6	0.52	2.4	0.006	0.0027	16	0.00075	0.0002	0.0013	0.009	0.00014	6.0	0.0034	0.017	0.004	0.014	6.0	0.00032	13	0.15	0.00113	0.0088
Col 4: PK - DGM 717 Coarse - Processed Kimberlite Coarse: May 26, 2011 - June 23, 2011																								
TOP	Minimum	7.5	1.0	0.4	0.08	0.0024	0.0005	1.4	0.00025	0.000035	0.0007	0.001	0.00005	0.66	0.0006	0.00082	0.0006	0.0045	1.4	0.00002	2.0	0.02	0.0000005	0.006
	Maximum	7.9	4.0	0.6	0.13	0.011	0.0022	3.3	0.0005	0.0003	0.0049	0.007	0.0027	1.6	0.003	0.0016	0.0014	0.041	2.4	0.00057	2.9	0.048	0.000021	0.017
	Average	7.7	2.6	0.5	0.11	0.0047	0.0014	2.4	0.0003	0.000095	0.0028	0.0026	0.0006	1.2	0.0014	0.00112	0.00096	0.018	2.0	0.00019	2.6	0.035	0.000013	0.0098
BOTTOM	Minimum	7.8	16.0	2.5	0.35	0.0038	0.0015	5.7	0.0005	0.000051	0.0010	0.010	0.00005	3.1	0.0009	0.0063	0.0019	0.0045	7.5	0.00016	18	0.088	0.000067	0.003
	Maximum	8.2	63	8	0.47	0.007	0.0058	19	0.0016	0.00017	0.0042	0.034	0.002	11	0.004	0.03	0.0036	0.056	16	0.00056	39	0.29	0.00078	0.011
	Average	8.0	34.4	6.0	0.43	0.0047	0.0036	14	0.0012	0.000097	0.0022	0.02	0.00047	8.3	0.003	0.022	0.0025	0.021	14	0.00034	32	0.21	0.00028	0.0066
Col 5: PK - DGM 737 Coarse - Processed Kimberlite Coarse: May 19, 2011 - June 16, 2011																								
TOP	Minimum	7.2	1.0	40.0	0.06	0.0016	0.0003	5.0	0.00025	0.000089	0.0006	0.001	0.00005	1.6	0.0021	0.00004	0.0015	0.0045	1.7	0.00002	1.76	0.048	0.0000005	0.006
	Maximum	7.5	4.0	75	0.18	0.0031	0.0014	19	0.0006	0.00028	0.0049	0.01	0.00016	7.2	0.014	0.0022	0.0056	0.022	4.5	0.0005	3.8	0.28	0.00039	0.014
	Average	7.4	2.0	57	0.09	0.0024	0.0009	14	0.0003	0.00021	0.0031	0.005	0.0001	5.4	0.0075	0.00051	0.0037	0.0107	3.4	0.00025	2.7	0.2	0.000081	0.0094
BOTTOM	Minimum	7.2	4.0	410	0.24	0.0012	0.0059	110	0.0012	0.000343	0.0011	0.005	0.00008	42.5	0.0028	0.0002	0.0011	0.015	28.0	0.00037	21.4	1.76	0.000005	0.007
	Maximum	7.5	6.0	590	0.36	0.017	0.0084	173	0.0026	0.00063	0.0031	0.01	0.00015	61	0.005	0.0013	0.016	0.064	38	0.015	28	2.6	0.000054	0.017
	Average	7.4	4.6	502	0.33	0.0054	0.0068	153	0.0018	0.00049	0.0019	0.0074	0.000116	55	0.0043	0.00075	0.0074	0.037	34	0.0034	25	2.3	0.000018	0.0114
Col 6: DGM 713 Fine - Processed Kimberlite Fines: June 30, 2011 - July 28, 2011																								
TOP	Minimum	7.7	1.0	0.1	0.10	0.0038	0.0003	3.7	0.00025	0.000098	0.0015	0.001	0.00002	0.91	0.0025	0.00083	0.0016	0.0045	2.8	0.00002	1.03	0.031	0.00003	0.002
	Maximum	7.8	3.0	0.8	0.12	0.013	0.0005	4.9	0.0003	0.00016	0.0035	0.16	0.00027	1.3	0.006	0.0019	0.0026	0.012	3.3	0.00002	1.5	0.04	0.000049	0.004
	Average	7.7	2.3	0.4	0.113	0.0067	0.00038	4.6	0.00025	0.000123	0.0024	0.045	0.00009	1.2	0.0036	0.00118	0.0021	0.0075	3.0	0.00002	1.2	0.036	0.00004	0.0033
BOTTOM	Minimum	7.8	67.0	5.7	1.38	0.0036	0.0040	27	0.00025	0.000128	0.00025	0.001	0.00007	8.4	0.0037	0.076	0.0010	0.0045	18	0.00013	16	0.24	0.00065	0.005
	Maximum	8.2	180	21	2.8	0.33	0.006	48	0.002	0.00093	0.0068	0.5	0.0014	15	0.014	0.092	0.014	0.005	29	0.00063	30	0.44	0.0032	0.023
	Average	7.9	106	11.7	2.1	0.079	0.0047	36	0.00082	0.00032	0.0032	0.113	0.0004	11.2	0.008	0.085	0.0051	0.0045	25	0.00039	24	0.31	0.002	0.0122
Col 7: DGM 717 Fine - Processed Kimberlite Fines: June 30, 2011 - July 28, 2011																								
TOP	Minimum	7.4	2.0	3.2	0.03	0.0022	0.0003	2.1	0.00025	0.000062	0.0009	0.001	0.00005	1.2	0.0032	0.00237	0.0019	0.0045	4.6	0.00002	3.02	0.036	0.000003	0.005
	Maximum	7.6	8.0	7.2	0.1	0.003	0.0006	3.9	0.0003	0.00011	0.0035	0.028	0.00008	1.8	0.045	0.0055	0.0038	0.035	5.7	0.00044	4.5	0.057	0.000035	0.02
	Average	7.5	4.4	5.2	0.076	0.0027	0.00044	3.2	0.00025	0.000081	0.0016	0.0078	0.00006	1.6	0.0122	0.0038	0.0027	0.0123	5.2	0.00015	3.5	0.049	0.000015	0.0092
BOTTOM	Minimum	7.5	53	6.8	0.24	0.0021	0.0034	14.1	0.00025	0.000048	0.00025	0.001	0.00005	6.4	0.0012	0.059	0.0015	0.0045	21	0.00002	20.4	0.197	0.000075	0.003
	Maximum	8.5	329	100	0.57	0.003	0.01	60	0.0006	0.00024	0.0027	0.025	0.00022	29	0.048	0.32	0.0038	0.022	57	0.0012	89	0.88	0.00036	0.18
	Average	7.8	173	52	0.35	0.0026	0.0062	34	0.00037	0.000131	0.0014	0.007	0.00014	15	0.0131	0.19	0.0023	0.008	39	0.00048	54	0.47	0.000152	0.047

Table 8.III-21a First Flush Concentrations in Leachate from Processed Kimberlite Submerged Column Tests (continued)

		pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Col 8: DGM 737 Fine - Processed Kimberlite Fines: June 30, 2011 - July 28, 2011																								
TOP	<i>Minimum</i>	7.1	2.0	30.0	0.03	0.0015	0.0005	8.0	0.00025	0.000209	0.0009	0.001	0.00005	1.74	0.0078	0.0004	0.0037	0.0045	11.6	0.00002	3.92	0.185	0.0000020	0.004
	<i>Maximum</i>	7.3	4.0	50	0.34	0.003	0.0023	18	0.0003	0.00049	0.0022	0.027	0.00035	2.7	0.048	0.0061	0.0092	0.017	17	0.00081	7.0	0.4	0.000016	0.027
	<i>Average</i>	7.2	2.6	37	0.21	0.0023	0.00126	12.4	0.00025	0.00035	0.0014	0.008	0.00013	2.2	0.02	0.002	0.0067	0.0083	14	0.0003	5.3	0.28	0.0000106	0.013
BOTTOM	<i>Minimum</i>	7.6	6.0	24	1.21	0.0023	0.0006	13	0.00025	0.000027	0.0009	0.001	0.00005	1.22	0.0001	0.0024	0.0005	0.0045	14	0.00002	1.7	0.26	0.0000005	0.003
	<i>Maximum</i>	8.2	49	760	1.6	0.004	0.014	263	0.0006	0.00062	0.0017	0.006	0.00023	3.7	0.002	0.011	0.009	0.005	238	0.001	147	7.1	0.000008	0.044
	<i>Average</i>	7.8	23	321	1.3	0.0033	0.006	109	0.00039	0.00022	0.0012	0.0032	0.00011	2.3	0.0006	0.0054	0.0026	0.0045	107	0.0004	51	2.6	0.000003	0.013
Col 12: Tuzo and Hearne Fine - Processed Kimberlite Fine: June 16, 2011 - July 14, 2011																								
TOP	<i>Minimum</i>	7.5	2.0	0.1	0.08	0.0064	0.0003	1.5	0.00025	0.00008	0.0005	0.002	0.00005	0.62	0.0012	0.0028	0.0012	0.0045	2.0	0.00002	1.8	0.014	0.000016	0.004
	<i>Maximum</i>	7.7	4.0	0.3	0.16	0.035	0.0006	3.1	0.0006	0.00017	0.0027	0.095	0.00019	0.95	0.028	0.011	0.0034	0.045	4.7	0.00047	5.1	0.035	0.00005	0.021
	<i>Average</i>	7.6	3.2	0.18	0.134	0.016	0.00042	2.4	0.00032	0.00011	0.0016	0.032	0.00011	0.81	0.0069	0.0074	0.002	0.0126	3.8	0.00015	4.0	0.027	0.00003	0.0106
BOTTOM	<i>Minimum</i>	7.4	884	130.0	0.41	0.0018	0.0015	9.1	0.0016	0.000262	0.0045	0.002	0.00014	3.1	0.0046	0.212	0.0068	0.0045	13	0.00037	17	0.11	0.00051	0.006
	<i>Maximum</i>	7.8	2038	180	0.5	0.064	0.0037	391	0.0039	0.0018	0.01	0.12	0.00031	153	0.044	3.7	0.04	0.069	135	0.014	312	4.6	0.0024	0.013
	<i>Average</i>	7.7	1461	155	0.5	0.023	0.0029	201	0.003	0.00111	0.0072	0.046	0.00024	75	0.027	2.2	0.024	0.028	81	0.0079	178	2.4	0.0017	0.0093
Col 13: East Lobe Fine - Processed Kimberlite Fine: June 16, 2011 - July 14, 2011																								
TOP	<i>Minimum</i>	7.2	1.0	8.2	0.03	0.0017	0.0004	4.7	0.00025	0.000033	0.0011	0.001	0.00003	0.39	0.0001	0.00008	0.0005	0.0045	7.3	0.00002	2.17	0.096	0.0000005	0.004
	<i>Maximum</i>	7.7	3.0	18	0.03	0.0044	0.0033	6.5	0.0006	0.00012	0.0046	0.008	0.00044	0.51	0.0036	0.032	0.0016	0.005	9.1	0.00034	3.7	0.12	0.000022	0.023
	<i>Average</i>	7.4	1.6	13.2	0.03	0.0029	0.00122	5.6	0.0004	0.000074	0.0022	0.0048	0.00016	0.44	0.00132	0.018	0.0010	0.0045	8.3	0.00009	2.9	0.105	0.000015	0.012
BOTTOM	<i>Minimum</i>	7.1	3.0	220.0	0.07	0.0017	0.0021	56.6	0.0008	0.000269	0.0022	0.001	0.00004	3.18	0.0006	0.00012	0.0025	0.0045	73	0.00037	20.7	1.33	0.0000005	0.003
	<i>Maximum</i>	7.4	8.0	1500	0.08	0.032	0.012	354	0.002	0.00063	0.06	0.02	0.0002	9.3	0.004	0.0054	0.01	0.005	385	0.0041	334	7.2	0.00011	0.018
	<i>Average</i>	7.2	5.0	976	0.07	0.0086	0.0084	251	0.0012	0.00045	0.0142	0.011	0.00011	6.3	0.002	0.0033	0.0058	0.005	251	0.0019	172	5.3	0.000027	0.0092
Col 14: Tuzo and Hearne Coarse - Processed Kimberlite Coarse: June 16, 2011 - July 14, 2011																								
TOP	<i>Minimum</i>	7.7	26.0	4.0	0.06	0.0035	0.0015	9.5	0.00025	0.000074	0.0016	0.001	0.00007	3.2	0.0006	0.0325	0.0018	0.0045	6.1	0.00002	10.5	0.118	0.00092	0.009
	<i>Maximum</i>	7.9	58	9	0.14	0.0059	0.0022	20	0.0008	0.00016	0.0056	0.012	0.0014	7.1	0.0037	0.06	0.0055	0.005	7.0	0.00092	17	0.25	0.0024	0.016
	<i>Average</i>	7.8	43	6.0	0.11	0.0044	0.0018	13.6	0.0005	0.00012	0.0034	0.0056	0.00047	4.8	0.0018	0.046	0.0035	0.0045	6.7	0.00064	13.6	0.17	0.0016	0.0114
BOTTOM	<i>Minimum</i>	7.9	35	2.8	0.66	0.0017	0.0012	18	0.0014	0.000138	0.0006	0.002	0.00008	6.2	0.0052	0.592	0.006	0.0045	14	0.00081	25	0.21	0.0019	0.004
	<i>Maximum</i>	8.2	591	54	1.0	0.11	0.0027	124	0.0037	0.00036	0.007	0.16	0.0023	41	0.013	1.8	0.013	0.012	53	0.0046	136	1.5	0.0037	0.006
	<i>Average</i>	8.0	309	30.1	0.8	0.024	0.0019	69	0.0023	0.00028	0.0035	0.047	0.00056	23	0.0103	1.38	0.0092	0.006	34	0.0026	82	0.84	0.0029	0.0048
Col 15: East Lobe Coarse - Processed Kimberlite Coarse: June 16, 2011 - July 14, 2011																								
TOP	<i>Minimum</i>	7.1	1.0	18.0	0.03	0.0014	0.0003	5.3	0.00025	0.000041	0.0006	0.001	0.00004	0.36	0.0005	0.00015	0.0007	0.0045	9.9	0.00002	3.48	0.104	0.000014	0.006
	<i>Maximum</i>	7.5	5.0	30	0.03	0.0029	0.0017	9.0	0.0011	0.00011	0.003	0.01	0.00055	0.84	0.0032	0.021	0.0016	0.01	11	0.00042	5.8	0.14	0.00015	0.015
	<i>Average</i>	7.4	2.2	25.0	0.03	0.002	0.0007	7.6	0.0005	0.000076	0.0019	0.005	0.00017	0.58	0.00128	0.0136	0.00114	0.0056	10.3	0.00023	4.7	0.13	0.000047	0.0096
BOTTOM	<i>Minimum</i>	7.2	1.0	520	0.03	0.0019	0.0042	110	0.0012	0.000219	0.0010	0.001	0.00004	1.77	0.0001	0.00013	0.0024	0.0045	132	0.00051	70.9	2.32	0.0000005	0.004
	<i>Maximum</i>	7.6	4.0	1200	0.08	0.004	0.013	243	0.0035	0.00049	0.015	0.015	0.00044	12	0.0038	0.0036	0.0082	0.005	297	0.0021	215	6.1	0.000016	0.012
	<i>Average</i>	7.4	2.8	766	0.05	0.0029	0.0068	198	0.002	0.00035	0.0051	0.0068	0.00014	6.1	0.00156	0.0021	0.0046	0.0045	193	0.00118	125	4.4	0.0000097	0.0062

Note: s.u. = standard units; µs/cm = microSiemens per centimetre; mg/L = milligrams per litre.

Table 8.III-21b Steady State Concentrations in Leachate from Processed Kimberlite Submerged Column Tests

			pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
			s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Steady State																									
Col 1: PK - Fines Composite - Processed Kimberlite Fines: Nov 3, 2011 - Dec 1, 2011																									
TOP	Minimum	7.4	1.0	0.1	0.03	0.0052	0.0001		3.0	0.00025	0.000014	0.0006	0.0015	0.00007	0.66	0.0001	0.0012	0.0007	0.0045	1.0	0.00002	0.13	0.03	0.000002	0.005
	Maximum	7.8	3.0	7.5	0.03	0.051	0.0006		3.2	0.003	0.000092	0.0011	0.017	0.00039	0.71	0.0019	0.003	0.0014	0.009	1.2	0.00006	1.42	0.032	0.000019	0.014
	Average	7.6	2.2	2.0	0.03	0.027	0.00026		3.1	0.0008	0.000039	0.00084	0.012	0.00018	0.68	0.00082	0.0017	0.00098	0.0054	1.1	0.000028	0.49	0.031	0.0000074	0.008
BOTTOM	Minimum	8.2	1.0	0.4	1.4	0.88	0.0001		3.3	0.0006	0.00011	0.001	0.068	0.00028	0.75	0.0005	0.039	0.0018	0.13	5.2	0.00002	9.4	0.042	0.000005	0.004
	Maximum	8.4	3.0	3.9	1.8	1.3	0.0008		4.0	0.0036	0.00019	0.0036	0.16	0.00048	1.1	0.003	0.045	0.0033	0.16	6.0	0.00007	13	0.05	0.000087	0.006
	Average	8.3	2.2	1.2	1.6	1.0	0.00034		3.7	0.0012	0.00014	0.002	0.095	0.00039	0.85	0.002	0.042	0.0024	0.15	5.5	0.00004	11	0.045	0.000023	0.0052
Col 2: PK - Coarse Composite - Processed Kimberlite Coarse: Nov 10, 2011 - Dec 8, 2011																									
TOP	Minimum	7.4	1.0	1.2	0.14	0.0071	0.0001		2.8	0.00025	0.000012	0.0007	0.0015	0.00005	0.84	0.0001	0.00064	0.0005	0.0045	2.5	0.00002	1.9	0.033	0.0000005	0.005
	Maximum	7.7	3.0	5.6	0.22	0.053	0.001		3.0	0.0036	0.00004	0.0011	0.07	0.00035	0.98	0.005	0.0011	0.0007	0.072	2.9	0.00025	4.4	0.038	0.000018	0.019
	Average	7.6	2.0	2.3	0.18	0.023	0.00034		2.9	0.0019	0.000024	0.00086	0.017	0.00016	0.93	0.0012	0.0008	0.0006	0.02	2.7	0.000076	2.6	0.036	0.00001	0.0082
BOTTOM	Minimum	8.4	4.0	5.5	0.78	0.011	0.0005		3.6	0.00025	0.000016	0.00025	0.0015	0.00005	0.83	0.0001	0.0027	0.0003	0.0045	5.1	0.00016	14	0.047	0.0000005	0.003
	Maximum	8.7	5.0	11	1.1	0.054	0.0015		3.8	0.003	0.000035	0.0018	0.014	0.00035	0.91	0.0012	0.0035	0.0005	0.045	5.6	0.00066	18	0.051	0.000006	0.006
	Average	8.6	4.8	6.9	0.93	0.03	0.00086		3.7	0.0016	0.000021	0.00079	0.0073	0.00015	0.87	0.00052	0.0031	0.00038	0.02	5.5	0.0003	15	0.049	0.0000043	0.0038
Col 3: PK - DGM 713 Coarse - Processed Kimberlite Coarse: Oct 6, 2011 - Nov 10, 2011																									
TOP	Minimum	7.4	1.0	0.1	0.09	0.0027	0.0027		3.3	0.00025	0.000017	0.0006	0.0015	0.0001	1.1	0.0003	0.00028	0.0017	0.0045	0.94	0.00002	0.57	0.03	0.000019	0.004
	Maximum	7.6	2.0	1.3	0.12	0.024	0.003		3.6	0.0029	0.000026	0.0007	0.004	0.00032	1.2	0.0015	0.00078	0.0018	0.0045	1.1	0.00005	1.1	0.033	0.000022	0.005
	Average	7.5	1.8	0.56	0.11	0.013	0.0029		3.5	0.0016	0.000022	0.00065	0.0028	0.00021	1.1	0.0009	0.00053	0.0018	0.0045	1.0	0.000035	0.82	0.031	0.000021	0.0045
BOTTOM	Minimum	7.9	1.0	0.3	1.3	0.0034	0.0022		15	0.00025	0.000088	0.0007	0.006	0.00006	5.7	0.0023	0.0055	0.0025	0.0045	5.0	0.00002	7.4	0.14	0.000056	0.004
	Maximum	8.0	3.0	3.0	1.5	0.039	0.0025		16	0.0019	0.00011	0.0011	0.011	0.00028	6.1	0.003	0.0067	0.0027	0.0045	5.5	0.00031	8.7	0.15	0.000089	0.005
	Average	7.9	1.6	0.96	1.4	0.021	0.0024		15	0.0011	0.000098	0.0009	0.0085	0.00017	5.9	0.0027	0.0061	0.0026	0.0045	5.2	0.00017	8.0	0.14	0.000073	0.0045
Col 4: PK - DGM 717 Coarse - Processed Kimberlite Coarse: Oct 6, 2011 - Nov 10, 2011																									
TOP	Minimum	7.5	1.0	0.1	0.09	0.0024	0.0054		2.9	0.00025	0.000014	0.0006	0.0015	0.00005	1.5	0.0009	0.00027	0.0005	0.0045	1.6	0.00002	1.2	0.041	0.000008	0.004
	Maximum	7.7	2.0	1.0	0.12	0.025	0.0077		2.9	0.0019	0.000017	0.0007	0.007	0.00018	1.5	0.001	0.00052	0.0006	0.0045	1.7	0.00005	1.6	0.041	0.000008	0.008
	Average	7.6	1.8	0.32	0.11	0.014	0.0066		2.9	0.0011	0.000016	0.00065	0.0043	0.00012	1.5	0.00095	0.0004	0.00055	0.0045	1.7	0.000035	1.4	0.041	0.000008	0.006
BOTTOM	Minimum	8.1	1.0	0.8	0.48	0.018	0.0024		9.0	0.00025	0.000042	0.0016	0.007	0.00005	5.5	0.0023	0.0041	0.0007	0.0045	10	0.00005	20	0.14	0.000019	0.006
	Maximum	8.2	2.0	2.0	0.51	0.031	0.0045		9.5	0.0022	0.000046	0.0023	0.072	0.00042	5.7	0.0025	0.0053	0.0016	0.012	11	0.00006	21	0.15	0.000034	0.007
	Average	8.2	1.4	1.2	0.5	0.024	0.0035		9.2	0.0012	0.000044	0.002	0.04	0.00024	5.6	0.0024	0.0047	0.0012	0.0083	11	0.000055	20	0.14	0.000027	0.0065
Col 5: PK - DGM 737 Coarse - Processed Kimberlite Coarse: Sept 29, 2011 - Nov 3, 2011																									
TOP	Minimum	7.5	1.0	8.1	0.14	0.0022	0.003		6.1	0.0028	0.000015	0.00025	0.001	0.00017	1.7	0.0001	0.00008	0.001	0.0045	2.0	0.00002	0.42	0.078	0.000004	0.004
	Maximum	7.6	3.0	9.1	0.17	0.0026	0.0039		6.1	0.0039	0.000017	0.00025	0.013	0.00024	1.8	0.0001	0.00019	0.0011	0.0045	2.1	0.00028	0.44	0.083	0.000007	0.005
	Average	7.5	2.2	8.6	0.16	0.0024	0.0035		6.1	0.0034	0.000016	0.00025	0.007	0.00021	1.7	0.0001	0.00014	0.0011	0.0045	2.0	0.00015	0.43	0.081	0.0000055	0.0045
BOTTOM	Minimum	8.1	1.0	99	0.52	0.0034	0.0029		53	0.0022	0.00007	0.0005	0.006	0.00009	6.3	0.0008	0.00014	0.0001	0.0045	9.9	0.00002	3.8	0.85	0.000009	0.004
	Maximum	8.4	3.0	130	0.59	0.0042	0.0039		59	0.0024	0.000088	0.0006	0.022	0.00015	9.0	0.0011	0.00015	0.0013	0.0045	11	0.00017	4.3	0.95	0.000013	0.005
	Average	8.2	2.0	116	0.55	0.0038	0.0034		56	0.0023	0.000079	0.00055	0.014	0.00012	7.7	0.00095	0.00015	0.0007	0.0045	11	0.000095	4.1	0.9	0.000011	0.0045
Col 6: DGM 713 Fine - Processed Kimberlite Fines: Oct 6, 2011 - Nov 10, 2011																									
TOP	Minimum	7.6	1.0	0.1	0.03	0.0035	0.0003		3.7	0.00025	0.00003	0.00025	0.0015	0.00007	0.99	0.0014	0.00047	0.0011	0.0045	1.8	0.00002	0.27	0.027	0.000026	0.005
	Maximum	7.8	4.0	1.9	0.08	0.025	0.001		3.7	0.0026	0.00005	0.0008	0.005	0.00016	1.0	0.0016	0.00082	0.0012	0.0045	1.9	0.00018	1.6	0.027	0.000033	0.009
	Average	7.7	2.4	0.46	0.064	0.014	0.00065		3.7	0.0014	0.00004	0.00053	0.0033	0.00012	1.0	0.0015	0.00065	0.0012	0.0045	1.8	0.0001	0.93	0.027	0.00003	0.007
BOTTOM	Minimum	7.8	1.0	0.5	0.08	0.005	0.0005		14	0.00025	0.00003	0.0007	0.003	0.00004	4.7	0.0018	0.032	0.0005	0.0045	17	0.00002	14	0.12	0.00013	0.003
	Maximum	8.0	2.0	0.7	2.0	0.032	0.0007		14	0.0021	0.00005	0.002	0.008	0.00016	4.8	0.015	0.034	0.0012	0.014	18	0.00016	16	0.13	0.0003	0.003
	Average	7.9	1.6	0.6	1.6	0.018	0.0006		14	0.0012	0.00004	0.0014	0.0055	0.0001	4.7	0.0086	0.033	0.00085	0.0093	17	0.00009	15	0.12	0.00022	0.003
Col 7: DGM 717 Fine - Processed Kimberlite Fines: Oct 6, 2011 - Nov 10, 2011																									
TOP	Minimum	7.6	1.0	0.2	0.07	0.004	0.0004		3.2	0.00025	0.000036	0.0012	0.0015	0.00007	1.4	0.001	0.00029	0.001	0.0045	3.2	0.00002	0.77	0.044	0.000003	0.008
	Maximum	7.7	3.0	0.5	0.12	0.015	0.0004		3.2	0.0028	0.000036	0.0018	0.004	0.00046	1.4	0.0014	0.0013	0.0014	0.0045	3.4	0.00002	1.0	0.044	0.000005	0.012
	Average	7.6	1.6	0.32	0.084	0.0095	0.0004		3.2	0.0015	0.000036	0.0015	0.0028	0.00027	1.4	0.0012	0.0008	0.0012	0.0045	3.3	0.00002	0.91	0.044	0.000004	0.01
BOTTOM	Minimum	8.0	13	0.9	0.64	0.0057	0.0006		6.3	0.00025	0.000017	0.0007	0.0015	0.00008	3.0	0.0003	0.032	0.0009	0.0045	21	0.00005	42	0.097	0.000025	0.004
	Maximum	8.2	16	4.8	0.74	0.026	0.001		7.0	0.0016	0.000025	0.0029	0.002	0.00018	3.4	0.0012	0.046	0.0011	0.037	23	0.00008	43	0.11	0.000038	0

Table 8.III-21b Steady State Concentrations in Leachate from Processed Kimberlite Submerged Column Tests (continued)

		pH	SO ₄	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Col 8: DGM 737 Fine - Processed Kimberlite Fines: Oct 6, 2011 - Nov 10, 2011																								
TOP	Minimum	7.6	1.0	0.8	0.23	0.0048	0.0003	3.9	0.00025	0.000029	0.0006	0.0015	0.00007	0.37	0.0009	0.00067	0.0007	0.0045	4.1	0.00007	0.73	0.077	0.000003	0.008
	Maximum	7.8	3.0	3.7	0.38	0.03	0.0004	5.2	0.0021	0.000043	0.0011	0.006	0.00029	0.4	0.0009	0.00078	0.0009	0.0045	4.4	0.00027	2.0	0.10	0.000003	0.008
	Average	7.6	2.2	1.7	0.27	0.017	0.00035	4.5	0.0012	0.000036	0.00085	0.0038	0.00018	0.38	0.0009	0.00073	0.0008	0.0045	4.2	0.00017	1.3	0.088	0.000003	0.008
BOTTOM	Minimum	8.9	28	28	3.6	0.0025	0.0023	27	0.00025	0.000059	0.0007	0.0015	0.00004	0.11	0.0003	0.006	0.0006	0.0045	24	0.00025	6.7	0.64	0.000002	0.003
	Maximum	9.1	35	59	5.3	0.051	0.0032	51	0.0024	0.000077	0.001	0.006	0.00017	0.25	0.0009	0.0071	0.0016	0.0045	34	0.00082	8.6	1.2	0.000003	0.003
	Average	9.0	31	40	4.1	0.027	0.0028	39	0.0013	0.000068	0.00085	0.0038	0.00011	0.18	0.0006	0.0066	0.0011	0.0045	29	0.00054	7.7	0.92	0.0000025	0.003
Col 12: Tuzo and Hearne Fine - Processed Kimberlite Fine: Sept 22, 2011 - Oct 27, 2011																								
TOP	Minimum	7.3	1.0	0.1	0.03	0.0043	0.0004	2.5	0.0018	0.000021	0.0006	0.009	0.00006	0.86	0.0001	0.0011	0.0007	0.0045	2.4	0.00002	1.2	0.03	0.000007	0.006
	Maximum	7.5	3.0	3.1	0.06	0.0055	0.0005	2.7	0.0018	0.000044	0.0008	0.013	0.00007	0.88	0.001	0.0023	0.001	0.0045	2.6	0.00009	1.8	0.031	0.00065	0.009
	Average	7.4	2.2	1.0	0.048	0.0049	0.00045	2.6	0.0018	0.000033	0.0007	0.011	0.000065	0.87	0.00055	0.0017	0.00085	0.0045	2.5	0.000055	1.5	0.03	0.00033	0.0075
BOTTOM	Minimum	8.1	12	0.4	2.0	0.013	0.0065	8.8	0.0018	0.000041	0.0008	0.009	0.0001	4.0	0.001	0.032	0.002	0.0045	23	0.00002	57	0.13	0.0023	0.006
	Maximum	8.2	18	3.5	2.5	0.041	0.0068	9.8	0.0023	0.000075	0.001	0.013	0.00018	4.2	0.0012	0.055	0.0029	0.0045	24	0.00018	63	0.13	0.0032	0.01
	Average	8.2	15	1.1	2.1	0.027	0.0067	9.3	0.0021	0.000058	0.0009	0.011	0.00014	4.1	0.0011	0.044	0.0025	0.0045	23	0.0001	60	0.13	0.0028	0.008
Col 13: East Lobe Fine - Processed Kimberlite Fine: Sept 22, 2011 - Oct 27, 2011																								
TOP	Minimum	7.5	1.0	0.3	0.03	0.0022	0.0003	2.9	0.0025	0.00001	0.0011	0.011	0.00005	0.24	0.0001	0.0003	0.0003	0.0045	3.6	0.00002	0.92	0.05	0.000008	0.005
	Maximum	7.7	2.0	1.2	0.11	0.0025	0.0005	3.5	0.003	0.000022	0.0013	0.011	0.00011	0.28	0.0007	0.0008	0.0005	0.013	4.8	0.00007	1.2	0.066	0.000024	0.007
	Average	7.6	1.4	0.52	0.058	0.0024	0.0004	3.2	0.0028	0.000016	0.0012	0.011	0.00008	0.26	0.0004	0.00055	0.0004	0.0088	4.2	0.000045	1.1	0.058	0.000016	0.006
BOTTOM	Minimum	9.1	5.0	5.9	0.45	0.0026	0.001	7.3	0.0018	0.000018	0.0007	0.012	0.00006	0.05	0.0001	0.00052	0.0004	0.0045	21	0.0002	5.3	0.21	0.000003	0.005
	Maximum	9.4	6.0	7.0	0.56	0.0031	0.0013	13	0.003	0.000018	0.0008	0.012	0.00022	0.068	0.0003	0.00053	0.0005	0.0045	23	0.00026	7.1	0.35	0.000005	0.005
	Average	9.2	5.6	6.3	0.5	0.0029	0.0012	9.9	0.0024	0.000018	0.00075	0.012	0.00014	0.059	0.0002	0.00053	0.00045	0.0045	22	0.00023	6.2	0.28	0.000004	0.005
Col 14: Tuzo and Hearne Coarse - Processed Kimberlite Coarse: Sept 22, 2011 - Oct 27, 2011																								
TOP	Minimum	7.8	1.0	0.1	0.08	0.0019	0.0014	3.4	0.0016	0.000034	0.0011	0.006	0.00003	1.2	0.0006	0.0022	0.0008	0.0045	2.7	0.00006	1.6	0.043	0.000061	0.005
	Maximum	8.0	2.0	2.3	0.12	0.0028	0.0018	3.8	0.003	0.000042	0.0011	0.013	0.00003	1.3	0.001	0.0033	0.0009	0.014	3.1	0.00008	2.4	0.047	0.000083	0.006
	Average	7.9	1.6	1.1	0.1	0.0024	0.0016	3.6	0.0023	0.000038	0.0011	0.0095	0.00003	1.3	0.0008	0.0028	0.00085	0.0093	2.9	0.00007	2.0	0.045	0.000072	0.0055
BOTTOM	Minimum	8.2	10	0.4	2.4	0.014	0.0069	10	0.002	0.000048	0.0009	0.02	0.0001	3.9	0.001	0.027	0.0017	0.0045	18	0.00005	53	0.13	0.0039	0.004
	Maximum	8.3	13	1.3	2.7	0.03	0.0075	11	0.0023	0.000063	0.0009	0.032	0.00011	4.0	0.0013	0.042	0.0018	0.0045	18	0.00007	54	0.14	0.0039	0.004
	Average	8.2	12	0.74	2.6	0.022	0.0072	11	0.0022	0.000056	0.0009	0.026	0.00011	3.9	0.0012	0.034	0.0018	0.0045	18	0.00006	53	0.13	0.0039	0.004
Col 15: East Lobe Coarse - Processed Kimberlite Coarse: Sept 22, 2011 - Oct 27, 2011																								
TOP	Minimum	7.5	1.0	1.2	0.06	0.0027	0.0011	4.5	0.0027	0.000021	0.0008	0.017	0.00007	0.15	0.0003	0.00022	0.0004	0.0045	4.4	0.00002	0.92	0.049	0.000018	0.005
	Maximum	7.7	3.0	2.9	0.08	0.0029	0.0012	5.0	0.0032	0.000032	0.0015	0.021	0.00014	0.17	0.0006	0.00053	0.0005	0.012	4.5	0.00008	1.2	0.063	0.00003	0.011
	Average	7.6	2.0	1.7	0.072	0.0028	0.0012	4.8	0.003	0.000027	0.0012	0.019	0.00011	0.16	0.00045	0.00038	0.00045	0.0083	4.5	0.00005	1.1	0.056	0.000024	0.008
BOTTOM	Minimum	9.0	1.0	22	0.28	0.0027	0.0014	17	0.0017	0.000024	0.00025	0.007	0.00002	0.058	0.0001	0.00024	0.0004	0.0045	26	0.00002	5.1	0.35	0.000006	0.004
	Maximum	9.4	4.0	34	0.3	0.0039	0.0018	29	0.0018	0.000043	0.0008	0.012	0.00014	0.12	0.0003	0.00033	0.0006	0.015	30	0.00029	7.2	0.64	0.000013	0.009
	Average	9.3	2.6	28	0.28	0.0033	0.0016	23	0.0018	0.000034	0.00053	0.0095	0.00008	0.09	0.0002	0.00029	0.0005	0.0098	28	0.00016	6.2	0.5	0.0000095	0.0065

Note: s.u. = standard units; µs/cm = microSiemens per centimetre; mg/L = milligrams per litre.

Figure 8.III-10a Leachate Concentrations in Top Water from Processed Kimberlite Columns

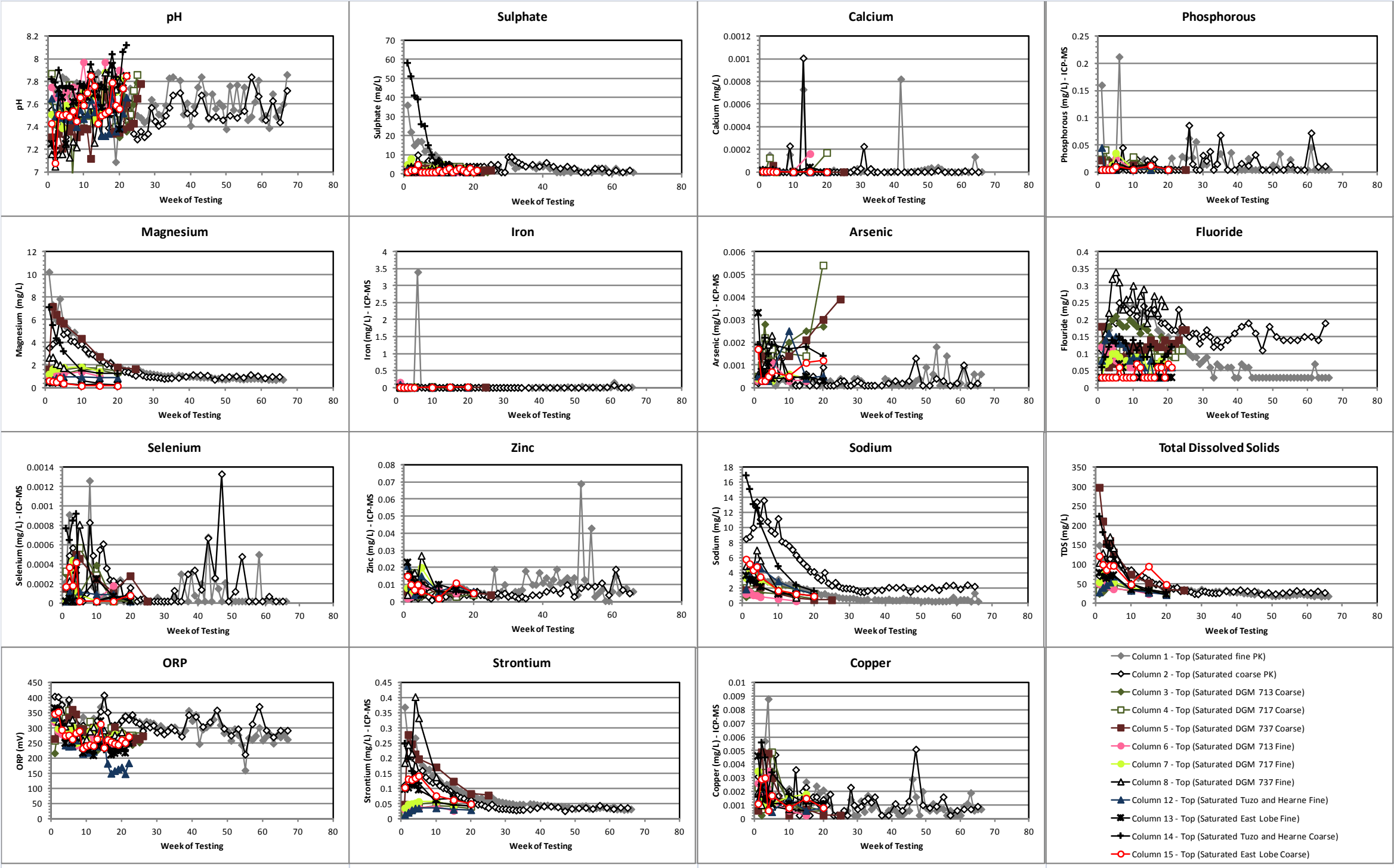
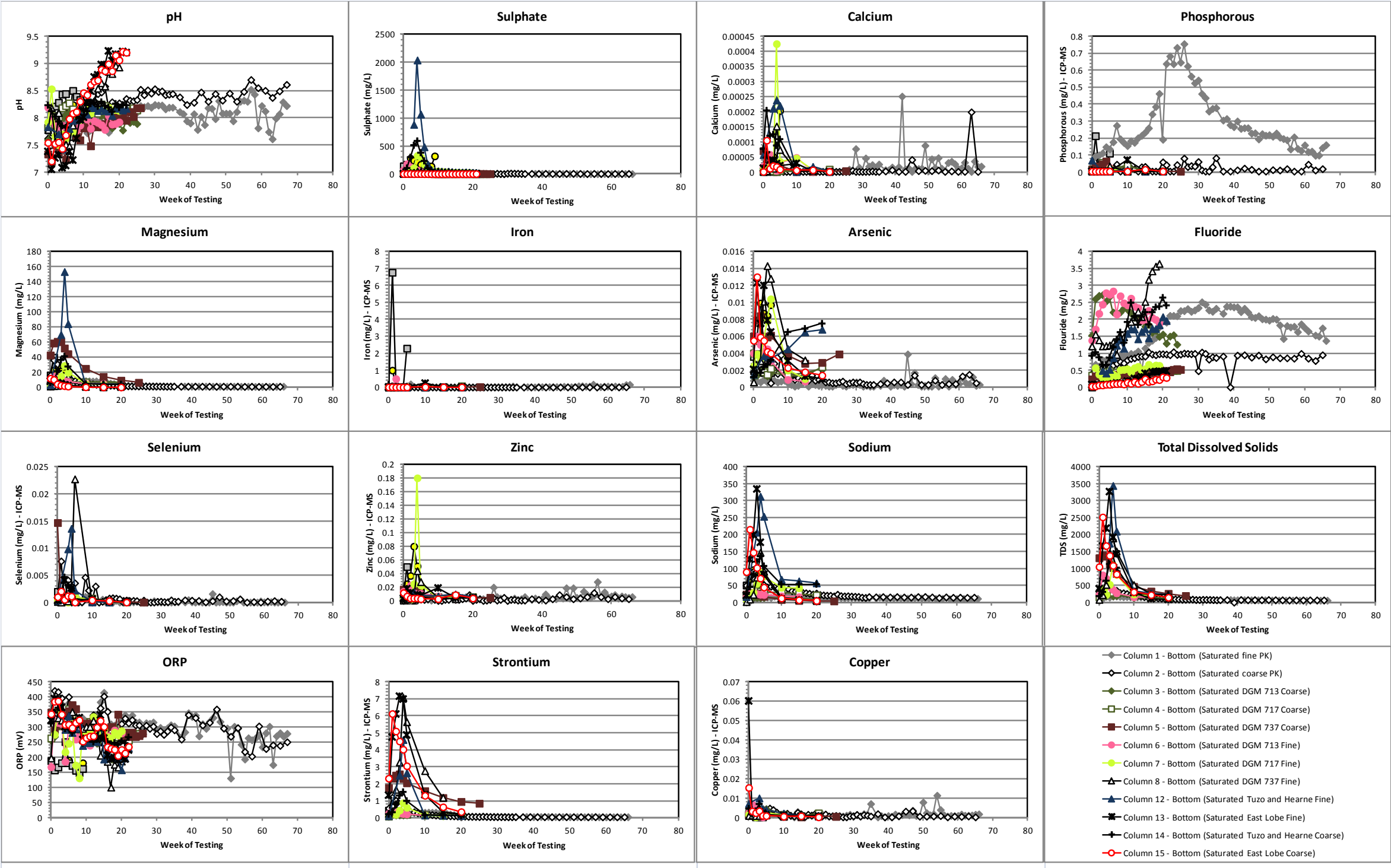


Figure 8.III-10b Leachate Concentrations in Bottom Water from Processed Kimberlite Columns



8.III.4.2.7 Comparison of PK Geochemical Test Leachates

Table 8.III-22 compares the average concentrations in the initial weeks of the PK coarse and fine column tests to the results of humidity cell tests conducted on the same samples, and process water collected during metallurgical testing. General observations include the following:

- The pH values of all test leachates were alkaline. The lower pH values were reported in leachates collected from the tops of the submerged column tests (7.1 to 8.1) and the highest pH values were reported in leachates from the first flush of the PK fines humidity cells (7.6 to 9.3), the bottom of the submerged column tests (7.1 to 9.4), and the process water (7.9 to 8.8).
- Sulphate concentrations were generally highest in the first flush of the bottom water from the fine PK SCTs, and lowest at steady state in the humidity cells.
- Concentrations of major parameters including calcium, sodium, magnesium, and potassium were highest in leachates collected from the bottoms of the submerged columns.
- Concentrations of copper and zinc were highest in the first flush of the bottom of the fine PK SCT, and generally similar in the other tests.
- Nickel concentrations were generally highest in the first flush of the bottom of the fine PK SCT, and the first flush of both the coarse and fine PK HCTs.
- Cobalt and chromium concentrations were generally similar in all tests.
- Concentrations of arsenic and selenium were highest in leachates collected from the bottom of the coarse PK column, from the first flush of the coarse PK humidity cell, and in the first flush of the bottom of the coarse and fine PK SCTs.
- Concentrations of iron were highest in leachates collected from the first flush of the top of the fine PK SCT.
- Fluoride concentrations were generally highest in the process water, and lowest at steady state conditions in both the coarse and fine HCTs.
- Phosphorus concentrations were highest in the bottom water of the fine PK, increasing up to 0.16 mg/L in the first flush and steady state, and up to a maximum 0.76 mg/L overall throughout testing. However, the elevated phosphorus concentrations were only observed in the single fine PK SCT from 2010. An anomalous value of 0.88 mg/L phosphorus was reported in the first flush of HCT test DGM 713 Coarse; however, all other values were below 0.1 mg/L. All other tests, including the other fine PK SCTs, reported relatively similar phosphorus concentrations, generally below 0.1 mg/L. Golder (2011) discusses the influence of solid phase composition and leach testing on the mobility of phosphorus. The results of this report show that phosphorus is associated with apatite in the solid phase and that the release of phosphorus is dependent on pH, redox conditions, and the availability of free (liberated) apatite minerals.

Table 8.III-22 Comparison of Processed Kimberlite Geochemical Test Leachates

		pH	SO ₄	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Process Water	Minimum	7.9	16	5.0	94	0.0052	0.0011	23	0.0021	0.000044	0.0014	0.001	0.00002	3.0	0.0001	0.0033	0.0004	0.034	5.0	0.00014	3.9	0.13	0.000042	0.001
	Maximum	8.8	23	5.5	111	0.043	0.0016	30	0.0041	0.00011	0.0024	0.002	0.00008	4.0	0.0075	0.0038	0.0021	0.089	7.8	0.00019	6.1	0.16	0.00023	0.001
Submerged Column Tests - Fine PK - First Flush ^(a)	Fine PK - Top																							
	Minimum	7.1	1.0	0.1	0.03	0.0015	0.0003	1.5	0.00025	0.000033	0.0005	0.001	0.00002	0.39	0.0001	0.00008	0.00050	0.0045	2.0	0.00002	1.03	0.014	0.0000005	0.0020
	Maximum	7.8	36	50	0.34	0.035	0.0033	35	0.002	0.00049	0.0088	0.2	0.0004	10	0.048	0.032	0.0092	0.16	17	0.0009	7.0	0.4	0.00047	0.027
	Fine PK - Bottom																							
	Minimum	7.1	1.0	2.1	0.07	0.0012	0.0006	9.1	0.00025	0.000027	0.00025	0.001	0.00004	1.22	0.0001	0.00012	0.00030	0.0045	2.5	0.00002	0.64	0.107	0.0000005	0.0005
	Maximum	8.5	2,038	1,500	2.8	0.3	0.014	391	0.0039	0.0018	0.06	0.5	0.0014	153	0.048	3.7	0.04	0.15	385	0.015	334	7.2	0.0032	0.18
	Coarse PK - Top																							
	Minimum	7.1	1.0	0.1	0.03	0.0014	0.0002	1.4	0.00025	0.000035	0.00025	0.001	0.00002	0.36	0.0001	0.00004	0.0006	0.0045	0.65	0.00002	0.83	0.015	0.0000005	0.002
	Maximum	7.9	58	75	0.21	0.011	0.0028	20	0.0027	0.0003	0.0056	0.012	0.0027	7.2	0.014	0.06	0.0056	0.041	11	0.0009	17	0.28	0.0024	0.017
	Coarse PK - Bottom																							
	Minimum	7.2	1.0	0.3	0.03	0.0012	0.0005	5.7	0.00025	0.000047	0.0006	0.001	0.00002	1.77	0.0001	0.00013	0.00080	0.0045	4.7	0.00002	10.8	0.088	0.0000005	0.0010
	Maximum	8.2	591	1,200	2.7	0.11	0.013	243	0.009	0.00063	0.015	0.16	0.0023	61	0.013	1.8	0.016	0.064	297	0.015	215	6.1	0.0037	0.017
Submerged Column Tests - Fine PK - Steady State ^(b)	Fine PK - Top																							
	Minimum	7.3	1.0	0.1	0.03	0.0022	0.0001	2.5	0.00025	0.000010	0.00025	0.0015	0.00005	0.24	0.0001	0.00029	0.00030	0.0045	1.0	0.00002	0.13	0.027	0.0000020	0.0050
	Maximum	7.8	4.0	7.5	0.38	0.051	0.001	5.2	0.003	0.00009	0.0018	0.017	0.0005	1.4	0.002	0.003	0.0014	0.01	4.8	0.0003	2.0	0.1	0.00065	0.014
	Fine PK - Bottom																							
	Minimum	7.8	1.0	0.4	0.08	0.0025	0.0001	3.3	0.00025	0.000017	0.0007	0.0015	0.00004	0.05	0.0001	0.00052	0.0004	0.0045	5.2	0.00002	5.3	0.042	0.000002	0.003
	Maximum	9.4	35	59	5.3	1.3	0.0068	51	0.0036	0.00019	0.0036	0.16	0.00048	4.8	0.015	0.055	0.0033	0.16	34	0.00082	63	1.2	0.0032	0.01
	Coarse PK - Top																							
	Minimum	7.4	1.0	0.1	0.06	0.0019	0.0001	2.8	0.00025	0.000012	0.00025	0.001	0.00003	0.15	0.0001	0.00008	0.0004	0.0045	0.94	0.00002	0.42	0.03	0.0000005	0.004
	Maximum	8.0	3.0	9.1	0.22	0.053	0.0077	6.1	0.0039	0.000042	0.0015	0.07	0.00035	1.8	0.005	0.0033	0.0018	0.072	4.5	0.00028	4.4	0.083	0.000083	0.019
	Coarse PK - Bottom																							
	Minimum	7.9	1.0	0.3	0.28	0.0027	0.0005	3.6	0.00025	0.000016	0.00025	0.0015	0.00002	0.058	0.0001	0.00014	0.0001	0.0045	5.0	0.00002	3.8	0.047	0.0000005	0.003
	Maximum	9.4	13	130	2.7	0.054	0.0075	59	0.003	0.00011	0.0023	0.072	0.00042	9.0	0.003	0.042	0.0027	0.045	30	0.00066	54	0.95	0.0039	0.009
Humidity Cell Tests - First Flush ^(a)	PK Fines																							
	Minimum	7.6	1.0	0.37	0.05	0.0016	0.001	6.3	0.00025	0.000052	0.0006	0.001	0.00002	0.3	0.0001	0.00038	0.0008	0.0045	7.1	0.00002	7.1	0.071	0.0000005	0.001
	Maximum	9.3	703	810	2.4	0.19	0.42	155	0.0079	0.001	0.0069	0.3	0.001	72	0.013	1.6	0.031	0.15	196	0.011	187	4.1	0.0082	0.013
	Coarse PK																							
	Minimum	7.3	1.0	0.1	0.09	0.0012	0.0004	4.4	0.00025	0.000001	0.00025	0.001	0.00001	0.86	0.0001	0.00016	0.0006	0.0045	2.8	0.00002	1.8	0.046	0.0000005	0.001
	Maximum	8.3	585	540	2.6	0.17	0.0071	171	0.0042	0.00093	0.024	0.26	0.00014	66	0.013	1.5	0.053	0.88	152	0.059	214	2.1	0.024	0.083
Humidity Cell Tests - Steady State ^(b)	PK Fines																							
	Minimum	7.4	1.0	0.2	0.025	0.0004	0.0002	1.8	0.0002	0.000019	0.00025	0.002	0.00002	0.11	0.0001	0.0001	0.0001	0.0045	3.2	0.00002	0.92	0.019	0.000001	0.0005
	Maximum	9.1	16.0	2.0	1.55	0.0680	0.1050	17.8	0.0022	0.00020	0.0048	0.109	0.00020	6.32	0.0024	0.00554	0.0035	0.030	26.7	0.00020	11.2	0.303	0.002663	0.0070
	Coarse PK																							
	Minimum	7.4	1.0	0.1	0.09	0.0011	0.0004	3.5	0.00025	0.000016	0.00025	0.0015	0.00001	1.0	0.0001	0.00019	0.0002	0.0045	3.5	0.00002	0.63	0.044	0.0000005	0.001
	Maximum	8.4	5.0	17	0.54	0.065	0.003	11	0.0023	0.00021	0.0041	0.064	0.00043	6.9	0.001	0.023	0.0027	0.0045	22	0.00057	19	0.21	0.001	0.007

Note: s.u. = standard units; µs/cm = microSiemens per centimetre; mg/L = milligrams per litre; PK = processed kimberlite.

^(a) First five weeks of sampling.

^(b) Last five weeks of sampling.

8.III.4.3 Mine Rock

8.III.4.3.1 Static Testing

Mineralogy

In 2004, three granite samples were submitted for qualitative optical mineralogy analysis (Petrascience, 2004 – Attachment 8.III-3). Results are summarized in Table 8.III-23. Major mineral phases included potassium feldspar, quartz, and plagioclase. One sample reported approximately 40% clay minerals. Sulphide minerals were reported in trace concentrations in two of the granite samples and mostly consist of pyrite with lesser chalcopyrite and trace pyrrhotite. Trace calcite was reported in one of the granite samples.

Table 8.III-23 Summary of Mine Rock Mineralogy

	04-ARD-139-004	04-ARD-199-002	04-ARD-191-06/07/08/09
	Granite	Granite	Granite
Mineral Phases Observed in Optical Microscopy	Major: K-feldspar [KAlSi ₃ O ₈], quartz [SiO ₂], biotite [K(Mg,Fe) ₃ (AlSi ₃ O ₁₀)(OH) ₂] Minor: Plagioclase [NaAlSi ₃ O ₈ – CaAl ₂ Si ₂ O ₈], muscovite-sericite [KAl ₂ (AlSi ₃ O ₁₀)(F,OH) ₂], Fe-Ti oxides, chlorite [(Fe,Mg,Al) ₆ (Si,Al) ₄ O ₁₀ (OH) ₈] Trace: Pyrite [FeS ₂], magnetite [Fe ₃ O ₄]	Major: K-feldspar, quartz, biotite, plagioclase Minor: Muscovite-sericite, chlorite, magnetite Trace: Calcite [CaCO ₃], pyrite	Major: Clay minerals, plagioclase, pyroxene [(Ca,Mg,Fe)SiO ₃], olivine [(Mg,Fe) ₂ SiO ₄] Minor: Quartz, biotite, chlorite, magnetite Trace: K-feldspar, pyrite, pyrrhotite [FeS _(1-x)], chalcopyrite [CuFeS ₂]

Note: Semi-quantitative XRD was not conducted on these samples.

Acid Base Accounting

Results of ABA testing for the mine rock are provided in Table 8.III-24 and Figures 8.III-11 to 8.III-13. Attachment 8.III-3IV contains detailed ABA results. All mine rock lithology results are presented together to reflect their treatment as a single waste management group. It is expected that granite will comprise greater than 95% of all mine rock.

The principal observations with respect to the ABA characteristics of mine rock are:

- The paste pH of all the mine rock samples was 5.5 or greater.
- Mine rock samples contained between <0.01% to 2.18% total sulphur, with an average concentration of 0.04%. Sulphur is primarily in the form of sulphide sulphur (Figure 8.III-11). Based on average concentrations, granite contains the lowest amounts of total and sulphide sulphur of all the mine rock lithologies (average concentration of 0.03 wt%). The low sulphide sulphur concentrations are supported by mineralogical results.

The altered granite, altered granodiorite, and diorite have average sulphide sulphur concentrations of 0.28 wt%, 0.16 wt%, and 0.16 wt%, respectively.

- Eighteen of 1,242 mine rock samples (1%) had total sulphur concentrations greater than 0.3 wt%. Ninety-one of 1,242 samples (7%) had sulphide sulphur concentrations greater than 0.1 wt%, which may be considered acid generating due to the very low NP content of the mine rock.
- Values for NP range from <0.1 to 272 kg CaCO₃/t and carbonate NP values range from 0.11 to 138 kg CaCO₃/t.
- At NP values less than approximately 10 kg CaCO₃/t, the modified Sobek NP is typically 30% greater than the carbonate NP suggesting non-carbonate minerals are contributing to the overall NP at the lower range of values (Figure 8.III-12). At NP values greater than approximately 10 kg CaCO₃/t the modified Sobek NP is approximately equal to the carbonate NP.
- The NP/AP ratio of the mine rock samples ranged from 0.04 to 576. Approximately 13% of all mine rock samples had an NP/AP between one and three and had an uncertain acid generating potential (Figure 8.III-13). Additionally, 4% of mine rock samples had NP/AP values less than one and are classified as PAG.
- Although there is very little NP in the mine rock, there is generally very low concentrations of sulphide. Less than 10% of all the mine rock samples are classified as PAG and another 30% of samples have an uncertain PAG classification. This includes samples with less than 0.3 wt% total sulphur. Fourteen of the 1242 samples (1.1%) reported a combination of sulphide concentrations exceeding 0.3% and NP/AP ratios of less than 3.

Table 8.III-24 Summary of Acid Base Accounting Results for Mine Rock Samples

Sample ID	Paste pH	CO ₂ %	Total Sulphur wt%	Sulphate wt%	Sulphide wt%	AP kg CaCO ₃ /t	NP kg CaCO ₃ /t	NP/AP kg CaCO ₃ /t	CaNP kg CaCO ₃ /t
Altered Granite, n= 10									
Minimum	7.5	0.02	0.01	<0.01	0.01	0.31	3.7	0.39	0.5
Maximum	9.4	1.3	0.42	0.015	0.41	13	54	43	30
Mean	8.1	0.37	0.23	0.01	0.23	7.0	17	8.6	8.5
Median	8.0	0.22	0.28	0.01	0.27	8.6	11	2.1	4.9
Standard Deviation	0.59	0.42	0.15	0.00	0.15	4.5	16	15	9.6
Diabase, n=7									
Minimum	8.4	0.01	0.08	<0.01	0.08	2.5	5.5	1.9	0.1
Maximum	9.5	0.75	0.15	<0.01	0.15	4.7	28	5.9	17
Mean	9.1	0.14	0.10	<0.01	0.10	3.2	12	3.5	3
Median	9.2	0.03	0.09	<0.01	0.09	2.8	10	3.3	0.7
Standard Deviation	0.38	0.27	0.02	<0.01	0.02	0.74	7.3	1.2	6.2
Gneissic Granite, n=9									
Minimum	8.7	<0.01	<0.01	<0.01	<0.01	<0.3	3.2	0.36	0.11
Maximum	9.6	0.16	0.29	0.01	0.29	9.1	7.7	16	3.6
Mean	9.2	0.04	0.061	0.006	0.061	1.9	4.2	8	1.0
Median	9.2	0.03	0.02	0.005	0.02	0.63	3.7	12	0.68
Standard Deviation	0.26	0.053	0.094	0.0017	0.094	2.95	1.4	6.0	1.2
Granite, n=1189									
Minimum	5.6	<0.01	<0.01	<0.01	<0.01	<0.3	<0.1	0.04	0.11
Maximum	10	6.1	2.2	0.027	2.2	68	207	576	137
Mean	9.0	0.11	0.035	0.0055	0.035	1.08	6	12	2.5
Median	9.1	0.06	0.01	0.005	0.01	0.3	4.4	8.3	1.4
Standard Deviation	0.43	0.34	0.101	0.002	0.10	3.13	12	25	7.7
Granodiorite, n=6									
Minimum	9.0	<0.1	0.01	0.005	0.010	0.30	8.0	1.0	2.3
Maximum	10	0.3	0.31	0.020	0.32	10	11	37	6.8
Mean	9.4	0.21	0.063	0.013	0.072	2.0	9.3	20	4.8
Median	9.5	0.23	0.01	0.010	0.025	0.45	9.0	23	5.2
Standard Deviation	0.3	0.093	0.12	0.0061	0.122	3.8	1.0	14	2.1
Altered Granodiorite, n=16									
Minimum	8.4	0.01	0.10	0.005	0.01	3.10	8.0	0.82	0.23
Maximum	9.0	4.5	0.31	0.17	0.30	10	272	54	102
Mean	8.8	0.97	0.173	0.063	0.11	5.39	77	15	22
Median	8.9	0.1	0.16	0.020	0.12	5.0	38	9.2	2.3
Standard Deviation	0.2	1.661	0.068	0.072	0.10	2.14	87	17	38
Fresh Granodiorite, n=5									
Minimum	9.0	<0.1	0.01	<0.01	<0.01	0.30	9.0	1.0	2.3
Maximum	10	0.30	0.31	0.02	0.32	10	11	37	6.8
Mean	9.5	0.2	0.07	0.014	0.08	2.2	10	23	4.5
Median	9.5	0.2	0.01	0.010	0.02	0.3	9.0	30	4.5
Standard Deviation	0.29	0.10	0.134	0.005	0.13	4.2	0.89	14	2.3
Diorite, n=1									
06-ARD-277-009	8.9	0.15	0.16	<0.01	0.16	5.0	12	2.3	3.4
All Mine Rock, n=1242									
Minimum	5.6	<0.01	<0.01	<0.01	<0.01	<0.3	<0.1	0.04	0.11
Maximum	10	6.1	2.2	0.17	2.2	68	272	576	137
Mean	9.0	0.12	0.04	0.006	0.04	1.2	7.0	12	2.8
Median	9.1	0.06	0.02	0.005	0.01	0.31	4.5	8.3	1.4
Standard Deviation	0.43	0.39	0.10	0.01	0.102	3.21	17	25	9.0

Note: AP = acid potential (calculated using total sulphur); NP = neutralization potential; CaNP = calcium neutralization potential; % = percent; wt% = percent by weight; kg CaCO₃/t = kilograms of calcium carbonate per tonne; CO₂ = carbon dioxide.

Figure 8.III-11 Concentration of Total Sulphur versus Sulphide Sulphur in Mine Rock Samples

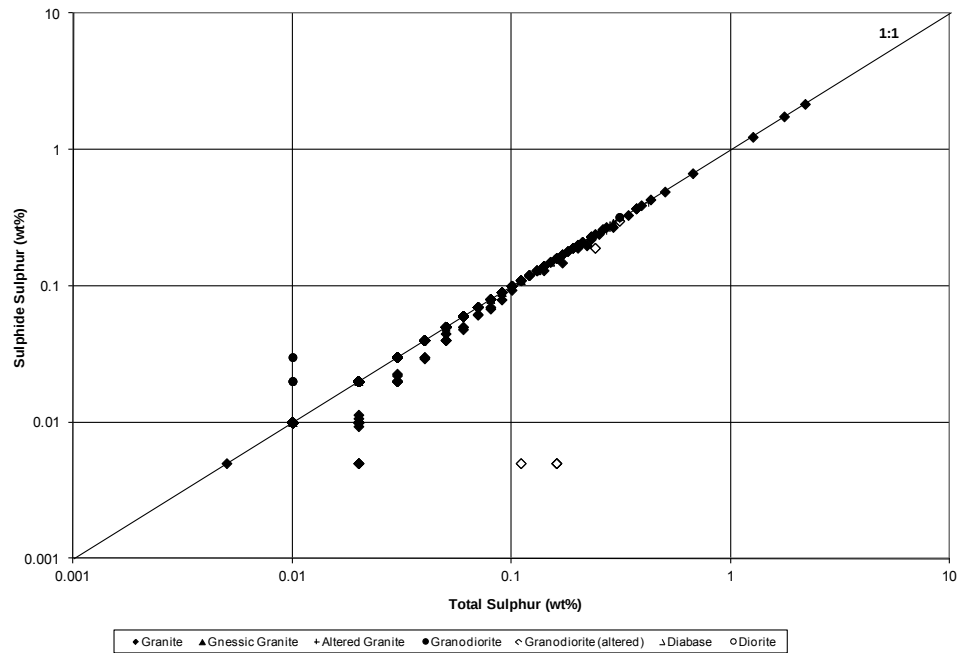


Figure 8.III-12 Neutralization Potential versus Carbonate Neutralization Potential for Mine Rock

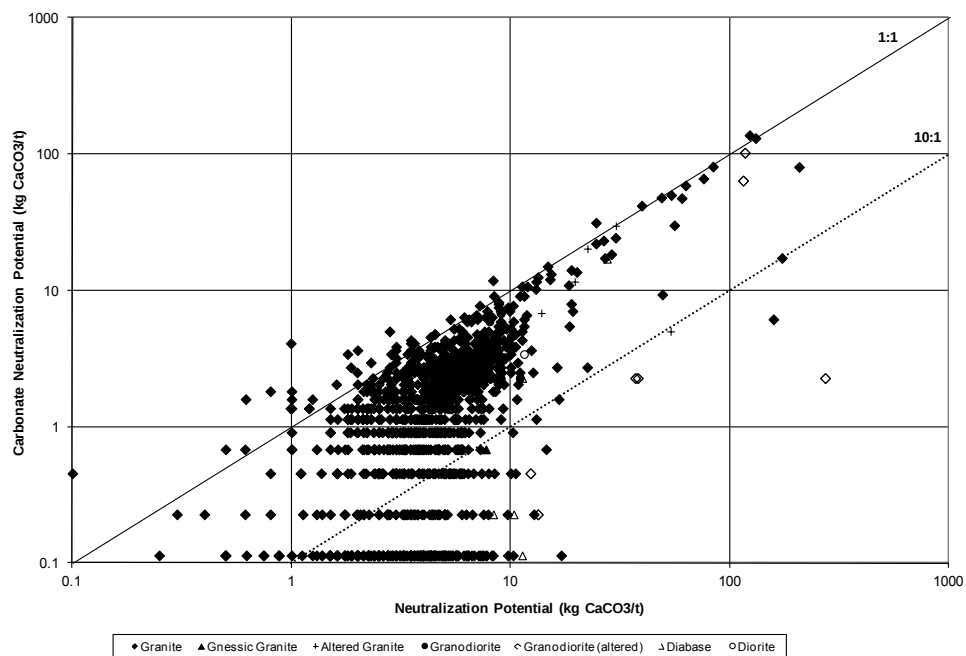
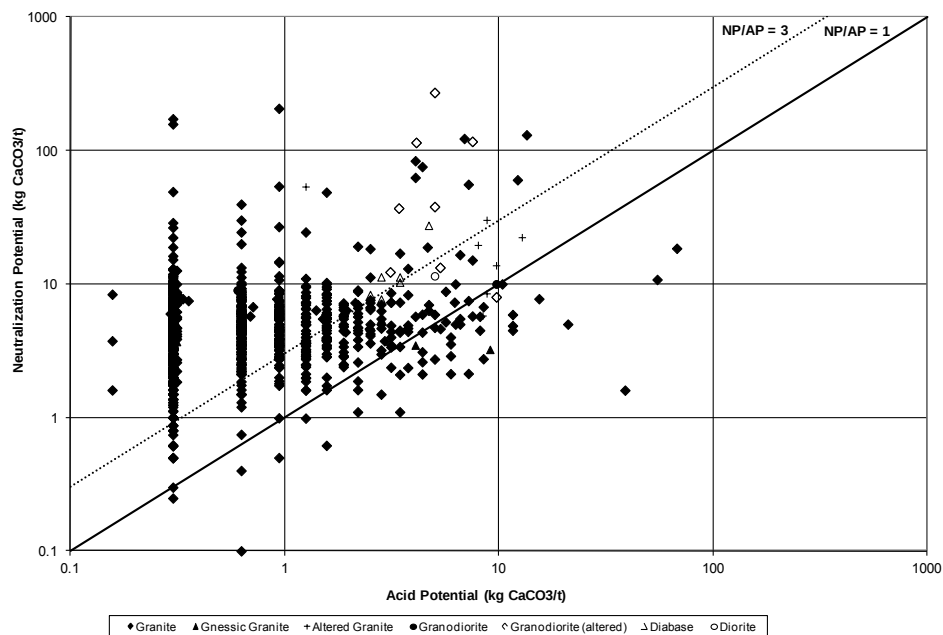


Figure 8.III-13 Neutralization Potential versus Acid Potential for Mine Rock



8.III.4.3.2 Whole Rock and Trace Element Chemistry

A complete record of the analytical results and a summary of the chemistry of the mine rock are provided in Attachment 8.III-4. A summary of the whole rock results is presented in Table 8.III-25 and bulk metal results are reported in Table 8.III-26.

Results of the whole rock chemistry analyses indicate that the non-kimberlite units are enriched in molybdenum, zinc, silica, and aluminum relative to the kimberlite facies. Aluminum is the major element and the average silica concentration is greater than 50% for all mine rock lithologies, with a maximum of 70% for the granite.

The chemical composition of the granitic lithologies is similar to the average crustal abundances of granitic rocks presented in Price (1997). Total concentrations of nickel in the altered granite are greater than the other mine rock lithologies.

8.III.4.3.3 Shake Flask Extraction Testing

Table 8.III-27 provides the average, standard deviation (SD), and range of values in the SFE testing of the granite lithology (mean $\pm$ SD, [range]). Complete results are in Attachment 8.III-7.

The results indicate that the pH of all leachates is near-neutral to alkaline. The average concentrations of most key elements are less than the average concentrations from the kimberlite SFE. However, several elements, including antimony, lead, and zinc had higher concentrations relative to the kimberlite results.

Table 8.III-25 Summary of Mine Rock Whole Rock Results

Parameter Unit	SiO ₂ %	TiO ₂ %	Al ₂ O ₃ %	Fe ₂ O ₃ %	MnO %	MgO %	CaO %	Na ₂ O %	K ₂ O %	P ₂ O ₅ %	Ba(F) %	LOI %	Total %
Altered Granite, n= 3													
Minimum	45	0.3	4.8	2.4	0.01	1.6	1.2	0.1	1.1	0.1	0.05	1.3	99
Maximum	67	1.1	17	8.3	0.1	26	6.0	3.3	5.3	0.36	0.11	14	100
Mean	56	0.64	13	5.8	0.047	11	2.9	2.1	2.9	0.26	0.083	5.4	99
Median	56	0.56	16	6.6	0.03	4.7	1.4	3.0	2.2	0.33	0.09	1.5	100
Standard Deviation	11	0.39	6.8	3.0	0.047	13	2.7	1.8	2.2	0.14	0.031	7.0	0.2
Gneissic Granite, n= 9													
Minimum	57	0.12	13	1.1	0.01	0.6	0.67	2.4	2.8	0.03	0.04	0.61	100
Maximum	73	1.0	18	7.9	0.1	4.5	4.5	4.5	4.9	0.38	0.18	1.8	100
Mean	67	0.51	16	4.1	0.037	2.1	2.0	3.6	3.7	0.12	0.097	1.1	100
Median	69	0.34	16	2.5	0.01	1.3	1.7	3.4	3.2	0.09	0.1	1.1	100
Standard Deviation	5.6	0.3	1.4	2.5	0.039	1.5	1.1	0.69	0.87	0.1	0.043	0.45	0.072
Granite, n= 874													
Minimum	37	0.07	3.0	0.67	0.0054	0.15	0.11	0.01	0.85	0.01	0.01	0.0097	98
Maximum	80	2.0	21	16	0.22	32	9.6	7.0	13	1.2	0.3	12	100
Mean	70	0.32	15	2.5	0.018	1.3	1.4	3.4	4.8	0.14	0.095	1.0	100
Median	70	0.29	15	2.3	0.01	0.91	1.3	3.4	4.9	0.12	0.09	0.77	100
Standard Deviation	4.2	0.16	1.4	1.5	0.019	1.9	0.94	1.0	1.7	0.11	0.034	1.1	0.23
Diorite, n= 1													
04-ARD-120-012	54	1.3	14	12	0.11	5.4	7.6	2.7	1.0	0.31	0.05	0.62	100
Granodiorite, n=1													
04-ARD-120-011	70	0.34	15	2.4	0.01	0.77	1.6	3.9	4.3	0.07	0.07	0.76	99
Diabase, n= 5													
Minimum	48	1.6	13	11	0.03	5.1	0.48	0.1	0.64	0.21	0.02	0.7	99
Maximum	50	2.1	16	16	0.22	8.0	9.7	3.6	5.4	0.3	0.02	7.3	100
Mean	49	1.8	14	15	0.17	6.3	7.2	2.0	1.8	0.24	0.02	2.7	100
Median	49	1.8	13	15	0.2	5.5	9.1	2.2	0.99	0.23	0.02	1.4	100
Standard Deviation	0.83	0.19	1.4	1.9	0.079	1.3	3.9	1.3	2.0	0.037	0	2.7	0.21

Note: % =percent; n = number of samples.

Table 8.III-26 Summary of Mine Rock Bulk Metal Results

Parameter Unit	Ag mg/kg	Al %	As mg/kg	B mg/kg	Ba mg/kg	Bi mg/kg	Ca %	Cd mg/kg	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe %	K %	La mg/kg	Mg %	Mn mg/kg	Mo mg/kg	Na %	Ni mg/kg	P %	Pb mg/kg	Sb mg/kg	Se mg/kg	Sr mg/kg	Ti %	Tl mg/kg	U mg/kg	Zn mg/kg
PRICE CRUSTAL ABUNDANCE ^(a)	---	8.2	1.8	10	---	0.0085	4.2	3.0	25	102	60	5.6	2.1	20	2.3	950	1.2	2.4	84	0.11	14	0.2	0.05	370	0.57	0.85	2.7	70
Altered Granite, n= 3																												
Minimum	0.05	0.79	0.25	4.0	56	0.05	0.2	0.05	5.1	40	1.7	1.4	0.26	31	0.93	253	0.2	0.019	11	0.048	1.7	0.05	0.25	13	0.044	0.1	0.7	28
Maximum	0.1	2.1	2.3	26	842	0.3	0.95	0.05	68	244	47	3.5	1.2	75	10	459	2.7	0.083	909	0.13	2.0	0.1	0.25	295	0.17	0.3	1.3	60
Mean	0.067	1.4	1.5	12	405	0.15	0.59	0.05	29	115	18	2.4	0.74	47	4.2	329	1.6	0.048	318	0.1	1.9	0.083	0.25	111	0.10	0.17	1.0	44
Median	0.05	1.3	1.9	6.0	317	0.1	0.62	0.05	15	60	4.9	2.2	0.8	35	1.4	276	1.9	0.042	34	0.12	1.9	0.1	0.25	24	0.09	0.1	1.0	44
Standard Deviation	0.029	0.64	1.1	12	400	0.13	0.38	8.5E-18	34	112	25	1.0	0.46	24	5.3	113	1.3	0.032	512	0.046	0.15	0.029	0	160	0.061	0.12	0.3	16
Gneissic Granite, n= 9																												
Minimum	0.05	0.31	0.25	1.0	34	0.05	0.04	0.05	1.9	41	1.4	0.59	0.13	11	0.3	104	2.2	0.015	6.3	0.007	2.0	0.05	0.25	5.0	0.023	0.05	0.3	22
Maximum	0.05	3.3	0.6	13	296	0.1	0.53	0.1	26	209	65	4.8	2.0	34	2.1	532	7.6	0.046	99	0.13	5.2	0.2	0.25	27	0.37	1.0	1.0	93
Mean	0.05	1.3	0.33	5.0	129	0.056	0.18	0.056	11	91	17	2.2	0.73	26	1.0	274	4.3	0.025	32	0.041	3.3	0.15	0.25	12	0.15	0.35	0.52	57
Median	0.05	0.71	0.25	4.0	88	0.05	0.16	0.05	5.3	57	9.1	1.5	0.41	29	0.65	207	3.8	0.022	10	0.039	2.9	0.2	0.25	10	0.12	0.1	0.5	51
Standard Deviation	7.4E-18	1.0	0.15	3.8	98	0.017	0.15	0.017	8.8	66	22	1.4	0.67	8.3	0.69	143	1.8	0.011	34	0.038	1.1	0.061	0	7.0	0.12	0.37	0.2	22
Granite, n= 880																												
Minimum	0.02	0.18	0.25	0.5	4.0	0.01	0.02	0.005	1.0	17	0.7	0.39	0.04	4.0	0.08	48	0.2	0.003	1.6	0.003	0.6	0.025	0.25	3.0	0.0005	0.02	0.1	7.0
Maximum	2.1	4.6	8.7	187	1,000	0.3	4.5	5.7	89	594	258	12	2.4	288	15	1100	403	0.41	1372	0.44	1008	124	0.9	475	0.39	1.8	9.2	2916
Mean	0.06	0.71	0.63	6.1	53	0.051	0.23	0.061	5.1	75	9.6	1.5	0.29	45	0.66	178	5.8	0.029	13	0.052	8.3	0.34	0.26	11	0.068	0.14	0.91	48
Median	0.05	0.63	0.5	4.0	38	0.05	0.18	0.05	4.1	67	4.9	1.3	0.24	44	0.5	161	4.8	0.025	6.1	0.045	5.4	0.1	0.25	8.0	0.065	0.1	0.7	43
Standard Deviation	0.083	0.38	0.61	9.3	62	0.013	0.31	0.19	6.2	43	21	0.74	0.23	24	0.88	97	14	0.02	67	0.044	37	4.2	0.058	21	0.055	0.12	0.86	100
Diorite, n= 1																												
04-ARD-120-012	0.1	1.0	0.9	2.0	323	0.1	1.0	0.05	24	49	60	3.4	0.45	29	1.1	242	5.0	0.099	9.4	0.15	3.6	0.3	0.25	33	0.15	0.1	2.2	54
Granodiorite, n =1																												
04-ARD-120-011	0.1	0.69	2.0	2.0	55	0.05	0.28	0.05	5.2	81	33	1.5	0.47	72	0.41	192	7.1	0.027	6.2	0.032	12	0.4	0.25	6.0	0.11	0.3	2.8	63
Diabase, n= 5																												
Minimum	0.05	1.4	0.25	7.0	10	0.05	0.28	0.05	22	16	1.5	4.5	0.09	9.0	0.71	253	0.7	0.005	20	0.079	0.9	0.05	0.25	10	0.008	0.05	0.1	48
Maximum	0.05	3.6	3.0	18	18	0.1	1.2	0.1	37	68	155	7.7	0.12	28	4.6	531	1.6	0.14	47	0.13	2.9	0.3	0.25	24	0.25	0.1	0.4	78
Mean	0.05	2.0	0.8	13	14	0.06	0.8	0.07	28	32	110	5.6	0.1	14	1.9	329	1.3	0.081	28	0.094	2.1	0.15	0.25	20	0.19	0.09	0.22	68
Median	0.05	1.6	0.25	13	16	0.05	0.85	0.05	24	21	131	4.8	0.1	11	0.85	290	1.4	0.088	22	0.091	2.1	0.1	0.25	22	0.23	0.1	0.2	68
Standard Deviation	0	0.9	1.2	4.3	3.7	0.022	0.32	0.027	6.4	22	62	1.4	0.013	8.0	1.7	115	0.36	0.049	11	0.018	0.74	0.1	0	5.7	0.1	0.022	0.11	12

Notes: mg/kg = milligrams per kilogram; % = percent; n = number of samples.

^(a) Typical crustal abundance for continental rocks taken from Price (1997).

>1 x	- Concentration greater than typical crustal abundance.
>5 x	- Concentration greater than 5 x the typical crustal abundance.
>10 x	- Concentration greater than 10 x the typical crustal abundance.

Table 8.III-27 Summary of Mine Rock Shake Flask Extraction Tests

Parameter Unit	pH s.u.	Cl mg/L	SO ₄ mg/L	Al mg/L	As mg/L	Ca mg/L	Cr mg/L	Co mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Ni mg/L	P ^(a) mg/L	K mg/L	Se mg/L	Na mg/L	Sr mg/L	U mg/L	Zn mg/L
Granite, n = 40																						
Minimum	5.5	0.91	1.0	<0.005	<0.001	0.25	<0.001	0.000007	<0.001	0.004	<0.00002	0.27	0.0007	<0.00003	<0.0003	0.01	2.8	0.00004	1.8	0.003	<0.0005	<0.005
Maximum	9.8	99	119	6.3	0.048	35	0.003	0.0124	0.005	6.9	0.057	13.6	0.36	0.033	0.0337	1.5	48	<0.001	23	0.54	0.0038	0.06
Mean	8.5	7.1	10.8	1.3	0.0057	6.4	0.001	0.0012	0.0017	0.72	0.0039	1.9	0.023	0.0046	0.002	0.23	8.5	0.0009	5.2	0.072	0.00061	0.0081
Median	8.6	1.6	2.6	1.2	0.004	3.4	0.001	0.001	0.001	0.36	0.001	0.81	0.007	0.0017	0.001	0.15	7.4	0.001	3.8	0.024	0.0005	0.005
Standard Deviation	0.67	18	22.5	1.2	0.0079	8.2	0.0004	0.0019	0.0013	1.2	0.009	2.7	0.061	0.007	0.00522	0.25	7.3	0.0003	4.6	0.12	0.0006	0.011

Note: s.u. = standard units; mg/L = milligrams per litre.

^(a) Phosphorus detection limit was 0.15 mg/L for 34/40 samples.

8.III.4.3.4 Kinetic Testing

Humidity Cells

Tables 8.III-28a and 8.III-28b contain a summary of the leachate chemistry for selected parameters from the standard humidity cells calculated from both first flush (Table 8.III-28a) and the steady-state rates (Table 8.III-28b). Figure 8.III-14 plots the pH and concentrations of key parameters. Attachment 8.III-8 provides the weekly results of the HC tests. The results of the three 2011 confirmation cells for HC 9, HC 12 and HC 16 are also included.

The principal observations with respect to the mine rock humidity cells are:

- Throughout the duration of testing, the pH of the humidity cells generally ranges between 5.5 and 8.5, with the exception of granite cell HC 16, which ranges from 3.2 to 6.2. The pH values of the most leachates generally decrease slightly over time. The pH of leachate from HC 16 decreased after the first flush, reporting the lowest values near 40 weeks, after which the pH values increased steadily over time.
- Sulphate concentrations were greatest in HC 16 compared to the other mine rock HCTs. Sulphate concentrations decreased steadily from week 31, stabilizing below 10 mg/L after week 118.
- Concentrations of major ions including sodium, magnesium, and calcium generally decreased over time after five weeks.
- Key metal concentrations including selenium, zinc, and iron were below the detection limits in most samples. In HC 16, zinc concentrations peaked to a maximum of 0.25 mg/L at 30 weeks then decreased over time to steady state values near the detection limit.
- Arsenic concentrations decreased after the first flush to a steady state concentration below the detection limit.
- Tables 8.III-28a and 8.III-28b list the average concentration of selected parameters in the first flush and at steady state. Mercury, chloride, phosphorus, and chromium were less than the method detection limit (MDL) in all 2008 humidity cells. Cadmium, cobalt, iron, and nickel concentrations were less than method detection limit in all but one humidity cell. Metal concentrations in HC 16 are elevated, likely due to the acidic pH.
- Generally, the three confirmation cells initiated in 2011 reported similar results to the cells constructed with adjacent core samples in 2008. However, the detection limits of many of the parameters decreased, and therefore more accurate measurements of several parameters were possible in 2011.

- Chloride, phosphorus, and chromium were less than or near the method detection limit (MDL) in all 2008 humidity cells. Cadmium, cobalt, iron, and nickel concentrations were less than method detection limit in all but one humidity cell. Metal concentrations in HC 16 are elevated relative to the other humidity cells, likely due to the acidic pH.
- Phosphorus concentrations decreased after the first flush in the 2011 confirmation cells, from a maximum of 0.04 mg/L to below the MDL. Fluoride concentrations decreased after the first flush in the confirmation cells for HC 9 and HC 12, and increased after ten weeks in the confirmation cell for HC 16. The results indicate that for all humidity cells with the exception of HC 7, HC 9, and HC 14, sulphide sulphur will be depleted before NP (Table 8.III-29). The more conservative carbonate NP is predicted to deplete before sulphide sulphur in all cells with the exception of HC 12, the 2011 confirmation cell for HC 12, and HC 15. Given the extremely low sulphur concentrations remaining at the point when carbonate NP is depleted, neutralization by non-carbonate NP minerals in the material will likely be sufficient to buffer any potential acidity generated from the oxidation of remaining sulphides to circum-neutral pH values.

Table 8.III-28a First Flush Concentrations in Leachate from Mine Rock Humidity Cells

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
First Flush																							
HC 7 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.4	<1	--	--	0.069	0.005	4.0	<0.001	<0.001	<0.001	<0.05	<0.001	0.45	0.006	0.0046	<0.001	<0.15	1.0	<0.001	<0.05	0.041	<0.0005	<0.005
Maximum	8.2	8.0	--	--	0.11	0.025	5.8	<0.001	<0.001	0.002	<0.05	<0.001	0.58	0.037	0.014	<0.001	<0.15	2.6	<0.001	3.2	0.05	0.0042	<0.005
Average	7.6	4.2	--	--	0.087	0.012	4.8	<0.001	<0.001	0.0013	<0.05	<0.001	0.51	0.025	0.0088	<0.001	<0.15	1.9	<0.001	1.3	0.045	0.0026	<0.005
HC 8 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.4	<1	--	--	0.056	<0.001	2.4	<0.001	<0.001	<0.001	<0.05	<0.001	0.19	0.004	0.0003	<0.001	<0.15	0.59	<0.001	<0.05	0.016	<0.0005	<0.005
Maximum	8.2	2.0	--	--	0.1	<0.001	4.1	<0.001	<0.001	0.001	0.08	<0.001	0.47	0.021	0.0019	<0.001	<0.15	2.5	<0.001	2.1	0.034	0.0006	<0.005
Average	7.6	1.4	--	--	0.08	<0.001	3.3	<0.001	<0.001	0.001	0.06	<0.001	0.35	0.011	0.0013	<0.001	<0.15	1.7	<0.001	0.8	0.028	0.00053	<0.005
HC 9 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.4	8.0	--	--	0.059	<0.001	7.9	<0.001	<0.001	<0.001	<0.05	<0.001	0.94	0.02	0.0012	<0.001	<0.15	0.95	<0.001	<0.05	0.077	0.003	<0.005
Maximum	8.1	40	--	--	0.14	<0.001	13	<0.001	<0.001	<0.001	<0.05	<0.001	2.2	0.072	0.002	<0.001	<0.15	3.6	<0.001	6.2	0.14	0.0046	<0.005
Average	7.7	24	--	--	0.10	<0.001	9.6	<0.001	<0.001	<0.001	<0.05	<0.001	1.5	0.047	0.0016	<0.001	<0.15	2.2	<0.001	2.3	0.11	0.0038	<0.005
HC 10 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.2	1.0	--	--	0.047	0.0008	2.7	<0.001	<0.001	<0.001	<0.05	<0.001	0.53	0.004	0.0024	<0.001	<0.15	1.1	<0.001	<0.05	0.015	<0.0005	<0.005
Maximum	8.0	4.0	--	--	0.091	0.002	3.3	<0.001	<0.001	0.001	0.05	<0.001	0.68	0.046	0.0046	<0.001	<0.15	2.4	<0.001	2.6	0.021	0.0016	<0.005
Average	7.4	2.8	--	--	0.063	0.0016	3.0	<0.001	<0.001	0.001	0.05	<0.001	0.58	0.025	0.0033	<0.001	<0.15	2.0	<0.001	1.2	0.019	0.0011	<0.005
HC 12 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.5	5.0	--	--	0.041	<0.001	5.7	<0.001	<0.001	<0.001	<0.05	<0.001	0.67	0.0081	0.01	<0.001	<0.15	1.3	<0.001	<0.05	0.073	<0.0005	<0.005
Maximum	8.0	20	--	--	0.11	0.0011	7.6	<0.001	<0.001	0.002	<0.05	<0.001	0.84	0.013	0.029	<0.001	<0.15	2.6	<0.001	4.9	0.09	0.0006	<0.005
Average	7.7	12	--	--	0.075	0.001	6.5	<0.001	<0.001	0.0013	<0.05	<0.001	0.78	0.011	0.02	<0.001	<0.15	2.1	<0.001	2.3	0.084	0.00053	<0.005
HC 13 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.6	<1	--	--	0.081	<0.001	3.0	<0.001	<0.001	<0.001	<0.05	<0.001	0.24	0.006	0.0011	<0.001	<0.15	0.98	<0.001	0.4	0.017	<0.0005	<0.005
Maximum	8.3	3.0	--	--	0.13	0.002	5.3	<0.001	<0.001	0.002	0.06	<0.001	0.41	0.049	0.0039	<0.001	<0.15	2.5	0.001	2.3	0.02	0.0055	<0.005
Average	7.8	1.8	--	--	0.1	0.0013	3.9	<0.001	<0.001	0.0013	0.053	<0.001	0.33	0.028	0.0025	<0.001	<0.15	1.6	0.001	1.5	0.019	0.0036	<0.005
HC 14 - Granite and Diorite: Dec 14 - Jan 11, 2005																							
Minimum	7.7	1.0	--	--	0.075	<0.001	3.2	<0.001	<0.001	<0.001	<0.05	<0.001	0.37	0.003	0.0027	<0.001	<0.15	1.3	<0.001	0.65	0.022	<0.0005	<0.005
Maximum	8.4	8.0	--	--	0.13	0.001	6.4	<0.001	<0.001	0.001	0.09	<0.001	1.1	0.083	0.0051	<0.001	<0.15	2.1	<0.001	2.3	0.047	0.0044	<0.005
Average	7.9	4.2	--	--	0.095	0.001	5.1	<0.001	<0.001	0.001	0.063	<0.001	0.71	0.048	0.004	<0.001	<0.15	1.7	<0.001	1.5	0.035	0.0027	<0.005
HC 15 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.0	2.0	--	--	0.029	<0.001	0.83	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	0.26	0.003	0.0009	< 0.001	< 0.15	1.2	< 0.001	1.2	0.011	< 0.0005	< 0.005
Maximum	8.0	8.0	--	--	0.1	<0.001	1.4	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	0.41	0.012	0.0015	< 0.001	< 0.15	2.4	0.001	3.0	0.018	< 0.0005	0.005
Average	7.4	4.6	--	--	0.06	<0.001	1.1	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	0.31	0.0074	0.0011	< 0.001	< 0.15	1.7	0.001	2.3	0.015	< 0.0005	0.005
HC 16 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	4.9	37	--	--	0.044	<0.001	7.6	<0.001	0.0024	<0.001	<0.05	0.0029	3.4	0.19	<0.0005	0.0092	<0.15	3.9	<0.001	0.68	0.07	<0.0005	0.056
Maximum	6.2	195	--	--	0.13	<0.001	44	<0.001	0.01	0.003	1.6	0.011	16	0.69	<0.0005	0.033	<0.15	9.6	<0.001	3.6	0.29	<0.0005	0.16
Average	5.2	106	--	--	0.098	<0.001	24	<0.001	0.0058	0.0017	0.64	0.0066	9.3	0.44	<0.0005	0.021	<0.15	6.6	<0.001	2.2	0.17	<0.0005	0.11
HC 17 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.0	2.0	--	--	0.032	<0.001	1.2	<0.001	<0.001	<0.001	<0.05	<0.001	0.27	0.004	0.0009	<0.001	<0.15	0.99	<0.001	0.95	0.012	<0.0005	<0.005
Maximum	8.0	7.0	--	--	0.099	<0.001	1.9	<0.001	<0.001	0.001	0.05	<0.001	0.43	0.025	0.0013	<0.001	<0.15	2.1	0.001	3.3	0.02	<0.0005	<0.005
Average	7.4	4.2	--	--	0.067	<0.001	1.6	<0.001	<0.001	0.001	0.05	<0.001	0.34	0.017	0.0011	<0.001	<0.15	1.5	0.001	2.1	0.017	<0.0005	<0.005
HC 18 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.7	<1	--	--	0.07	<0.001	2.3	<0.001	<0.001	<0.001	<0.05	<0.001	0.38	0.002	<0.0005	<0.001	<0.15	0.87	<0.001	0.61	0.016	<0.0005	<0.005
Maximum	8.5	2.0	--	--	0.13	<0.001	4.9	<0.001	<0.001	0.001	<0.05	<0.001	0.91	0.014	0.001	<0.001	<0.15	2.7	<0.001	3.8	0.043	<0.0005	<0.005
Average	8.0	1.4	--	--	0.11	<0.001	3.6	<0.001	<0.001	0.001	<0.05	<0.001	0.61	0.0069	0.0008	<0.001	<0.15	1.8	<0.001	2.5	0.03	<0.0005	<0.005
HC 19 - Granite and Granodiorite: Dec 14 - Jan 11, 2005																							
Minimum	7.8	<1	--	--	0.085	0.001	4.0	<0.001	<0.001	<0.001	<0.05	<0.001	0.32	0.005	0.0071	<0.001	<0.15	1.2	<0.001	0.39	0.019	0.0006	<0.005
Maximum	8.6	3.0	--	--	0.15	0.002	7.2	<0.001	<0.001	0.004	<0.05	<0.001	0.66	0.062	0.015	<0.001	<0.15	2.7	0.001	2.5	0.03	0.02	<0.005
Average	8.0	1.6	--	--	0.12	0.0014	6.1	<0.001	<0.001	0.002	<0.05	<0.001	0.49	0.037	0.012	<0.001	<0.15	2.0	0.001	1.5	0.025	0.013	<0.005

Table 8.III-28a First Flush Concentrations in Leachate from Mine Rock Humidity Cells (continued)

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HC 20 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.6	<1	--	--	0.067	0.0014	3.4	<0.001	<0.001	<0.001	<0.05	<0.001	0.28	0.005	0.0033	<0.001	<0.15	1.3	<0.001	0.71	0.019	<0.0005	<0.005
Maximum	8.1	4.0	--	--	0.16	0.003	4.7	<0.001	<0.001	0.002	<0.05	<0.001	0.48	0.057	0.011	<0.001	<0.15	2.9	<0.001	2.6	0.027	0.0012	<0.005
Average	7.7	2.6	--	--	0.11	0.0021	4.2	<0.001	<0.001	0.0013	<0.05	<0.001	0.37	0.036	0.0067	<0.001	<0.15	2.0	<0.001	1.7	0.023	0.00087	<0.005
HC 21 - Granite: Dec 14 - Jan 11, 2005																							
Minimum	7.4	27	--	--	0.087	<0.001	13	<0.001	<0.001	<0.001	<0.05	<0.001	1.6	0.007	0.001	<0.001	<0.15	2.0	<0.001	1.1	0.19	<0.0005	<0.005
Maximum	8.4	82	--	--	0.12	<0.001	30	<0.001	<0.001	<0.001	<0.05	<0.001	2.4	0.012	0.0024	<0.001	<0.15	4.6	<0.001	4.1	0.29	<0.0005	<0.005
Average	7.7	47	--	--	0.1	<0.001	20	<0.001	<0.001	<0.001	<0.05	<0.001	1.9	0.0091	0.0017	<0.001	<0.15	3.2	<0.001	2.6	0.23	<0.0005	<0.005
HC 2 - Granite HC 9 Confirmation: Apr 28 - May 26, 2011																							
Minimum	7.28	9.0	0.1	0.23	0.071	0.0001	6.6	0.00025	0.00003	0.0006	0.001	0.00003	1.1	0.0028	0.00071	0.0001	0.0045	1.3	0.00002	1.2	0.058	0.00016	0.001
Maximum	7.51	66	7.8	0.4	0.14	0.0004	17	0.00025	0.00024	0.0018	0.002	0.0011	4.4	0.0078	0.0028	0.0011	0.04	7.2	0.00064	8.4	0.18	0.0019	0.003
Average	7.41	31	2.9	0.34	0.089	0.00024	11	0.00025	0.000088	0.00098	0.0012	0.00026	2.4	0.0053	0.0015	0.00058	0.013	3.7	0.00016	4.6	0.11	0.00081	0.002
HC 2 - Granite HC 12 Confirmation: Apr 28 - May 26, 2011																							
Minimum	7.53	3.0	0.3	0.26	0.084	0.0004	3.4	0.00025	0.000015	0.0008	0.001	0.00001	0.57	0.0018	0.00051	0.0002	0.0045	1.5	0.00002	2.1	0.05	0.000047	0.001
Maximum	7.73	7.0	12	0.37	0.28	0.0008	6.1	0.00025	0.00011	0.0053	0.022	0.00035	0.82	0.0045	0.0027	0.001	0.009	5.9	0.00023	13	0.082	0.00068	0.003
Average	7.63	5.0	4.2	0.32	0.14	0.00062	4.2	0.00025	0.000061	0.002	0.0062	0.00011	0.67	0.0027	0.0015	0.00046	0.0054	3.0	0.00013	6.2	0.061	0.0004	0.0018
HC 4 - Granite HC 16 Confirmation: Apr 28 - May 26, 2011																							
Minimum	4.81	84	0.4	0.13	0.24	0.0001	15	0.00025	0.012	0.0086	0.6	0.0013	8.9	0.28	0.00007	0.026	0.0045	6.8	0.00002	1.2	0.14	0.00028	0.044
Maximum	5.77	368	5.2	0.3	1.3	0.0009	70	0.0014	0.045	0.028	2.4	0.016	44	1.2	0.00029	0.11	0.03	25	0.00084	7.2	0.51	0.0012	0.19
Average	5.25	204	2.1	0.21	0.64	0.00032	36	0.00076	0.025	0.017	1.1	0.0055	23	0.67	0.00016	0.063	0.018	13	0.00034	3.4	0.29	0.00068	0.1

Note: s.u. = standard units; mg/L = milligrams per litre.

Table 8.III-28b Steady State Concentrations in Leachate from Mine Rock Humidity Cells

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Steady State																							
HC 7 - Granite: Jul 26 - Aug 23, 2005																							
Minimum	7.0	<1	--	--	0.071	0.003	2.0	<0.001	<0.001	<0.001	<0.05	<0.001	0.13	<0.001	0.0006	<0.001	<0.15	0.3	<0.001	<0.05	0.008	<0.0005	<0.005
Maximum	7.5	<1	--	--	0.092	0.003	4.0	<0.001	<0.001	<0.001	<0.05	<0.001	0.24	<0.001	0.0012	<0.001	<0.15	0.4	<0.001	0.09	0.018	0.0008	<0.005
Average	7.2	<1	--	--	0.08	0.003	3.2	<0.001	<0.001	<0.001	<0.05	<0.001	0.2	<0.001	0.00097	<0.001	<0.15	0.33	<0.001	0.067	0.014	0.0007	<0.005
HC 8 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.8	<1	< 0.2	--	0.008	<0.0002	1.3	<0.0002	<0.0002	0.0024	<0.01	<0.0002	0.07	0.0011	<0.0001	<0.0002	<0.03	0.14	<0.0002	0.03	0.0019	<0.0001	<0.001
Maximum	7.0	2.0	0.29	--	0.01	<0.0002	1.4	<0.0002	<0.0002	0.006	<0.01	<0.0002	0.12	0.0015	<0.0001	<0.0002	<0.03	0.15	<0.0002	0.06	0.0027	<0.0001	<0.001
Average	6.9	1.2	0.25	--	0.009	<0.0002	1.3	<0.0002	<0.0002	0.0042	<0.01	<0.0002	0.095	0.0013	<0.0001	<0.0002	<0.03	0.15	<0.0002	0.045	0.0023	<0.0001	<0.001
HC 9 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.9	<1	0.99	--	0.009	<0.0002	2.7	<0.0002	<0.0002	0.0067	<0.01	<0.0002	0.19	0.0006	0.0005	<0.0002	<0.03	0.2	<0.0002	0.04	0.003	<0.0001	0.001
Maximum	7.1	2.0	1.9	--	0.017	<0.0002	3.0	<0.0002	<0.0002	0.011	<0.01	<0.0002	0.3	0.0014	0.0005	0.0002	<0.03	0.21	<0.0002	0.07	0.0039	<0.0001	0.002
Average	7.0	1.4	1.5	--	0.013	<0.0002	2.8	<0.0002	<0.0002	0.0089	<0.01	<0.0002	0.25	0.001	0.0005	0.0002	<0.03	0.21	<0.0002	0.055	0.0035	<0.0001	0.0015
HC 10 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.1	<1	<0.2	--	0.004	<0.0002	0.45	<0.0002	<0.0002	0.0056	<0.01	0.0002	0.14	0.0048	<0.0001	<0.0002	<0.03	0.08	<0.0002	0.04	0.0024	<0.0001	0.001
Maximum	6.4	1.0	<0.2	--	0.006	<0.0002	0.47	<0.0002	<0.0002	0.015	<0.01	0.0002	0.15	0.0067	<0.0001	<0.0002	<0.03	0.08	<0.0002	0.04	0.0025	<0.0001	0.002
Average	6.2	1.0	<0.2	--	0.005	<0.0002	0.46	<0.0002	<0.0002	0.01	<0.01	0.0002	0.15	0.0058	<0.0001	<0.0002	<0.03	0.08	<0.0002	0.04	0.0025	<0.0001	0.0015
HC 12 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.4	<1	3.3	--	0.03	<0.0002	1.8	<0.0002	<0.0002	0.0048	0.02	<0.0002	0.43	0.0034	<0.0001	0.0004	<0.03	0.3	<0.0002	0.08	0.0066	<0.0001	0.002
Maximum	6.6	2.0	4.7	--	0.3	0.0002	2.3	0.0004	<0.0002	0.015	0.44	0.0023	0.81	0.013	0.0002	0.0005	<0.03	0.45	<0.0002	0.11	0.0098	<0.0001	0.007
Average	6.5	1.4	4.0	--	0.17	0.0002	2.0	0.0003	<0.0002	0.0099	0.23	0.0013	0.62	0.0082	0.00015	0.00045	<0.03	0.38	<0.0002	0.095	0.0082	<0.0001	0.0045
HC 13 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.4	<1	<0.2	--	0.003	<0.0002	0.71	<0.0002	<0.0002	0.0035	<0.01	<0.0002	0.03	0.0041	<0.0001	<0.0002	<0.03	0.09	<0.0002	0.03	0.0009	<0.0001	0.001
Maximum	6.7	2.0	0.21	--	0.005	<0.0002	0.83	<0.0002	<0.0002	0.0038	<0.01	<0.0002	0.03	0.0044	<0.0001	<0.0002	<0.03	0.1	<0.0002	0.03	0.0011	<0.0001	0.001
Average	6.4	1.4	0.21	--	0.004	<0.0002	0.77	<0.0002	<0.0002	0.0037	<0.01	<0.0002	0.03	0.0043	<0.0001	<0.0002	<0.03	0.095	<0.0002	0.03	0.001	<0.0001	0.001
HC 14 - Granite and Diorite: Nov 4 - Dec 2, 2008																							
Minimum	7.0	<1	<0.2	--	0.015	<0.0002	2.1	<0.0002	<0.0002	0.0018	<0.01	<0.0002	0.04	0.0002	0.0003	<0.0002	<0.03	0.26	<0.0002	0.03	0.0024	<0.0001	<0.001
Maximum	7.2	2.0	<0.2	--	0.019	<0.0002	2.2	<0.0002	<0.0002	0.0048	<0.01	<0.0002	0.04	0.0005	0.0003	<0.0002	<0.03	0.27	<0.0002	0.04	0.0027	<0.0001	0.001
Average	7.1	1.4	<0.2	--	0.017	<0.0002	2.1	<0.0002	<0.0002	0.0033	<0.01	<0.0002	0.04	0.00035	0.0003	<0.0002	<0.03	0.27	<0.0002	0.035	0.0026	<0.0001	0.001
HC 15 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.3	1.0	--	--	0.016	< 0.001	0.35	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	0.11	0.006	< 0.0005	< 0.001	< 0.15	0.3	< 0.001	< 0.05	0.004	< 0.0005	< 0.005
Maximum	7.2	3.0	--	--	0.02	< 0.001	0.45	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	0.16	0.009	< 0.0005	< 0.001	< 0.15	0.4	< 0.001	0.15	0.005	< 0.0005	0.005
Average	6.5	1.4	--	--	0.018	< 0.001	0.38	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	0.13	0.0073	< 0.0005	< 0.001	< 0.15	0.37	< 0.001	0.093	0.0047	< 0.0005	0.005
HC 16 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	5.0	<1	<0.2	--	0.023	<0.0002	0.25	<0.0002	0.0005	0.0064	<0.01	<0.0002	0.33	0.0064	<0.0001	0.0011	<0.03	0.29	<0.0002	0.04	0.0018	<0.0001	0.007
Maximum	5.1	3.0	<0.2	--	0.024	<0.0002	0.28	<0.0002	0.0005	0.0067	<0.01	<0.0002	0.37	0.0069	<0.0001	0.0011	<0.03	0.29	<0.0002	0.04	0.002	<0.0001	0.007
Average	5.0	2.2	<0.2	--	0.024	<0.0002	0.27	<0.0002	0.0005	0.0066	<0.01	<0.0002	0.35	0.0067	<0.0001	0.0011	<0.03	0.29	<0.0002	0.04	0.0019	<0.0001	0.007
HC 17 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	5.7	<1	<0.2	--	0.002	<0.0002	0.23	<0.0002	<0.0002	0.0007	<0.01	0.0007	0.08	0.033	<0.0001	0.0003	<0.03	0.09	<0.0002	0.04	0.0018	<0.0001	<0.001
Maximum	5.9	2.0	<0.2	--	0.003	<0.0002	0.23	<0.0002	<0.0002	0.0044	<0.01	0.0007	0.08	0.037	<0.0001	0.0004	<0.03	0.1	<0.0002	0.06	0.002	<0.0001	0.001
Average	5.8	1.2	<0.2	--	0.0025	<0.0002	0.23	<0.0002	<0.0002	0.0026	<0.01	0.0007	0.08	0.035	<0.0001	0.00035	<0.03	0.095	<0.0002	0.05	0.0019	<0.0001	0.001
HC 18 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	7.4	<1	0.21	--	0.018	<0.0002	2.7	<0.0002	<0.0002	0.0026	<0.01	<0.0002	1.1	<0.0002	<0.0001	<0.0002	<0.03	0.2	<0.0002	0.04	0.0029	<0.0001	<0.001
Maximum	7.5	1.0	1.0	--	0.028	<0.0002	2.8	<0.0002	<0.0002	0.0051	0.01	<0.0002	1.2	0.0006	<0.0001	<0.0002	<0.03	0.22	<0.0002	0.04	0.0032	<0.0001	<0.001
Average	7.4	1.0	0.61	--	0.023	<0.0002	2.7	<0.0002	<0.0002	0.0039	0.01	<0.0002	1.2	0.0004	<0.0001	<0.0002	<0.03	0.21	<0.0002	0.04	0.0031	<0.0001	<0.001
HC 19 - Granite and Granodiorite: Nov 4 - Dec 2, 2008																							
Minimum	6.9	<1	<0.2	--	0.028	<0.0002	1.6	<0.0002	<0.0002	0.0044	<0.01	<0.0002	0.04	0.0005	0.0003	<0.0002	<0.03	0.15	<0.0002	0.05	0.0016	<0.0001	0.002
Maximum	7.1	2.0	<0.2	--	0.039	<0.0002	1.6	<0.0002	<0.0002	0.0055	<0.01	<0.0002	0.04	0.0026	0.0003	<0.0002	<0.03	0.15	<0.0002	0.05	0.0017	<0.0001	0.006
Average	7.0	1.4	<0.2	--	0.034	<0.0002	1.6	<0.0002	<0.0002	0.005	<0.01	<0.0002	0.04	0.0016	0.0003	<0.0002	<0.03	0.15	<0.0002	0.05	0.0017	<0.0001	0.004
HC 20 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.6	<1	<0.2	--	0.02	<0.0002	1.1	<0.0002	<0.0002	0.0026	<0.01	0.0002	0.02	0.0027	0.0002	<0.0002	<0.03	0.11	<0.0002	0.04	0.0012	<0.0001	<0.001
Maximum	6.7	2.0	<0.2	--	0.021	<0.0002	1.2	<0.0002	<0.0002	0.004	<0.01	0.0003	0.02	0.0033	0.0002	<0.0002	<0.03	0.11	<0.0002	0.05	0.0014	<0.0001	0.001
Average	6.7	1.2	<0.2	--	0.021	<0.0002	1.1	<0.0002	<0.0002	0.0033	<0.01	0.00025	0.02	0.003	0.0002	<0.0002	<0.03	0.11	<0.0002	0.045	0.0013	<0.0001	0.001

Table 8.III-28b Steady State Concentrations in Leachate from Mine Rock Humidity Cells (continued)

	pH	SO4	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HC 21 - Granite: Nov 4 - Dec 2, 2008																							
Minimum	6.4	<1	<0.2	--	0.003	<0.0002	0.53	<0.0002	<0.0002	0.0022	<0.01	<0.0002	0.17	0.0082	<0.0001	<0.0002	<0.03	0.21	<0.0002	0.04	0.0072	<0.0001	0.001
Maximum	6.5	2.0	0.55	--	0.005	<0.0002	0.68	<0.0002	<0.0002	0.0048	<0.01	<0.0002	0.25	0.0095	<0.0001	<0.0002	<0.03	0.22	<0.0002	0.06	0.01	<0.0001	0.002
Average	6.5	1.2	0.38	--	0.004	<0.0002	0.61	<0.0002	<0.0002	0.0035	<0.01	<0.0002	0.21	0.0089	<0.0001	<0.0002	<0.03	0.22	<0.0002	0.05	0.0086	<0.0001	0.0015
HC 2 - Granite HC 9 Confirmation: Oct 3 - Nov 17, 2011																							
Minimum	7.42	3.0	<0.2	0.22	0.057	0.0001	5.7	0.00025	0.000008	0.00025	0.001	0.00003	0.3	0.0001	0.00021	0.0002	0.0045	0.33	0.00002	0.15	0.023	0.00048	0.001
Maximum	7.67	6.0	1.2	0.26	0.071	0.0001	5.7	0.001	0.000014	0.0007	0.0015	0.00018	0.37	0.0013	0.005	0.0002	0.0045	0.41	0.00002	0.34	0.027	0.00052	0.003
Average	7.51	4.4	0.32	0.23	0.064	0.0001	5.7	0.00063	0.000011	0.00048	0.0013	0.00011	0.33	0.0007	0.0026	0.0002	0.0045	0.37	0.00002	0.25	0.025	0.0005	0.002
HC 2 - Granite HC 12 Confirmation: Oct 3 - Nov 17, 2011																							
Minimum	7.43	1.0	<0.2	0.08	0.067	0.0004	3.8	0.00025	0.000009	0.00025	0.001	0.00003	0.3	0.0001	0.00014	0.0001	0.0045	0.44	0.00002	0.21	0.033	0.00027	0.001
Maximum	7.64	2.0	<0.2	0.1	0.069	0.0004	4.0	0.0013	0.000019	0.00025	0.0015	0.00014	0.35	0.0005	0.00022	0.0002	0.0045	0.56	0.00002	0.33	0.036	0.00037	0.003
Average	7.50	1.4	<0.2	0.086	0.068	0.0004	3.9	0.00078	0.000014	0.00025	0.0013	0.000085	0.32	0.0003	0.00018	0.00015	0.0045	0.5	0.00002	0.27	0.035	0.00032	0.002
HC 4 - Granite HC 16 Confirmation: Oct 3 - Nov 17, 2011																							
Minimum	3.96	36	<0.2	0.23	0.8	0.0001	4.7	0.0008	0.011	0.0086	0.13	0.00091	3.5	0.11	0.000005	0.02	0.0045	2.4	0.00002	0.23	0.048	0.00072	0.051
Maximum	4.38	53	<0.2	0.28	1.2	0.0001	7.3	0.0022	0.015	0.015	0.24	0.0018	4.8	0.17	0.00004	0.027	0.0045	3.9	0.00016	0.34	0.079	0.0014	0.077
Average	4.09	44	<0.2	0.26	0.98	0.0001	6.0	0.0015	0.013	0.012	0.18	0.0014	4.1	0.14	0.000023	0.024	0.0045	3.1	0.00009	0.29	0.064	0.001	0.064

Note: s.u. = standard units; mg/L = milligrams per litre; <= less than.

Figure 8.III-14 Leachate Concentrations in Mine Rock Humidity Cells

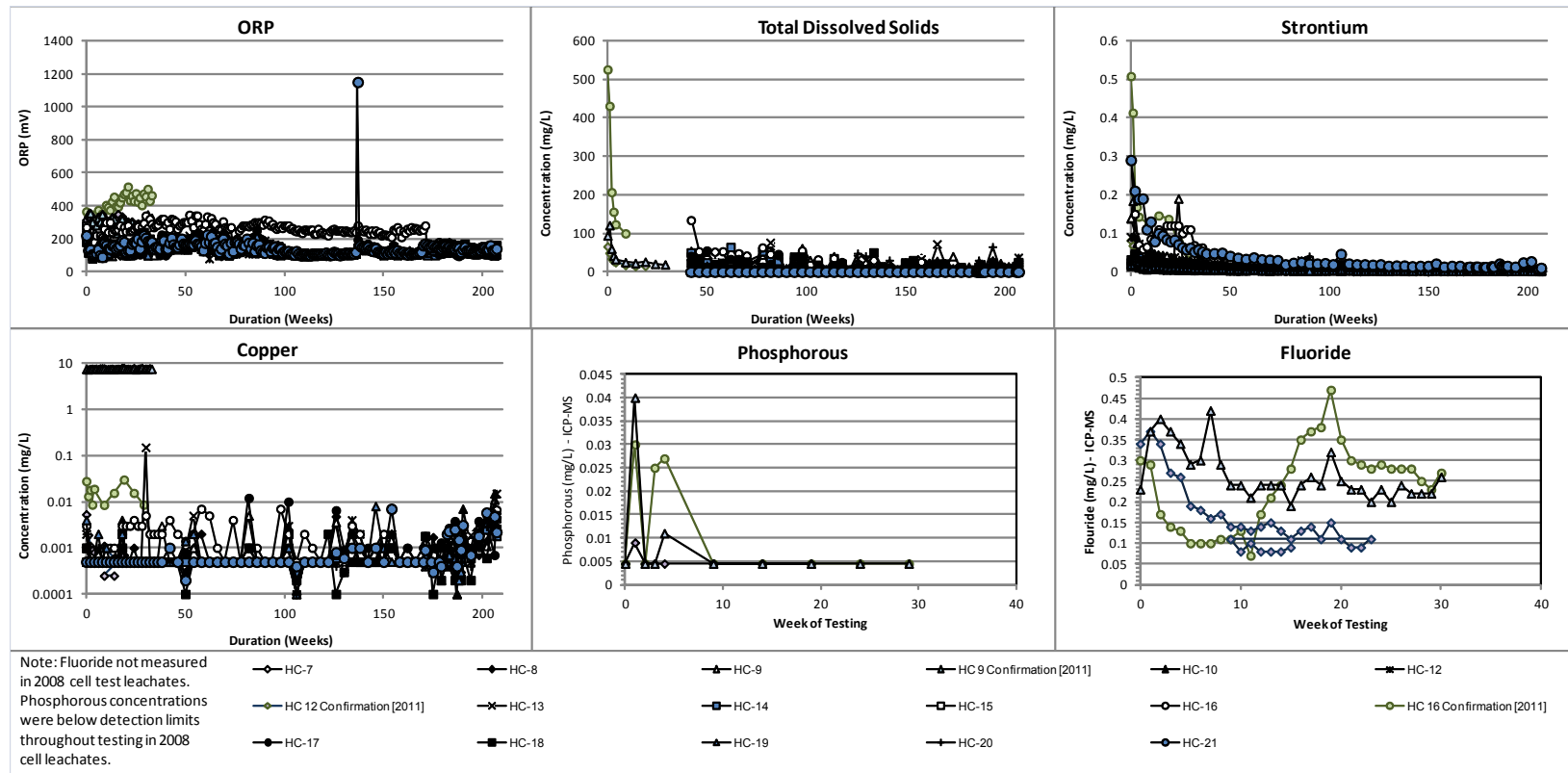


Table 8.III-29 Estimated Acid Potential and Neutralization Potential Depletion Times for Mine Rock Humidity Cells

Humidity Cell ID	Lithology	Sulphide Sulphur (wt%)	NP (kg CaCO ₃ /t)	Time to Depletion (Years)				
				Sulphide Sulphur	NP (emp)	CaNP (emp)	NP (SO ₄)	CaNP (SO ₄)
HC 7	Granite	0.02	5.2	48	15	6.9	247	119
HC 8	Granite	0.033	4.8	29	35	5.9	163	48
HC 9	Granite	0.073	2.5	59	28	0.6	172	31
HC 10	Granite	0.02	4.2	24	45	21	113	59
HC 12	Granite	0.023	9.6	15	74	17	213	66
HC 13	Granite	0.02	5.4	14	28	14	80	45
HC 14	Granite and Diorite	0.067	3.0	47	30	9.1	142	56
HC 15	Granite	0.02	4.7	25	545	82	115	17
HC 16	Granite	0.1	1.3	14	45	0	30	0
HC 17	Granite	0.04	1.6	35	34	7.5	59	15
HC 18	Granite	0.02	15	25	25	20	408	338
HC 19	Granite and Granodiorite	0.025	8.1	21	32	19	152	101
HC 20	Granite	0.02	12	20	62	14	263	75
HC 21	Granite	0.08	4.5	67	122	17	341	60
HC 2 [2011]	Granite	0.04	7.3	11	20	6	73	24
HC 3 [2011]	Granite	0.01	11	8.7	37	13	343	128
HC 4 [2011]	Granite	0.07	7.1	0.8	14	-1.0	6.5	-0.9

Note: NP = neutralization potential; emp = empirical; CaNP = calcium neutralization potential; wt% = percent by weight; kg CaCO₃/t = kilograms of calcium carbonate per tonne.

Pre-leached Granite

Generally, mine rock at the Project site has very low concentrations of total sulphur. Only 1.3% of all mine rock samples reported concentrations greater than 0.3 wt% sulphur. However, the mine rock has low neutralization potential values compared to kimberlite samples. To examine the potential leachate geochemistry from mine rock following neutralization potential depletion, four humidity cell tests were constructed with granite after complete removal of NP (confirmed by ABA) (Table 8.III-30). Tables 8.III-31a and 31b contain a summary of the leachate chemistry for selected parameters from the standard humidity cells. Results are presented for both the first flush (the first five weeks) in Table 8.III-31a and steady state conditions (the last five weeks) in Table 8.III-31b. Figure 8.III-15 plots the pH and concentrations of key parameters. Attachment 8.III.9 provides the weekly results of the HC tests. The principal observations with respect pre-leached granite humidity cells are:

- The pH of the pre-leached cells HC (HC 28 through HC 31) initially reported low pH values likely due to remaining acidity from the pre-leaching process; however within the first five weeks of testing, the pH was similar to the input water pH. The initial reported acidic pH values suggest that there is little remaining readily available neutralization potential in these samples (Figure 8.III-15). The pH of HC 29 is similar to mine rock HC 16 with pH values between four and five. Leachate pH

stabilized for all cells after approximately 25 weeks, though a slight increase in pH was observed over the last 50 weeks of testing. Results of the pre-leached humidity cells suggests that, even after removal of carbonate and modified Sobek NP, the granite mine rock may buffer leachate to a pH between five and six, suggesting that non-carbonate minerals may contribute to overall neutralization.

- The concentrations of major elements including magnesium, sodium, and calcium decreased to steady state concentrations after less than ten weeks.
- Although the observed metal concentrations decreased over time, the concentrations of metals in the HCT leachate were greater in the pre-leached granites than the unleached granites for several elements including aluminum, copper, lead, iron, and zinc.

Table 8.III-30 Comparison of Acid Base Accounting Results for Pre-Leached Mine Rock Humidity Cells

Sample	Paste pH		NP (kg CaCO ₃ /t)		Total Sulphur (wt%)	
	Original	Post Leach	Original	Post Leach	Original	Post Leach
HC 28	9.4	5.6	4.5	0	4.5	0
HC 29	8.3	5.1	5.3	0	5.3	0
HC 30	8.9	6.9	4.3	0.8	4.3	0.8
HC 31	8.9	6.4	1.8	0.3	1.8	0.3

Note: NP = neutralization potential; wt% = percent by weight; kg CaCO₃/t = kilograms of calcium carbonate per tonne.

Table 8.III-31a First Flush Concentrations in Leachate from Pre-leached Mine Rock Humidity Cells

	pH	SO4	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
First Flush																					
HC 28 - Pre-leached Granite: Nov 15, 2005 - Dec 13, 2005																					
<i>Minimum</i>	2.9	1.0	0.42	<0.001	1.2	<0.001	<0.001	<0.001	0.28	<0.001	0.22	0.011	<0.0005	<0.001	<0.15	0.6	<0.001	<0.05	0.003	<0.0005	<0.005
<i>Maximum</i>	4.2	2.0	74	<0.001	365	0.051	0.035	0.043	88	0.038	67	2.5	<0.0005	0.068	1.4	50	<0.001	1.6	0.11	0.0028	0.67
<i>Average</i>	3.3	1.3	37	<0.001	183	0.026	0.018	0.022	44	0.02	34	1.3	<0.0005	0.035	0.78	25	<0.001	0.82	0.057	0.0017	0.34
<i>Median</i>	3.5	1.0	37	<0.001	183	0.026	0.018	0.022	44	0.02	34	1.3	<0.0005	0.035	0.78	25	<0.001	0.82	0.057	0.0017	0.34
HC 29 - Pre-leached Granite: Nov 15, 2005 - Dec 13, 2005																					
<i>Minimum</i>	3.1	2.0	0.54	<0.001	1.1	<0.001	0.002	0.003	0.42	<0.001	0.86	0.012	<0.0005	<0.001	<0.15	1.2	<0.001	0.25	0.005	<0.0005	0.039
<i>Maximum</i>	4.2	5.0	44	<0.001	141	0.015	0.034	0.14	25	0.023	79	1.3	<0.0005	0.065	<0.15	19	<0.001	1.6	0.17	0.0023	0.7
<i>Average</i>	3.5	3.3	22	<0.001	71	0.008	0.018	0.072	13	0.012	40	0.68	<0.0005	0.033	<0.15	10	<0.001	0.92	0.088	0.0014	0.37
<i>Median</i>	3.8	3.0	22	<0.001	71	0.008	0.018	0.072	13	0.012	40	0.68	<0.0005	0.033	<0.15	10	<0.001	0.92	0.088	0.0014	0.37
HC 30 - Pre-leached Granite: Nov 15, 2005 - Dec 13, 2005																					
<i>Minimum</i>	3.8	1.0	0.035	<0.001	1.6	<0.001	<0.001	<0.001	<0.05	<0.001	0.3	0.002	<0.0005	<0.001	<0.15	0.7	<0.001	0.52	0.011	<0.0005	<0.005
<i>Maximum</i>	4.8	11	6.5	<0.001	248	<0.001	0.013	0.065	0.82	0.43	32	0.81	<0.0005	0.029	<0.15	1.6	<0.001	4.0	0.078	0.0022	0.2
<i>Average</i>	4.2	3.2	3.3	0.001	125	<0.001	0.007	0.033	0.44	0.22	16	0.41	<0.0005	0.015	<0.15	1.2	<0.001	2.3	0.045	0.0014	0.1
<i>Median</i>	4.5	1.0	3.3	0.001	125	<0.001	0.007	0.033	0.44	0.22	16	0.41	<0.0005	0.015	<0.15	1.2	<0.001	2.3	0.045	0.0014	0.1
HC 31 - Pre-leached Granite: Nov 15, 2005 - Dec 13, 2005																					
<i>Minimum</i>	3.4	<1	0.26	<0.001	0.99	<0.001	<0.001	<0.001	0.26	<0.001	0.27	0.005	<0.0005	<0.001	<0.15	0.2	<0.001	<0.05	0.002	<0.0005	<0.005
<i>Maximum</i>	4.4	2.0	31	<0.001	361	0.007	0.018	0.02	28	0.025	43	0.88	<0.0005	0.033	<0.15	2.0	<0.001	0.87	0.1	0.0015	0.19
<i>Average</i>	3.7	1.4	15	<0.001	181	0.004	0.0095	0.011	14	0.013	22	0.44	<0.0005	0.017	<0.15	1.1	<0.001	0.46	0.051	0.001	0.098
<i>Median</i>	3.9	1.0	15	<0.001	181	0.004	0.0095	0.011	14	0.013	22	0.44	<0.0005	0.017	<0.15	1.1	<0.001	0.46	0.051	0.001	0.098

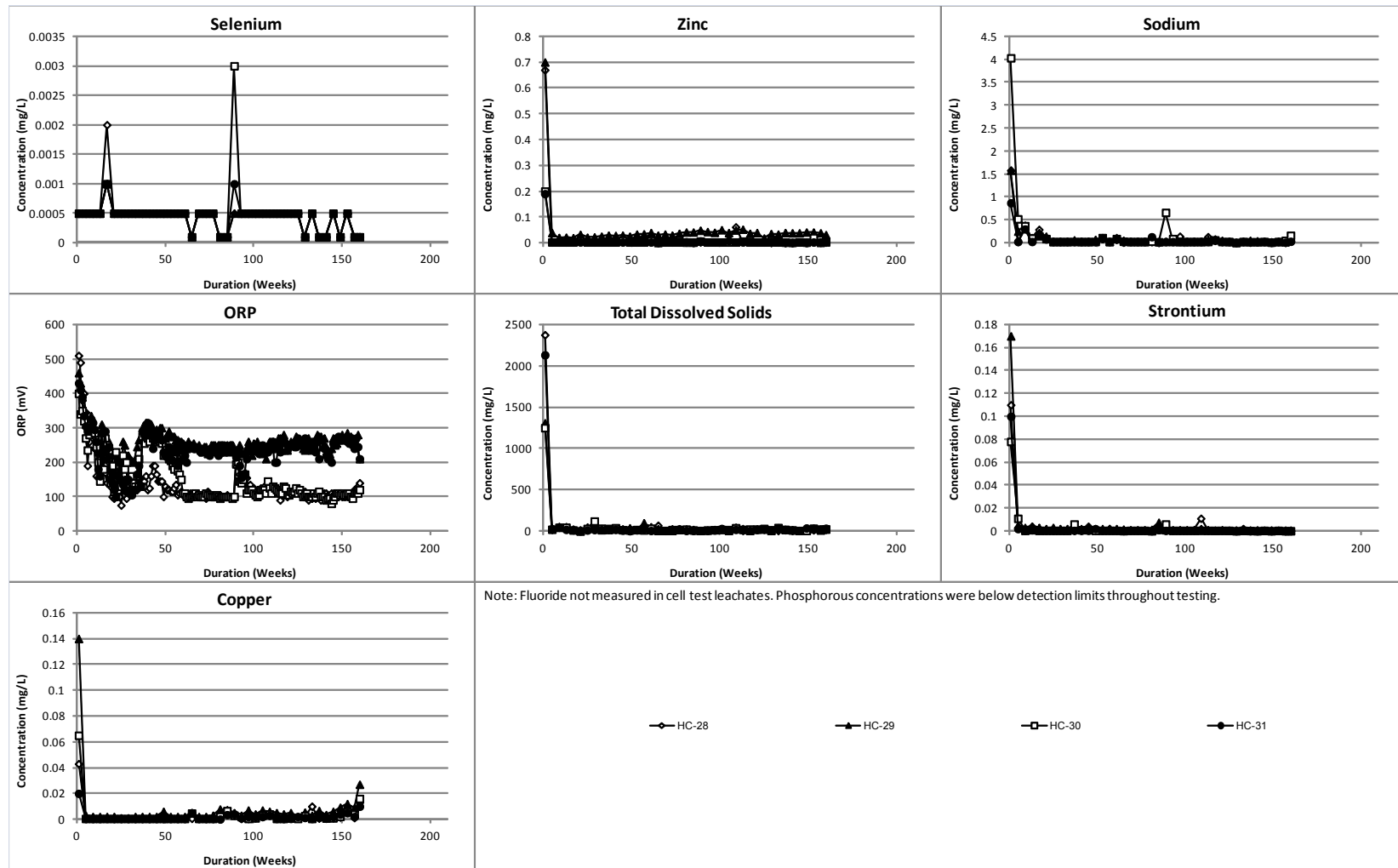
Note: s.u. = standard units; mg/L = milligrams per litre.

Table 8.III-31b Steady State Concentrations in Leachate from Pre-leached Mine Rock Humidity Cells

	pH	SO4	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Steady State																					
HC 28 - Pre-leached Granite: Nov 4, 2008 - Dec 2, 2008																					
<i>Minimum</i>	6.1	<1	<0.001	<0.0002	0.04	<0.0002	<0.0002	0.0012	<0.01	<0.0002	0.01	0.0004	<0.0001	<0.0002	0.09	0.05	<0.0002	<0.01	<0.0002	<0.0001	0.001
<i>Maximum</i>	6.3	2.0	0.002	<0.0002	0.08	<0.0002	<0.0002	0.013	<0.01	<0.0002	0.02	0.0005	<0.0001	0.0002	0.19	0.06	<0.0002	0.05	0.0003	<0.0001	0.002
<i>Average</i>	6.2	1.2	0.0015	<0.0002	0.06	<0.0002	<0.0002	0.0071	<0.01	<0.0002	0.015	0.00045	<0.0001	0.0002	0.14	0.055	<0.0002	0.03	0.00025	<0.0001	0.0015
<i>Median</i>	6.3	1.0	0.0015	<0.0002	0.06	<0.0002	<0.0002	0.0071	<0.01	<0.0002	0.015	0.00045	<0.0001	0.0002	0.14	0.055	<0.0002	0.03	0.00025	<0.0001	0.0015
HC 29 - Pre-leached Granite: Nov 4, 2008 - Dec 2, 2008																					
<i>Minimum</i>	5.0	<1	0.005	<0.0002	0.06	<0.0002	0.0004	0.0089	0.06	<0.0002	0.13	0.0016	<0.0001	0.0007	<0.03	0.16	<0.0002	0.02	0.0007	<0.0001	0.031
<i>Maximum</i>	5.3	3.0	0.007	<0.0002	0.13	<0.0002	0.0005	0.027	0.1	<0.0002	0.15	0.0022	<0.0001	0.0009	0.1	0.16	<0.0002	0.1	0.0007	<0.0001	0.038
<i>Average</i>	5.1	1.6	0.006	<0.0002	0.095	<0.0002	0.00045	0.018	0.08	<0.0002	0.14	0.0019	<0.0001	0.0008	0.065	0.16	<0.0002	0.06	0.0007	<0.0001	0.035
<i>Median</i>	5.1	1.0	0.006	<0.0002	0.095	<0.0002	0.00045	0.018	0.08	<0.0002	0.14	0.0019	<0.0001	0.0008	0.065	0.16	<0.0002	0.06	0.0007	<0.0001	0.035
HC 30 - Pre-leached Granite: Nov 4, 2008 - Dec 2, 2008																					
<i>Minimum</i>	5.8	<1	<0.001	<0.0002	0.03	<0.0002	<0.0002	0.0039	<0.01	<0.0002	0.02	0.0007	<0.0001	<0.0002	<0.03	0.05	<0.0002	0.05	<0.0002	<0.0001	0.001
<i>Maximum</i>	6.0	2.0	0.002	<0.0002	0.09	<0.0002	<0.0002	0.016	<0.01	<0.0002	0.02	0.0007	<0.0001	0.0005	0.18	0.05	<0.0002	0.16	<0.0002	<0.0001	0.003
<i>Average</i>	5.9	1.2	0.0015	<0.0002	0.06	<0.0002	<0.0002	0.010	<0.01	<0.0002	0.02	0.0007	<0.0001	0.00035	0.11	0.05	<0.0002	0.11	<0.0002	<0.0001	0.002
<i>Median</i>	5.9	1.0	0.0015	<0.0002	0.06	<0.0002	<0.0002	0.010	<0.01	<0.0002	0.02	0.0007	<0.0001	0.00035	0.11	0.05	<0.0002	0.11	<0.0002	<0.0001	0.002
HC 31 - Pre-leached Granite: Nov 4, 2008 - Dec 2, 2008																					
<i>Minimum</i>	6.1	<1	<0.001	<0.0002	0.01	<0.0002	<0.0002	0.002	<0.01	<0.0002	<0.01	0.0003	<0.0001	<0.0002	<0.03	0.04	<0.0002	0.01	<0.0002	<0.0001	<0.005
<i>Maximum</i>	6.4	2.0	0.002	<0.0002	0.06	<0.0002	<0.0002	0.01	<0.01	<0.0002	<0.01	0.0003	<0.0001	<0.0002	<0.03	0.05	<0.0002	0.03	<0.0002	<0.0001	0.005
<i>Average</i>	6.2	1.2	0.0015	<0.0002	0.035	<0.0002	<0.0002	0.006	<0.01	<0.0002	<0.01	0.0003	<0.0001	<0.0002	<0.03	0.045	<0.0002	0.02	<0.0002	<0.0001	0.005
<i>Median</i>	6.2	1.0	0.0015	<0.0002	0.035	<0.0002	<0.0002	0.006	<0.01	<0.0002	<0.01	0.0003	<0.0001	<0.0002	<0.03	0.045	<0.0002	0.02	<0.0002	<0.0001	0.005

Note: s.u. = standard units; mg/L = milligrams per litre.

Figure 8.III-15 Leachate Concentrations in Pre-leached Granite Humidity Cells



8.III.4.4 Column Tests

Tables 8.III-32a and 8.III-32b contain a summary of the leachate chemistry for selected parameters from the mine rock column cells calculated from the first flush using the first five sampling events (8.III-33a) and for steady state rates using the last five sampling events (8.III-33b). Figure 8.III-16 presents the concentrations of key parameters and pH values of the leachates. Attachment 8.III-7 provides the detailed results. The principal observations with respect to the mine rock columns are:

- The pH values of leachate from the columns ranged between a maximum of 8.2 and a minimum of 6.4. The pH values were generally stable except for lower values in all cells on week 30. The week 30 values are suspect as all columns display the same trend. Likely causes are all laboratory related such as different water used, or incorrect calibration of the probes, therefore these data are not included in the assessment.
- Sulphate concentrations decreased throughout the test. The TDS concentrations also rapidly decreased throughout the test.
- Overall, the concentrations of metals in leachate from the granite columns were very low. Concentrations for most parameters including sulphate, chloride, and TDS were less than the kimberlite column leach.

Table 8.III-32a First Flush Concentrations in Leachate from Mine Rock Column Tests

		pH	Sulphat e	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	(mg/L)	(mg/L)	(mg/L)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Column 1 - Granite : Jan 31, 2005 - Feb 28, 2005																								
Minimum		7.3	1.0	0.32	---	0.039	0.002	8.8	<0.001	<0.001	<0.001	<0.05	<0.001	2.5	0.084	0.014	<0.001	<0.15	6.0	<0.001	3.4	0.078	<0.0005	<0.005
Maximum		7.5	9.0	3.5	---	0.047	0.004	13	<0.001	<0.001	0.003	<0.05	<0.001	3.9	0.36	0.035	0.001	<0.15	16	<0.001	15	0.11	0.0012	<0.005
Average		7.3	2.8	0.47	---	0.029	0.001	3.4	0.00052	0.00052	0.00055	0.034	0.00052	1.0	0.062	0.0027	0.00052	0.077	1.8	0.00094	0.77	0.027	0.00038	0.003
Column 2 - Granite : Jan 31, 2005 - Feb 28, 2005																								
Minimum		7.5	24	1.8	---	0.041	0.004	17	<0.001	<0.001	<0.001	<0.05	<0.001	4.6	0.061	0.015	<0.001	<0.15	9.8	<0.001	8.0	0.21	0.0046	<0.005
Maximum		8.0	107	44	---	0.072	0.005	33	<0.001	<0.001	0.008	<0.05	<0.001	9.6	0.21	0.035	0.007	<0.15	17	<0.001	35	0.4	0.015	<0.005
Average		7.7	9.0	0.51	---	0.035	0.0027	9.4	0.00052	0.00052	0.00052	0.032	0.00052	2.4	0.035	0.0035	0.00052	0.077	3.1	0.001	1.6	0.11	0.01	0.0028
Column 3 - Granite : Jan 31, 2005 - Feb 28, 2005																								
Minimum		7.2	1.0	184	---	<0.005	<0.001	57	<0.001	<0.001	<0.001	<0.05	<0.001	7.3	0.002	<0.0005	0.001	<0.15	51	<0.001	7.3	1.1	<0.0005	<0.005
Maximum		7.4	6.0	393	---	0.031	0.003	88	<0.001	<0.001	0.001	0.56	<0.001	25	0.019	<0.0005	0.006	<0.15	69	<0.001	61	1.6	<0.0005	<0.005
Average		7.3	1.3	54	---	0.0062	0.00063	17	0.00053	0.00053	0.00053	0.033	0.00053	2.7	0.0017	0.00027	0.00057	0.08	22	0.0011	2.2	0.36	0.00027	0.0028
Column 4 - Granite : Jan 31, 2005 - Feb 28, 2005																								
Minimum		7.6	3.0	2.1	---	0.017	0.008	6.9	<0.001	<0.001	<0.001	<0.05	<0.001	1.9	0.015	0.0037	<0.001	<0.15	6.0	<0.001	4.6	0.079	<0.0005	<0.005
Maximum		8.0	7.0	23	---	0.075	0.016	15	<0.001	<0.001	0.002	<0.05	<0.001	4.4	0.18	0.0054	0.002	<0.15	10	<0.001	16	0.16	0.0037	<0.005
Average		7.8	1.2	0.68	---	0.063	0.003	9.4	0.00057	0.00053	0.00063	0.031	0.00053	1.4	0.036	0.00084	0.00053	0.08	1.8	0.0011	1.1	0.08	0.0033	0.003
Column 6 - Granite : Jan 31, 2005 - Feb 28, 2005																								
Minimum		7.8	21	1.4	---	0.025	0.004	18	0.002	<0.001	<0.001	<0.05	<0.001	5.2	0.076	0.0065	<0.001	<0.15	7.4	<0.001	3.8	0.3	0.0009	<0.005
Maximum		8.0	134	35	---	0.048	0.005	37	0.003	<0.001	0.002	<0.05	<0.001	10	0.22	0.01	0.002	<0.15	21	<0.001	24	0.4	0.0035	<0.005
Average		7.9	5.8	0.55	---	0.035	0.0039	9.6	0.00097	0.00052	0.00052	0.029	0.00052	2.2	0.019	0.0032	0.00052	0.077	2.4	0.00097	1.0	0.14	0.0022	0.0027
Col 9: PK - HC 9 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	7.4	3.0	0.5	0.09	0.0054	0.0004	2.5	0.00025	0.000026	0.0010	0.001	0.00006	0.37	0.0028	0.00023	0.00005	0.0045	0.81	0.00002	0.98	0.022	0.0000460	0.005
	Maximum	8.0	7.0	1.0	0.15	0.011	0.0069	4.8	0.0013	0.000042	0.002	0.007	0.0005	0.5	0.009	0.0008	0.0007	0.021	1.0	0.00019	1.2	0.036	0.000087	0.016
	Average	7.7	4.2	0.8	0.12	0.0074	0.0021	3.9	0.00053	0.000032	0.0015	0.0028	0.00018	0.5	0.006	0.00038	0.0005	0.0134	0.92	0.00007	1.1	0.03	0.000071	0.0104
BOTTOM	Minimum	7.7	16.0	2.3	1.2	0.0178	0.0014	28	0.0011	0.000081	0.0009	0.002	0.00006	5.9	0.0184	0.0048	0.0002	0.0045	8.0	0.00016	7.7	0.3	0.00159	0.005
	Maximum	8.0	176	20.0	1.5	0.025	0.0022	57	0.0035	0.00021	0.0023	0.149	0.00018	13.9	0.03	0.009	0.003	0.039	20.4	0.0007	30	0.7	0.0115	0.012
	Average	7.9	82.6	9.92	1.4	0.0213	0.0017	41	0.0020	0.00014	0.0018	0.077	0.00012	10.0	0.0234	0.007	0.0016	0.022	14.2	0.0004	18	0.49	0.00555	0.0086
Col 10: PK - HC 12 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	7.4	1.0	0.7	0.08	0.0054	0.0007	2.1	0.00025	0.000029	0.0007	0.001	0.00008	0.22	0.0032	0.00035	0.00005	0.0045	0.65	0.00002	1.01	0.024	0.0000200	0.008
	Maximum	7.9	4.0	2.1	0.11	0.011	0.0133	3.9	0.0007	0.000066	0.0032	0.007	0.0004	0.3	0.008	0.0007	0.0008	0.046	1.1	0.00053	2.2	0.037	0.000032	0.021
	Average	7.6	1.8	1.5	0.1	0.0077	0.0034	3.2	0.00041	0.000043	0.002	0.003	0.00018	0.3	0.0058	0.00045	0.0005	0.0147	0.92	0.00014	1.7	0.029	0.000026	0.0132
BOTTOM	Minimum	7.8	1.0	5.2	0.9	0.0237	0.0027	18	0.0009	0.00010	0.0008	0.007	0.00013	3.1	0.0082	0.005	0.0006	0.0045	7.7	0.00002	12.8	0.32	0.00114	0.007
	Maximum	7.9	17	21.0	1.2	0.065	0.0049	25	0.003	0.00023	0.005	0.121	0.00062	4.2	0.018	0.007	0.002	0.027	11.3	0.00118	27	0.41	0.0014	0.012
	Average	7.9	6.6	13.08	1.1	0.0354	0.0035	23	0.0018	0.00017	0.002	0.064	0.00031	3.8	0.0149	0.006	0.0012	0.016	9.9	0.00055	21	0.38	0.00126	0.009
Col 11: PK - HC 16 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	6.0	21.0	0.4	0.03	0.0373	0.0003	4.5	0.00025	0.00242	0.0008	0.209	0.00068	2.61	0.0809	0.00001	0.0073	0.0045	2.24	0.00002	0.65	0.042	0.0000530	0.023
	Maximum	7.4	41.0	0.7	0.08	0.097	0.0152	7.6	0.0006	0.00458	0.0195	0.319	0.00276	4.8	0.134	0.0003	0.0112	0.016	3.0	0.0006	0.9	0.065	0.000111	0.032
	Average	6.6	30.8	0.6	0.04	0.0677	0.0037	6.1	0.00046	0.00350	0.0084	0.2756	0.00158	3.8	0.1081	0.0001	0.0093	0.0089	2.58	0.00019	0.8	0.054	0.000091	0.0294
BOTTOM	Minimum	4.4	111.0	1.2	0.1	0.213	0.0005	19	0.0018	0.009722	0.0048	2.030	0.00209	11.2	0.377	0.0001	0.0255	0.0045	10.2	0.00013	2.5	0.18	0.000178	0.067
	Maximum	5.6	692	8.6	0.8	2.49	0.0043	161	0.008	0.0925	0.022	5.75	0.01056	92.3	3.00	0.00	0.226	0.076	30.8	0.00116	14	1.28	0.003	0.324
	Average	5.0	364.4	3.86	0.4	1.0258	0.0016	73	0.00416	0.0434	0.0133	3.934	0.00508	42.7	1.3834	0.00	0.1044	0.028	19.3	0.00053	7	0.61	0.00115	0.164

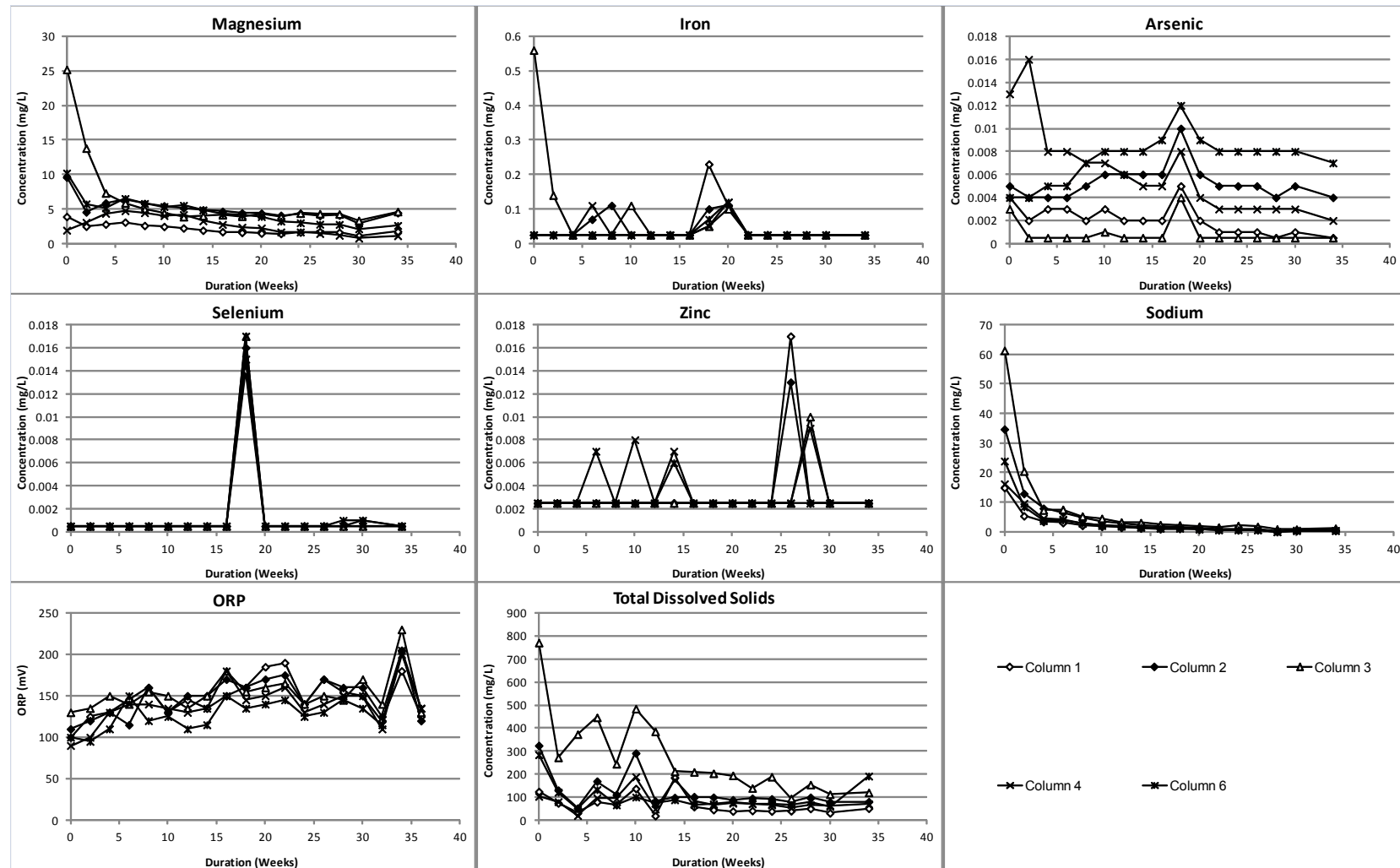
Note: s.u. = standard units; mg/L = milligrams per litre.

Table 8.III-32b Steady State Concentrations in Leachate from Mine Rock Column Tests

		pH	Sulphate	Cl	Cl	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	(mg/L)	(mg/L)	(mg/L)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Column 1 - Granite: Aug 29, 2005 - Sep 26, 2005																								
Minimum		6.4	3.0	0.37	0.37	0.054	<0.001	3.5	<0.001	<0.001	<0.001	<0.05	<0.001	1.1	<0.001	0.0019	<0.001	<0.15	1.6	<0.001	0.38	0.025	<0.0005	<0.005
Maximum		7.5	5.0	0.48	0.48	0.066	0.001	5.1	<0.001	<0.001	<0.001	<0.05	<0.001	1.8	<0.001	0.0028	<0.001	<0.15	1.8	<0.001	0.4	0.037	<0.0005	<0.005
Average		6.7	4.0	0.42	0.42	0.06	0.001	4.3	<0.001	<0.001	<0.001	<0.05	<0.001	1.5	<0.001	0.0024	<0.001	<0.15	1.7	<0.001	0.39	0.031	<0.0005	<0.005
Column 2 - Granite: Aug 29, 2005 - Sep 26, 2005																								
Minimum		7.1	9.0	0.38	0.38	0.059	0.004	14	<0.001	<0.001	<0.001	<0.05	<0.001	2.9	<0.001	0.0031	<0.001	<0.15	3.1	<0.001	0.62	0.13	0.0077	<0.005
Maximum		8.2	14	0.57	0.57	0.09	0.005	21	<0.001	<0.001	<0.001	<0.05	<0.001	4.5	<0.001	0.0053	<0.001	<0.15	3.5	0.001	0.78	0.19	0.014	<0.005
Average		7.5	12	0.48	0.48	0.075	0.0045	17	<0.001	<0.001	<0.001	<0.05	<0.001	3.7	<0.001	0.0042	<0.001	<0.15	3.3	0.001	0.7	0.16	0.011	<0.005
Column 3 - Granite: Aug 29, 2005 - Sep 26, 2005																								
Minimum		7.3	3.0	25	25	<0.005	<0.001	12	<0.001	<0.001	<0.001	<0.05	<0.001	3.3	<0.001	<0.0005	<0.001	<0.15	24	<0.001	0.88	0.32	<0.0005	<0.005
Maximum		8.1	3.0	33	33	0.006	<0.001	14	<0.001	<0.001	<0.001	<0.05	<0.001	4.6	<0.001	<0.0005	<0.001	<0.15	29	<0.001	1.2	0.4	<0.0005	<0.005
Average		7.6	3.0	29	29	0.0055	<0.001	13	<0.001	<0.001	<0.001	<0.05	<0.001	4.0	<0.001	<0.0005	<0.001	<0.15	26	<0.001	1.0	0.36	<0.0005	<0.005
Column 4 - Granite: Aug 29, 2005 - Sep 26, 2005																								
Minimum		7.2	1.0	0.43	0.43	0.14	0.002	14	<0.001	<0.001	<0.001	<0.05	<0.001	0.77	<0.001	<0.0005	<0.001	<0.15	1.8	<0.001	0.37	0.078	0.0031	<0.005
Maximum		8.1	2.0	0.6	0.6	0.25	0.003	20	<0.001	<0.001	<0.001	<0.05	<0.001	1.1	<0.001	0.0012	<0.001	<0.15	2.2	<0.001	0.42	0.11	0.004	<0.005
Average		7.6	1.3	0.51	0.51	0.2	0.0025	17	<0.001	<0.001	<0.001	<0.05	<0.001	0.95	<0.001	0.00085	<0.001	<0.15	2.0	<0.001	0.4	0.094	0.0036	<0.005
Column 6 - Granite: Aug 29, 2005 - Sep 26, 2005																								
Minimum		7.3	3.0	0.39	0.39	0.089	0.007	15	<0.001	<0.001	<0.001	<0.05	<0.001	2.1	<0.001	0.0054	<0.001	<0.15	2.5	<0.001	0.44	0.18	0.0023	<0.005
Maximum		8.2	3.0	0.49	0.49	0.11	0.008	19	<0.001	<0.001	<0.001	<0.05	<0.001	2.6	<0.001	0.0058	<0.001	<0.15	2.6	0.001	0.55	0.19	0.0025	<0.005
Average		7.6	3.0	0.44	0.44	0.10	0.0075	17	<0.001	<0.001	<0.001	<0.05	<0.001	2.4	<0.001	0.0056	<0.001	<0.15	2.6	0.001	0.5	0.19	0.0024	<0.005
Col 9: PK - HC 9 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	7.7	1.0	0.1	0.08	0.0039	0.0018	2.3	0.0022	0.000011	0.0008	0.003	0.00010	0.12	0.0034	0.00013	0.0002	0.0045	0.13	0.00002	0.12	0.01	0.0000690	0.005
	Maximum	8.0	2.0	0.3	0.1	0.004	0.0044	2.6	0.0031	0.000013	0.0011	0.017	0.00028	0.2	0.004	0.0001	0.0004	0.005	0.2	0.0001	0.2	0.013	0.000079	0.008
	Average	7.8	1.6	0.14	0.09	0.0039	0.0031	2.4	0.00265	0.000012	0.001	0.010	0.00019	0.1	0.0036	0.00013	0.0003	0.0045	0.15	0.00006	0.1	0.011	0.000074	0.0065
BOTTOM	Minimum	7.8	6.0	0.1	0.8	0.058	0.0017	20	0.0030	0.000035	0.00025	0.014	0.00009	1.6	0.0087	0.0005	0.0002	0.0045	1.4	0.00002	0.8	0.13	0.00296	0.004
	Maximum	7.9	8	0.3	0.9	0.072	0.0017	21	0.0033	0.00004	0.0008	0.021	0.00038	1.8	0.009	0.001	0.0005	0.005	1.8	0.00005	1	0.14	0.0031	0.016
	Average	7.8	7.0	0.22	0.9	0.0648	0.0017	21	0.00315	0.00004	0.0005	0.018	0.00024	1.7	0.0089	0.001	0.0004	0.005	1.6	0.00004	1	0.14	0.00301	0.010
Col 10: PK - HC 12 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	7.4	1.0	0.1	0.03	0.007	0.0015	3.2	0.0014	0.000012	0.00025	0.014	0.00006	0.16	0.0060	0.00008	0.0001	0.0045	0.23	0.00002	0.17	0.015	0.0000470	0.004
	Maximum	7.6	3.0	0.1	0.08	0.007	0.0031	3.2	0.0017	0.000012	0.0007	0.017	0.00016	0.2	0.006	0.0001	0.0003	0.01	0.2	0.00002	0.2	0.017	0.000055	0.005
	Average	7.5	2.0	0.1	0.04	0.007	0.0023	3.2	0.00155	0.000012	0.0005	0.0155	0.00011	0.2	0.0061	0.0001	0.0002	0.0073	0.24	0.00002	0.2	0.016	0.000051	0.0045
BOTTOM	Minimum	7.7	1.0	0.4	0.4	0.0311	0.0014	25	0.0018	0.000039	0.0006	0.047	0.00009	1.9	0.0174	0.0006	0.0001	0.0045	2.1	0.00002	1.3	0.24	0.000926	0.004
	Maximum	7.9	3	0.4	0.4	0.036	0.0025	26	0.0019	0.00005	0.0008	0.052	0.00035	2.1	0.018	0.001	0.0007	0.005	2.5	0.00002	2	0.26	0.0009	0.013
	Average	7.8	1.8	0.4	0.4	0.0335	0.002	25	0.00185	0.00004	0.0007	0.05	0.00022	2.0	0.0175	0.001	0.0004	0.005	2.3	0.00002	2	0.25	0.00093	0.0085
Col 11: PK - HC 16 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	5.9	3.0	0.1	0.03	0.0108	0.0003	0.8	0.0034	0.000569	0.0020	0.062	0.00024	0.38	0.0155	0.00006	0.0017	0.0045	0.6	0.00002	0.15	0.008	0.0000200	0.010
	Maximum	6.9	8.0	0.1	0.03	0.012	0.0004	0.9	0.0036	0.000628	0.002	0.072	0.00028	0.4	0.016	0.0004	0.0018	0.005	0.7	0.00002	0.2	0.009	0.000021	0.010
	Average	6.5	5.4	0.1	0.03	0.0114	0.0004	0.8	0.0035	0.000599	0.002	0.067	0.00026	0.4	0.016	0.00024	0.0018	0.0045	0.65	0.00002	0.2	0.008	0.000021	0.010
BOTTOM	Minimum	6.1	7.0	0.1	0.1	0.0486	0.0002	2	0.0019	0.00122	0.0005	0.745	0.00029	1.2	0.0464	0.0001	0.0033	0.0045	2.6	0.00002	0.4	0.02	0.000022	0.010
	Maximum	6.4	12	0.2	0.1	0.084	0.0013	2	0.0026	0.00124	0.0018	0.798	0.00042	1.4	0.052	0.00	0.0035	0.01	3.0	0.00058	0	0.03	0.000	0.045
	Average	6.2	9.8	0.12	0.1	0.0665	0.0008	2	0.00225	0.00123	0.0012	0.772	0.00036	1.3	0.0492	0.00	0.0034	0.007	2.8	0.0003	0	0.02	0.00004	0.0275

Note: s.u. = standard units; mg/L = milligrams per litre.

Figure 8.III-16 Leachate Concentrations in the Granite Columns



8.III.4.4.1 Submerged Column Tests

Submerged granite column tests (SCTs) were initiated in 2011, and were ongoing at the date of preparation of this report. The objective of the submerged column tests is to evaluate the possible influence on water quality that might result from submerging the mine rock. Leachate samples are collected from the top and bottom of the test column, and referenced as “top” and “bottom” samples within the report.

Tables 8.III-33a and 8.III-33b contain a summary of the column leachate concentrations for selected parameters. Results are presented for both the first flush (the first five weeks) in Table 8.III-33a and steady state conditions (the last five weeks) in Table 8.III-33b. Figure 8.III-17 presents the concentrations of key parameters and pH values of the leachates. Attachment 8.III-9 provides detailed results. The principal observations with respect to the submerged mine rock columns are:

- The pH values of leachate from the columns ranged between a maximum of 8.2 and a minimum of 4.4 throughout testing. The pH values were generally stable and near-neutral with the exception of Column 11. This column reported an increase in pH from the start of testing to the time of reporting in both the bottom (4.4 to 6.4) and the top (6.0 to 6.9).
- The three granite submerged columns reported a decrease in redox potential throughout testing, indicating oxygen content is decreasing.
- Sulphate concentrations decreased to steady state conditions after the first flush. No concentration trends with sample location (i.e., top vs. bottom) were evident.
- Concentrations of major parameters including sodium, magnesium, and calcium were highest in leachates collected during the first flush from the bottom of Column 11. Based on concentration trends of major ions that are typically associated with readily-soluble materials, it appears that readily-soluble materials were flushed during the initial weeks of testing.
- Arsenic and selenium concentrations were generally stable after the first flush.
- Key metal concentrations generally decreased after the first flush for all cells. The highest concentrations of most metals, including zinc, copper, iron, chromium, cobalt, molybdenum, nickel, and uranium were highest in the bottom water leachate from Column 11. This is likely associated with the lower pH values associated with the leachate from the cell.
- Fluoride concentrations generally decreased after the first flush to reach steady state conditions. The highest concentrations were reported in the bottom water from Columns 9 and 10.
- Phosphorus concentrations generally decreased after the first flush to reach steady state conditions. The highest concentration was reported in week one of sampling the bottom water of the Column 11 (0.07 mg/L).

Table 8.III-33a First Flush Concentrations in Leachate from Mine Rock Submerged Column Tests

		pH	Sulphate	Cl	F	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	(mg/L)	(mg/L)	(mg/L)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Col 9: PK - HC 9 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	7.4	3.0	0.5	0.09	0.0054	0.0004	2.5	0.00025	0.000026	0.0010	0.001	0.00006	0.37	0.0028	0.00023	0.00005	0.0045	0.81	0.00002	0.98	0.022	0.000046	0.005
	Maximum	8.0	7.0	1.0	0.15	0.011	0.0069	4.8	0.0013	0.000042	0.002	0.007	0.0005	0.5	0.009	0.0008	0.0007	0.021	1.0	0.00019	1.2	0.036	0.000087	0.016
	Average	7.7	4.2	0.8	0.12	0.0074	0.0021	3.9	0.00053	0.000032	0.0015	0.0028	0.00018	0.5	0.006	0.00038	0.0005	0.0134	0.92	0.00007	1.1	0.03	0.000071	0.0104
BOTTOM	Minimum	7.7	16.0	2.3	1.2	0.0178	0.0014	28	0.0011	0.000081	0.0009	0.002	0.00006	5.9	0.0184	0.0048	0.0002	0.0045	8.0	0.00016	7.7	0.3	0.00159	0.005
	Maximum	8.0	176	20.0	1.5	0.025	0.0022	57	0.0035	0.00021	0.0023	0.149	0.00018	13.9	0.03	0.009	0.003	0.039	20.4	0.0007	30	0.7	0.0115	0.012
	Average	7.9	82.6	9.92	1.4	0.0213	0.0017	41	0.0020	0.00014	0.0018	0.077	0.00012	10.0	0.0234	0.007	0.0016	0.022	14.2	0.0004	18	0.49	0.00555	0.0086
Col 10: PK - HC 12 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	7.4	1.0	0.7	0.08	0.0054	0.0007	2.1	0.00025	0.000029	0.0007	0.001	0.00008	0.22	0.0032	0.00035	0.00005	0.0045	0.65	0.00002	1.01	0.024	0.00002	0.008
	Maximum	7.9	4.0	2.1	0.11	0.011	0.0133	3.9	0.0007	0.000066	0.0032	0.007	0.0004	0.3	0.008	0.0007	0.0008	0.046	1.1	0.00053	2.2	0.037	0.000032	0.021
	Average	7.6	1.8	1.5	0.1	0.0077	0.0034	3.2	0.00041	0.000043	0.002	0.003	0.00018	0.3	0.0058	0.00045	0.0005	0.0147	0.92	0.00014	1.7	0.029	0.000026	0.0132
BOTTOM	Minimum	7.8	1.0	5.2	0.9	0.0237	0.0027	18	0.0009	0.00010	0.0008	0.007	0.00013	3.1	0.0082	0.005	0.0006	0.0045	7.7	0.00002	12.8	0.32	0.00114	0.007
	Maximum	7.9	17	21.0	1.2	0.065	0.0049	25	0.003	0.00023	0.005	0.121	0.00062	4.2	0.018	0.007	0.002	0.027	11.3	0.00118	27	0.41	0.0014	0.012
	Average	7.9	6.6	13.08	1.1	0.0354	0.0035	23	0.0018	0.00017	0.002	0.064	0.00031	3.8	0.0149	0.006	0.0012	0.016	9.9	0.00055	21	0.38	0.00126	0.009
Col 11: PK - HC 16 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	6.0	21.0	0.4	0.03	0.0373	0.0003	4.5	0.00025	0.00242	0.0008	0.209	0.00068	2.61	0.0809	0.00001	0.0073	0.0045	2.24	0.00002	0.65	0.042	0.000053	0.023
	Maximum	7.4	41.0	0.7	0.08	0.097	0.0152	7.6	0.0006	0.00458	0.0195	0.319	0.00276	4.8	0.134	0.0003	0.0112	0.016	3.0	0.0006	0.9	0.065	0.000111	0.032
	Average	6.6	30.8	0.6	0.04	0.0677	0.0037	6.1	0.00046	0.00350	0.0084	0.2756	0.00158	3.8	0.1081	0.0001	0.0093	0.0089	2.58	0.00019	0.8	0.054	0.000091	0.0294
BOTTOM	Minimum	4.4	111.0	1.2	0.1	0.213	0.0005	19	0.0018	0.009722	0.0048	2.030	0.00209	11.2	0.377	0.0001	0.0255	0.0045	10.2	0.00013	2.5	0.18	0.000178	0.067
	Maximum	5.6	692	8.6	0.8	2.49	0.0043	161	0.008	0.0925	0.022	5.75	0.01056	92.3	3.00	0.00	0.226	0.076	30.8	0.00116	14	1.28	0.003	0.324
	Average	5.0	364.4	3.86	0.4	1.0258	0.0016	73	0.00416	0.0434	0.0133	3.934	0.00508	42.7	1.3834	0.00	0.1044	0.028	19.3	0.00053	7	0.61	0.00115	0.164

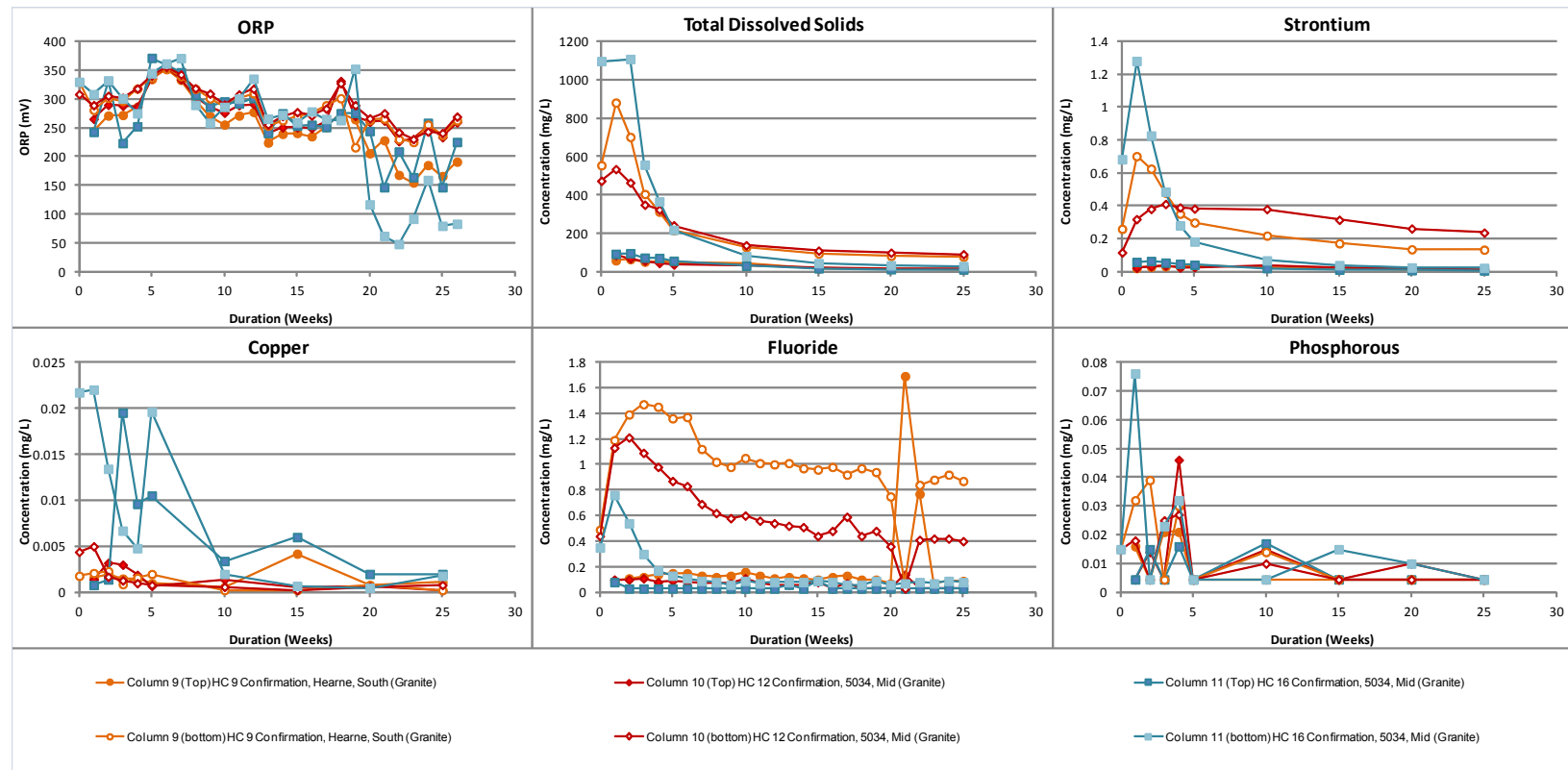
Note: s.u. = standard units; mg/L = milligrams per litre.

Table 8.III-33b Steady State Concentrations in Leachate from Mine Rock Submerged Column Tests

		pH	Sulphate	Cl	Cl	Al	As	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Se	Na	Sr	U	Zn
		s.u.	(mg/L)	(mg/L)	(mg/L)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
TOP	Minimum	7.7	1.0	0.1	0.08	0.0039	0.0018	2.3	0.0022	0.000011	0.0008	0.003	0.00010	0.12	0.0034	0.00013	0.0002	0.0045	0.13	0.00002	0.12	0.01	0.000069	0.005
	Maximum	8.0	2.0	0.3	0.1	0.004	0.0044	2.6	0.0031	0.000013	0.0011	0.017	0.00028	0.2	0.004	0.0001	0.0004	0.005	0.2	0.0001	0.2	0.013	0.000079	0.008
	Average	7.8	1.6	0.14	0.09	0.0039	0.0031	2.4	0.00265	0.000012	0.001	0.010	0.00019	0.1	0.0036	0.00013	0.0003	0.0045	0.15	0.00006	0.1	0.011	0.000074	0.0065
BOTTOM	Minimum	7.8	6.0	0.1	0.8	0.058	0.0017	20	0.0030	0.000035	0.00025	0.014	0.00009	1.6	0.0087	0.0005	0.0002	0.0045	1.4	0.00002	0.8	0.13	0.00296	0.004
	Maximum	7.9	8	0.3	0.9	0.072	0.0017	21	0.0033	0.00004	0.0008	0.021	0.00038	1.8	0.009	0.001	0.0005	0.005	1.8	0.00005	1	0.14	0.0031	0.016
	Average	7.8	7.0	0.22	0.9	0.0648	0.0017	21	0.00315	0.00004	0.0005	0.018	0.00024	1.7	0.0089	0.001	0.0004	0.005	1.6	0.00004	1	0.14	0.00301	0.010
Col 10: PK - HC 12 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	7.4	1.0	0.1	0.03	0.007	0.0015	3.2	0.0014	0.000012	0.00025	0.014	0.00006	0.16	0.0060	0.00008	0.0001	0.0045	0.23	0.00002	0.17	0.015	0.000047	0.004
	Maximum	7.6	3.0	0.1	0.08	0.007	0.0031	3.2	0.0017	0.000012	0.0007	0.017	0.00016	0.2	0.006	0.0001	0.0003	0.01	0.2	0.00002	0.2	0.017	0.000055	0.005
	Average	7.5	2.0	0.1	0.04	0.007	0.0023	3.2	0.00155	0.000012	0.0005	0.0155	0.00011	0.2	0.0061	0.0001	0.0002	0.0073	0.24	0.00002	0.2	0.016	0.000051	0.0045
BOTTOM	Minimum	7.7	1.0	0.4	0.4	0.0311	0.0014	25	0.0018	0.000039	0.0006	0.047	0.00009	1.9	0.0174	0.0006	0.0001	0.0045	2.1	0.00002	1.3	0.24	0.000926	0.004
	Maximum	7.9	3	0.4	0.4	0.036	0.0025	26	0.0019	0.00005	0.0008	0.052	0.00035	2.1	0.018	0.001	0.0007	0.005	2.5	0.00002	2	0.26	0.0009	0.013
	Average	7.8	1.8	0.4	0.4	0.0335	0.002	25	0.00185	0.00004	0.0007	0.05	0.00022	2.0	0.0175	0.001	0.0004	0.005	2.3	0.00002	2	0.25	0.00093	0.0085
Col 11: PK - HC 16 Confirmation - Granite: May 19, 2011 - June 6, 2011																								
TOP	Minimum	5.9	3.0	0.1	0.03	0.0108	0.0003	0.8	0.0034	0.000569	0.0020	0.062	0.00024	0.38	0.0155	0.00006	0.0017	0.0045	0.6	0.00002	0.15	0.008	0.00002	0.010
	Maximum	6.9	8.0	0.1	0.03	0.012	0.0004	0.9	0.0036	0.000628	0.002	0.072	0.00028	0.4	0.016	0.0004	0.0018	0.005	0.7	0.00002	0.2	0.009	0.000021	0.010
	Average	6.5	5.4	0.1	0.03	0.0114	0.0004	0.8	0.0035	0.000599	0.002	0.067	0.00026	0.4	0.016	0.00024	0.0018	0.0045	0.65	0.00002	0.2	0.008	0.000021	0.010
BOTTOM	Minimum	6.1	7.0	0.1	0.1	0.0486	0.0002	2	0.0019	0.00122	0.0005	0.745	0.00029	1.2	0.0464	0.0001	0.0033	0.0045	2.6	0.00002	0.4	0.02	0.000022	0.010
	Maximum	6.4	12	0.2	0.1	0.084	0.0013	2	0.0026	0.00124	0.0018	0.798	0.00042	1.4	0.052	0.00	0.0035	0.01	3.0	0.00058	0	0.03	0.000	0.045
	Average	6.2	9.8	0.12	0.1	0.0665	0.0008	2	0.00225	0.00123	0.0012	0.772	0.00036	1.3	0.0492	0.00	0.0034	0.007	2.8	0.0003	0	0.02	0.00004	0.0275

Note: s.u. = standard units; mg/L = milligrams per litre.

Figure 8.III-17 Leachate Concentrations in the Granite Submerged Columns



8.III.4.4.2 Comparison with Mine Rock at Other Diamond Projects

Table 8.III-34 summarizes steady state results (based on the last five measurements) of kinetic tests for selected parameters from mine rock lithologies at other northern Canadian diamond projects (Golder, 2002). The mine rock includes granite from Ekati Mine, mudstone from Diavik Diamond Mine, granite and metavolcanics from Snap Lake Mine, and granite from the Gahcho Kué Project (Project). The purpose of the comparison is to examine the range of mine rock leachate chemistry measured in kinetic tests at other northern Canadian diamond projects.

In comparison to other diamond mining projects in the North, mine rock from the Project has very low sulphur content (average 0.04%) (Table 8.III-34). However, mine rock from the Project also contains very little NP (average 7 kg CaCO₃/t). The results of kinetic testing show that for the single sample devoid of any carbonate NP (HC 16), the pH was quite low initially, increasing slightly to values of around 5, likely reflecting the influence of the influent water. For some parameters the corresponding metal concentrations for this sample appeared to be elevated relative to the other Humidity Cell samples. The implications of these concentrations based on the amount of PAG rock potentially exposed are considered within the context of mine rock seepage source inputs to the water quality predictive model used to determine Project effects to Kennady Lake and downstream waterbodies (Appendix 8.III.1).

The results suggest that the Project granitic kinetic leaching results are most similar to Ekati Mine mine rock and low sulphur granites from Snap Lake Mine (e.g., with low amounts of metavolcanic). The Snap Lake Mine high sulphide metavolcanic and the Diavik Diamond Mine mudstone have lower pH values and tend to have higher metal concentrations than the Project granitic mine rock.

The metal leaching potential of mine rock, indicated by the results of short-term leach testing and kinetic testing, is generally low in comparison to other mining projects in the North (Table 8.III-34). Based on the geochemical testing completed and the mine plan to date, it would be reasonable to use non-PAG materials for site development provided suitable monitoring and adaptive management programs are in place.

Table 8.III-34 Comparison of Selected Parameters at Steady State from Mine Rock Kinetic Tests

	Units	Ekati Mine		Diavik Diamond Mine	Snap Lake Mine			Gahcho Kué Project
		Granite	Granite	Mudstone	Granite/ metavolcanic (n=4)	Metavolcanic (n=8)	High S Metavolcanic	Granite (n=21)
Total sulphur	wt%	0.03	0.05	3.5	0.13 (0.11-0.17)	0.47 (0.03-1.04)	9.9	0.04 (0.02-0.2)
NP/AP		11 ^(a)	7 ^(a)	0.4	3.4 (2.90-3.60)	1.2 (0.3-18.3)	0.05	6.2 (0.53-22)
pH		9.1	9.4	3.5	7.3 (6.90-7.90)	7.4 (7.3-8.1)	4.2	6.6 (4.0-7.7)
SO ₄	mg/L	1.1	1.8	8,765	2.7 (0.10-6.20)	29.3 (2.1-53.6)	200	1.3 (<1.0-3.0)
Aluminum	mg/L	159.5	149.1	69,700	0.03 (0.01-0.06)	8.5 (0.01-0.11)	2,020	0.030 (0.002-0.092)
Arsenic	µg/L	4.2	2.5		0.7 (0.50-1.33)	0.6 (0.5-3.0)	0.8	1.6 (<2-3)
Copper	µg/L	4.1	4.1	217	0.5 (0.20-0.70)	0.4 (0.2-1.10)	2413	5.4 (<1-15)
Lead	µg/L	4.4	4.9		1.3 (1.0-2.0)	1.8 (1.0-2.67)	1.6	0.6 (<0.2-2.3)
Nickel	µg/L	0.8	0.6	19,500	0.5 (0.2-0.87)	9.7 (0.1-19)	119	0.5 (<0.2-2.4)
Zinc	µg/L	5.5	5.4	11,600	2.1 (0.5-3.08)	1.46 (0.25-2.42)	4.8	2.6 (<1-7)

Source: Golder 2002.

Note: wt% = percent by weight; mg/L = milligrams per litre; µg/L = micrograms per litre.

^(a) The NP/AP and pH values for Ekati Mine diabase and granite kinetic tests are taken from the average acid base accounting and paste pH results for the respective lithology.

8.III.5 GEOCHEMICAL IMPLICATIONS OF MINE WASTE MANAGEMENT

8.III.5.1 Overview of Supplemental Mitigation

In the Project Description of the 2010 EIS (De Beers 2010, Section 3.7), fine PK was stored in both Area 1 and Area 2 of the Fine PKC Facility. As a result of the supplemental mitigation, the Fine PKC Facility's footprint has been reduced by omitting Area 1, which included Lakes A1 and A2. This reduction in size allowed for a reduction in the long-term phosphorus loadings from the facility. To identify this supplemental mitigation, the term "Fine PKC Facility (mitigated)" is used. With the footprint of the facility reduced to Area 2, the fine PK that was to be stored in Area 1 has been relocated to the 5034 and Hearne pits. As a result of the supplemental mitigation of the Fine PKC Facility (mitigated), the size of the Project footprint has decreased by about 83 hectares compared to the footprint associated with the Project Description in the 2010 EIS.

In the 2010 EIS, reclamation of the Fine PKC Facility involved progressively covering both Area 1 and Area 2 with coarse PK and mine rock. As part of the supplemental mitigation, the coarse PK and mine rock that was to be used in reclamation of Area 1 will be transferred to the West Mine Rock Pile; this will result in an increase in the height of the West Mine Rock Pile. Within the 2010 EIS, the height of the West Mine Rock Pile was estimated at 70 metres (m); given the supplemental mitigation, the height of this pile is now estimated at 94 m. Hereafter, the pile will be referred to as "West Mine Rock Pile (mitigated)".

8.III.5.2 Mine Rock Management

Site development plans for the Project call for the use of mine rock as follows:

- Non-acid generating ("non-AG") mine rock will be used to construct site facilities (i.e., roads, building foundations, and the airstrip) and filter dykes.
- Non-AG mine rock not required for use in construction will be stored in the South Mine Rock Pile and the West Mine Rock Pile, located within Areas 6 and 5, respectively. Non-AG rock will be stored in the mined out 5034 pit once this facility becomes available. After the 5034 Pit is full, non-AG rock will continue to be placed in the West Mine Rock Pile (mitigated).
- Potentially acid generating (PAG) mine rock produced during the life of the mine will be encapsulated in the South Mine Rock Pile (mitigated) and West Mine Rock Pile (mitigated), and the mined-out 5034 Pit. From

Year 6 onwards, PAG mine rock can be placed within the mined-out 5034 Pit where it will be underwater when Kennady Lake is refilled.

8.III.5.2.1 Site Specific Mine Rock Classification Criteria

Based on the proposed site development plans, site specific criteria are required to classify non-AG and PAG rock for use in construction and for use during operations.

The acid potential of a sample is generally a function of sulphide mineral content. The results of ABA confirm that sulphide minerals are the dominant source of sulphur in most mine rock samples (Figure 8.III-11). Sulphide minerals identified in mine rock from the Project include trace quantities of pyrite, pyrrhotite, and chalcopyrite. According to AMEC (unpublished), sulphide minerals generally occur as replacement minerals or as post-intrusive secondary infilling of fractures. The majority of sulphide minerals occur near the contact between altered mine rock and kimberlite (AMEC unpublished).

The results of humidity cell testing suggest that mine rock containing greater than 0.1% total sulphur has some potential for generating acidity, owing to the lack of buffering capacity in mine rock. Granite mine rock HC 16 (total sulphur 0.1%) and the confirmation cell for HC 16 initiated in 2011 produced moderately acidic effluent for the duration of the test. In the other mine rock cells that had sulphur concentrations less than 0.1%, acidic drainage was not produced (AMEC unpublished). It is expected that even if small amounts of rock have up to 0.3% sulphide there will be limited capacity for generation of significant amounts of acidity once these rock units are blasted and placed due to the very low overall sulphide content.

Figure 8.III-18 and Table 8.III-35 show the distribution of total sulphur for each proposed pit and the distribution between the seven mine rock lithologies. There is little difference in the statistical distribution of sulphur concentrations in mine rock collected from the 5034, Hearne, and Tuzo pits, respectively. Most samples of granite, granodiorite, and gneissic granite have total sulphur concentrations less than 0.1%. Granite will be the dominant mine rock lithology at the Project, comprising at least 95% of all mine rock. Although most samples of diabase, diorite, and altered granite in the geochemistry dataset contained greater than 0.1% sulphur, the relatively small number of these samples limits the interpretation of acid generation potential from these units.

Figure 8.III-18 Distribution of Total Sulphur in Mine Rock from 5034, Hearne, and Tuzo Pits

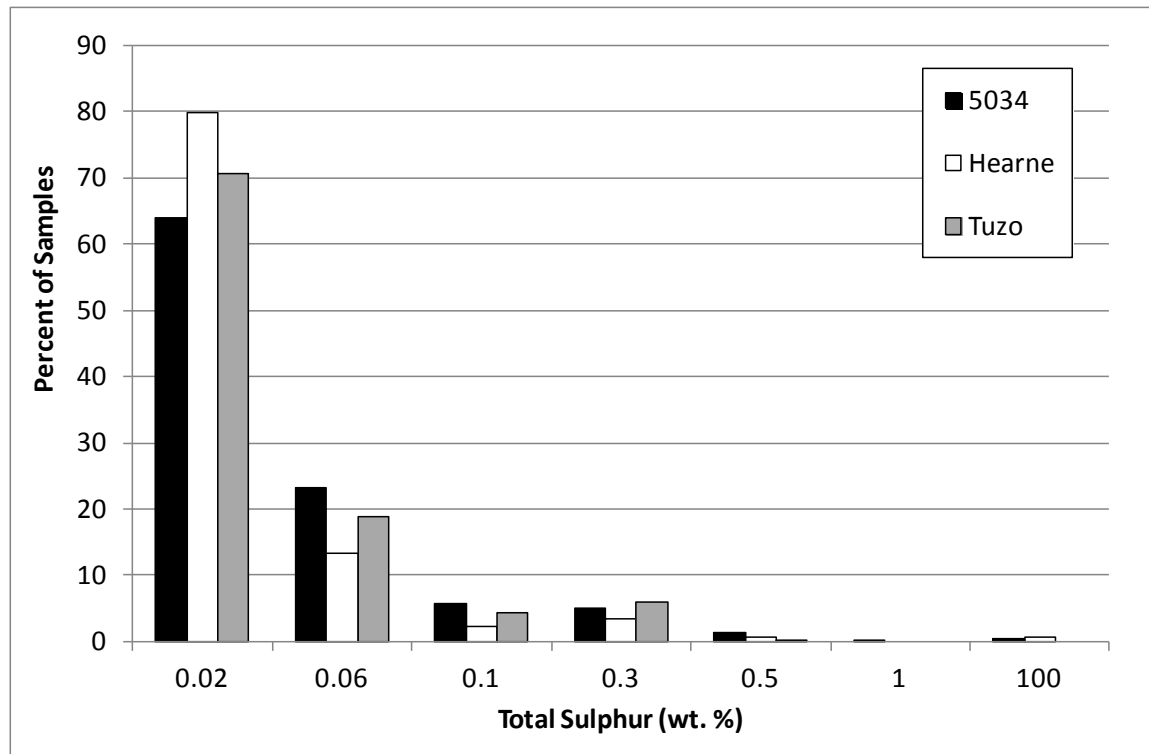


Table 8.III-35 Percent of Samples by Sulphur Concentration for Mine Rock Lithologies

Rock Type	Total Number of Samples	0.1% Sulphur		0.3% Sulphur	
	n	n	Percent	n	Percent
Granite	1,189	63	5%	11	1%
Altered granite	10	7	70%	3	30%
Diabase	7	3	43%	0	0%
Diorite	1	1	100%	0	0%
Gneissic granite	9	2	22%	0	0%
Granodiorite	6	1	17%	1	17%
Altered granodiorite	16	16	100%	2	13%

Note: n = number of samples; % = percent.

Assuming the AMEC (unpublished) geochemistry dataset, combined with the supplemental dataset, is spatially representative of the Project mine rock, a small quantity of mine rock will be classified as PAG based on the proposed sulphur cutoff criterion of 0.1%. Any volume of the granite or granodiorite that has a total sulphur concentration greater than 0.1 wt% will not be used for site development. A mine rock management plan will be developed for the Project.

8.III.5.3 Processed Kimberlite Management

Site development plans for PK management are as follows:

- All PK will be located within the disturbed Kennady Lake footprint and contained within the controlled area boundary of the Kennady Lake watershed.
- Fine PK will be stored in the Fine PKC Facility (mitigated) between Years 1 to 5. The Fine PKC Facility (mitigated) will be progressively reclaimed during operations with a 1 m layer of coarse PK overlain by 1 m of non-AG mine rock.
- Starting in Year 5, fine PK will be deposited in the mined-out 5034 Pit followed by the mined out Hearne Pit in mid-Year 7.
- Coarse PK will be placed on the Coarse PK Pile. In later years, coarse PK will be used for reclamation of the Fine PKC Facility (mitigated), and co-disposed with mine rock in the mine rock piles or the mined-out 5034 Pit.
- At closure, Kennady Lake will be allowed to refill to its natural lake elevation, effectively flooding all of the materials (i.e., mine rock and fine PK) stored in the mined out open pits. There will be some material in the Fine PK Facility (mitigated) that will remain above the water table however.

The results of geochemical testing of PK, and PK process water analyses can be used to infer the potential range of composition of water in contact with the various PK management areas during operations and at closure. Table 8.III-22 compares the range of composition of the various results of geochemical testing that were used to evaluate the composition of water expected to be in contact with PK.

The composition of seepage from the Fine PKC Facility (mitigated) is expected to be geochemically similar to the process water discharged with the fine PK slurry. Process water is water that is recycled through the process plant; it gains a mass load from the PK as water is cycled through the Process Plant. Table 8.III.18 presents the range of composition of process water based on laboratory testing as discussed in Section 8.III.4.2.4.

Fine PK and coarse PK exposed in the PKC Facility (mitigated) and Coarse PK Pile, respectively, will undergo seasonal wet and dry cycles during the summer months. The results of humidity cell testing were used to simulate the effects of accelerated chemical weathering. Recently deposited PK will contain residuals from the Process Plant and soluble minerals that are gradually flushed from the PK over the course of time. The range of “first flush” water quality values

presented in Table 8.III.19a is used to represent the range of water in contact with freshly deposited fine and coarse PK. As weathering progresses, soluble mineral phases will deplete and mineral reaction rates will stabilize, generating a "steady state" water quality, as represented by the values in Table 8.III.19b.

Submerged column tests were used to represent water quality values that might be expected as a result of submerging fine and coarse PK when Kennady Lake is allowed to re-flood during the closure period. Submerged column tests were initiated in July 2010 and in the spring and summer of 2011. The results of submerged column tests show metal and other key parameter concentrations, including phosphorus, are higher in the pore water ("bottom" submerged column test leachates) than those measured in the standing column of water overlying the PK. Additionally, key parameter concentrations measured in the fine PK columns were generally higher than those reported in the coarse PK columns. Phosphorus concentrations were particularly elevated in pore water collected from one of the fine PK columns. However, these results were not confirmed by the other ongoing fine PK columns.

8.III.6 LIMITATIONS

Due to the nature of the Project there are several limitations inherent in the data provided in this report. The results of baseline geochemical characterization presented in this report were provided to Golder Associates Limited (Golder) by De Beers. Golder collected a limited number of preliminary samples for this Project, as outlined in Golder (2002) and supplementary samples in 2010 and 2011. The remainder of the samples were collected by Canamara (1996) and AMEC (unpublished). The geochemical dataset presented in this report has been interpreted based on the understanding (as of the Project Description) of the Gahcho Kué Project, for the purpose of evaluating the geochemical characteristics of kimberlite, PK, and mine rock. The accuracy of any reporting is reflective of the availability and accuracy of the information presented in Canamara (1996) and AMEC (unpublished), and laboratory data provided by the analytical facilities. As with all geological sampling, the results of sample analyses are representative of a point in space and time. Conditions could vary significantly between sampling points, or over time, as conditions change.

8.III.7 SUMMARY OF KEY RESULTS

The following is a summary of key results from the geochemical program as of January 2012:

Kimberlite

- Kimberlite generally contains very little sulphide mineralization (represented by total sulphur concentrations). Most samples in the geochemical dataset have NP:AP ratios greater than 3, and are therefore classified as non-AG according to the Department of Indian Affairs and Northern Development (DIAND) criteria (DIAND 1992).
- Average concentrations of nickel, cobalt, chromium, magnesium, selenium, and strontium were greater in kimberlite samples than average concentrations in continental rock.
- The results of short-term and kinetic testing suggest that kimberlite has a low potential for metal leaching. Chloride, sulphate, and nickel concentrations are elevated relative to the mine rock leachates.

Processed Kimberlite

- The acid generation potential of PK is negligible according to the DIAND classification criteria.
- In general, metal concentrations were higher in fine PK than coarse PK samples. Metals that occurred at elevated concentrations (relative to crustal abundances) in coarse PK samples included nickel, cobalt, chromium, boron, and bismuth. Arsenic, boron, bismuth, cobalt, chromium, copper, magnesium, molybdenum, nickel, antimony, and selenium were elevated in fine PK samples.
- The results of SFE and humidity cell tests confirmed that fine PK and coarse PK are not expected to generate acidity in the long-term.
- SFE, HCT, and SCT leachates reported low sulphate and metal concentrations. Fine PK leachate concentrations were higher than coarse PK leachate concentrations of select metals. Generally, the highest metal and major parameter concentrations were reported in the pore water (bottom water) of the submerged column tests.
- Process water samples had a similar composition to PK SFE leachates.
- Elevated phosphorus concentrations were observed in the pore water (bottom water) of the single 2010 fine PK SCT. However, the elevated concentrations were not confirmed by any other samples or tests, including fine PK SCTs initiated in 2011.

Mine Rock

- The acid generation potential of mine rock is generally low. Most samples of mine rock contained very little sulphide mineralization; however, mine rock also has very little buffering capacity. Based on ABA results, 1.1% of mine rock samples are potentially acid generating, with NP/AP ratios below 3 and sulphide-sulphur concentrations exceeding 0.3%.
- The results of SFE, HCT, and SCT testing confirm that non-acid generating samples have a low potential for metal leaching. One HCT with a sulphur concentration of 0.1 wt% and NP of 4.3 kg CaCO₃/t was acid generating and leached metals at higher concentrations than the neutral pH HC.

8.III.8 CONCLUSIONS

The following is a summary of key conclusions based on the samples analysed or reviewed as part of the geochemical program as of January 2012:

- Based on a review of EAR documents from the other diamond mine sites in the Northwest Territories, kimberlite collected at the Gahcho Kué Project is geochemically similar to the kimberlite samples from the Snap Lake Mine. The Project mine rock is most similar to the Ekati Mine and the low sulphur granite at the Snap Lake Mine.
- Kimberlite samples and most mine rock are non-acid generating. A small fraction (<1.5 %) of the mine rock has some limited potential to generate acidity; however, the likelihood of significant amounts of acidic water to be released from the Project is low and will depend on the final site configuration and adherence to an appropriate mine rock management plan.
- Mine rock with visible sulphides and/or a sulphur concentration greater than 0.1 wt% should not be used for site construction unless additional testing suggests otherwise. A mine rock management plan is required to classify rock for use in site developments during operations.
- Based on the samples tested, processed kimberlite is considered non-AG.
- Concentrations of metals measured from leach testing should be evaluated in the context of overall site waste and water management. It is expected that monitoring programs and adaptive management will be implemented on site to minimize the potential for impact.

8.III.9 REFERENCES

8.III.9.1 Literature Cited

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8.III.10 ACRONYMS AND GLOSSARY

8.III.10.1 Acronyms

ABA	Acid Base Accounting
AP	Acid potential
ARD	Acid rock drainage
DIAND	Department of Indian Affairs and Northern Development
DMS	Dense-medium separation
Golder	Golder Associates Ltd.
HC	Humidity cell
HCT	Humidity cell tests
HPRC	High pressure roller crusher
ID	Identification
MDL	Method detection limit
ML	Metal leaching
NAG	Net acid generation
Non-AG	Non-acid generating
NP	Neutralization potential
NWT	Northwest territories
PAG	Potentially acid generating
PK	Processed kimberlite
Project	Gahcho Kué Project
QA/QC	Quality Assurance/Quality Control
RPD	Relative percent differences
SCT	Submerged column test
SD	Standard deviation
SFE	Shake flask extraction
TDS	Total Dissolved Solids
XRD	X-ray diffraction

8.III.10.2 Units of Measure

%	Percent
<	Less than
>	Greater than
kg	Kilogram
kg CaCO ₃ /t	Kilograms of calcium carbonate per tonne
kg/t	Kilogram per tonne
km	Kilometre
m	Metre
m ²	Square metres
mg/kg	Milligrams per kilogram
mg/L	Milligrams per litre
mg/L/wk	Milligrams per litre per week
mm	Millimetre
Mt	Million tonnes
s.u.	Standard unit
t	Tonnes
wt%	Percent by weight
µg/L	Micrograms per litre
µs/cm	MicroSiemens per centimetre

8.III.10.3 Glossary

Acid Base Accounting (ABA)	Acid base accounting; a static test that defines the amounts, and relative balance, of potentially acid-generating and acid-neutralizing (or base) minerals in a sample.
Acid mine drainage	A variation on acid rock drainage, mine site drainage with an acidic pH due to the oxidation of sulphide minerals exposed by mining activity
Acid potential	The acid potential (AP) represents the bulk amount of acidity that can be produced. The AP is calculated from the sulphide content and assumes that all sulphide minerals occur as pyrite.
Acid rock drainage (ARD)	Acidic pH rock drainage due to the oxidation of sulphide minerals that includes natural acidic drainage from rock not related to mining activity; an acidic pH is defined as a value less than 6.0.
Acidic drainage	A general term applied to any drainage with an acidic pH; an acidic pH is defined as a value less than 6.0.
Alkaline mine drainage	Mine site drainage with an alkaline pH; an alkaline pH is defined as a value greater than 8.5.

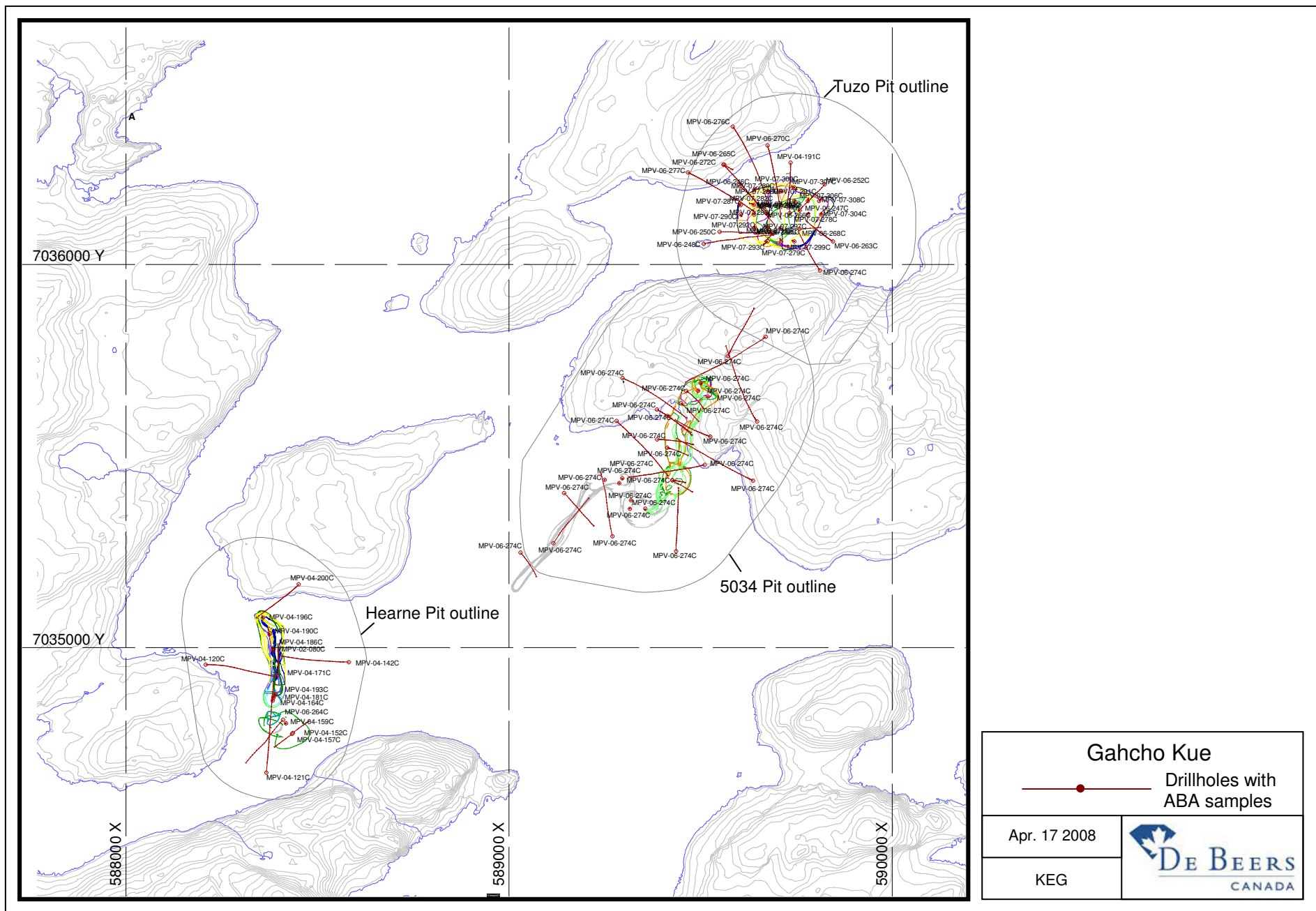
Basalt	A dark-coloured igneous rock, commonly extrusive, composed primarily of calcic plagioclase and pyroxene; the fine-grained equivalent of gabbro.
CCME guidelines	Canadian Council of Ministers of the Environment; body of Environment Canada that sets ambient guidelines for air, water, soil, and contaminants.
Column Test	Column tests are a kinetic test method that provides neutral drainage data that can be compared to the acid rock drainage and primary weathering data obtained from humidity cell testing.
Drainage chemistry	Concentrations of elements and other aqueous parameters in mine site drainage from mine site components through surface or subsurface pathways.
Gneiss	A coarse crystalline metamorphic rock in which there are bands of light and dark minerals of widely varying origin and mineralogy.
Granite	A coarsely crystalline igneous intrusive rock composed of quartz, potassium feldspar, mica, and/or hornblende.
Granitoid	Rocks with a composition the same as, or similar to granite.
Humidity cell	A type of kinetic test in which a small sample (about 1 kg) is placed in an enclosed chamber in a laboratory, alternating cycles of moist and dry air is constantly pumped through the chamber, and once a week the sample is rinsed with water; chemical analysis of rinse water yields concentrations of elements and other parameters used to calculate reaction rates.
Kinetic test	A geochemical procedure for characterizing the chemical status of a sample through time during continued exposure to a known set of environmental conditions, such as a humidity cell; see also static test.
Loading	Concentration multiplied by a flow, providing a mass per unit time flowing through or from a mine site component.
Metal leaching (ML)	The release of a metal from its solid-phase mineral into mine site drainage; described by concentrations in static tests and by metal release rates obtained from kinetic tests.
Metasediments	Sedimentary rocks that have been modified by metamorphic processes.
Metavolcanics	Volcanic rocks that have been modified by metamorphic processes.
Mine rock	The surrounding rock.
Mine rock pile	A general term referring to any accumulation of rock at a mine, including waste rock piles, ore and low grade ore stockpiles, roads, heap leach piles, and building foundations.
Mine site drainage	Water that runs off or flows through a mine site component, including surface and subsurface (groundwater) flow; see also acid mine drainage, neutral mine drainage, alkaline mine drainage, and drainage chemistry.
Neutralization potential	The neutralization potential (NP) represents the bulk amount of acidity that the sample can potentially consume or neutralize.

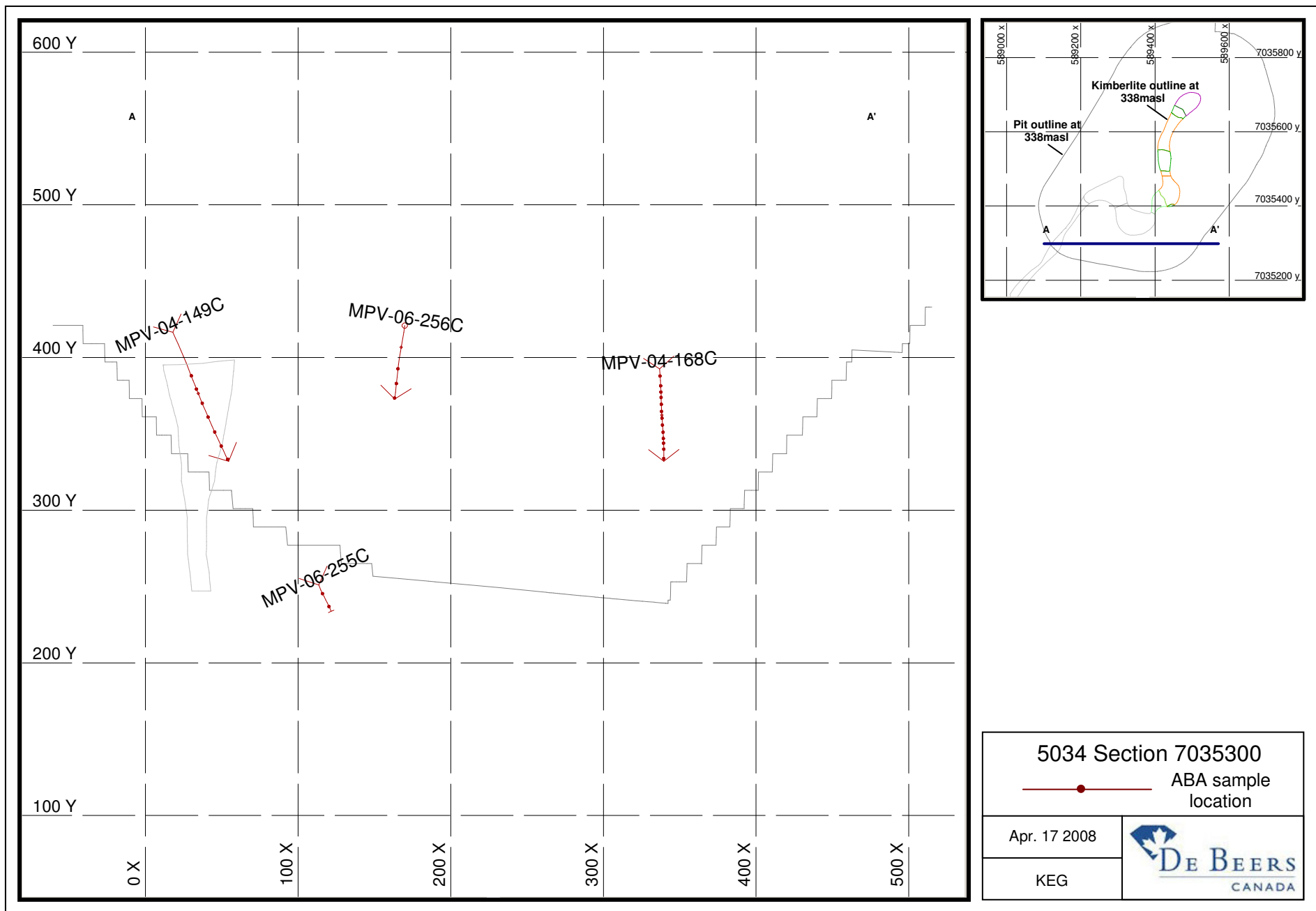
Overburden	A general term referring to soil and broken rock, lying above ore and waste rock, that can usually be removed without blasting; at mines in soft sedimentary rock like coal, overburden can be synonymous with waste rock.
Potentially acid generating (PAG)	Rock with an NP/AP ratio less than 3 as determined by static tests.
Primary minerals	Minerals that existed in the rock prior to disturbance by human activity, often occurring as (but not limited to) sulphide, aluminosilicate, and oxide minerals; see also secondary minerals.
Processed Kimberlite Containment	On-site storage facility for storing processed kimberlite.
Retention	Amount of oxidized primary minerals not released to mine drainage, but held within mine rock and tailings; reflects physical processes such as incomplete rinsing of mine site components and geochemical processes such as the formation of secondary minerals.
Secondary minerals	Minerals that formed in or on a mine site component after disturbance by human activity, often occurring as (but not limited to) sulphate, carbonate, and hydroxide minerals; see also kinetic test, primary minerals, and retention.
Static test	A procedure for characterizing the physical and/or chemical status of a sample at one point in time, such as acid base accounting.
Submerged Column Test (SCT)	Submerged column tests are kinetic tests designed to address the influence of submerging a material underwater. Sample charges with a weight of 3 kg were placed in a PVC column, which was inundated with an initial volume of distilled water of approximately 2.5 L. Each week, samples of water are collected from the base ("bottom") of the column and the water overlying the top of the column ("top"). Additional distilled water is added to the top of the column to replace the volume of water collected each week.
Sulphate sulphur	A part of acid base accounting that provides the sulphate content of a sample, expressed as %S.
Sulphide oxidation	Oxidation of chemically reduced sulphur, such as sulphide (S_2^{2-}) and elemental sulphur to a partially or fully oxidized form, such as sulphate (SO_4^{2-}). Generally used to refer to the oxidation of pyrite (FeS_2).
Sulphide sulphur	A part of acid base accounting that provides the sulphide content of a sample, expressed as %S.
Total sulphur	A part of acid base accounting that provides the total sulphur content of a sample, expressed as %S; see also sulphide sulphur, total sulphate sulphur.

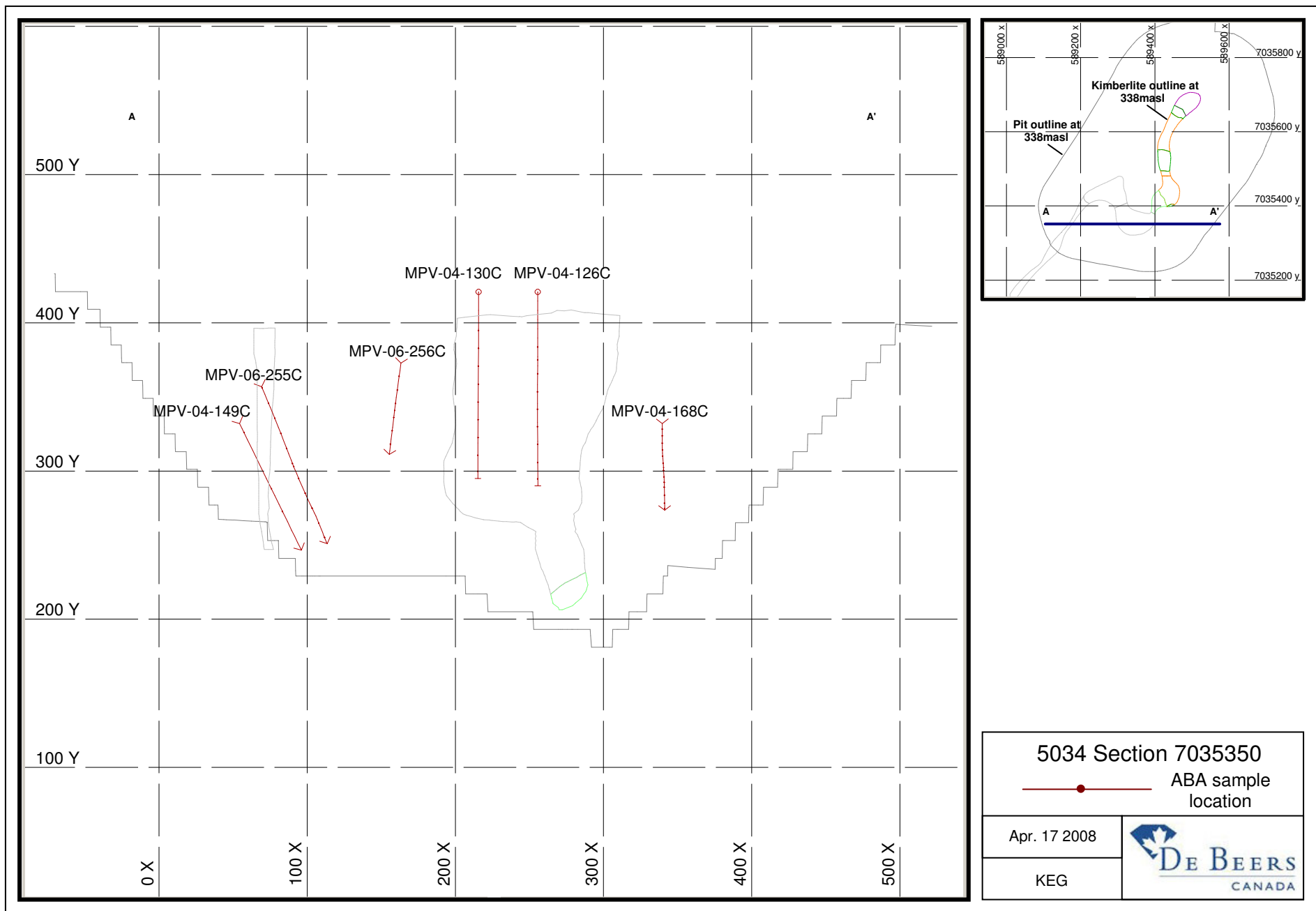
ATTACHMENT 8.III-1

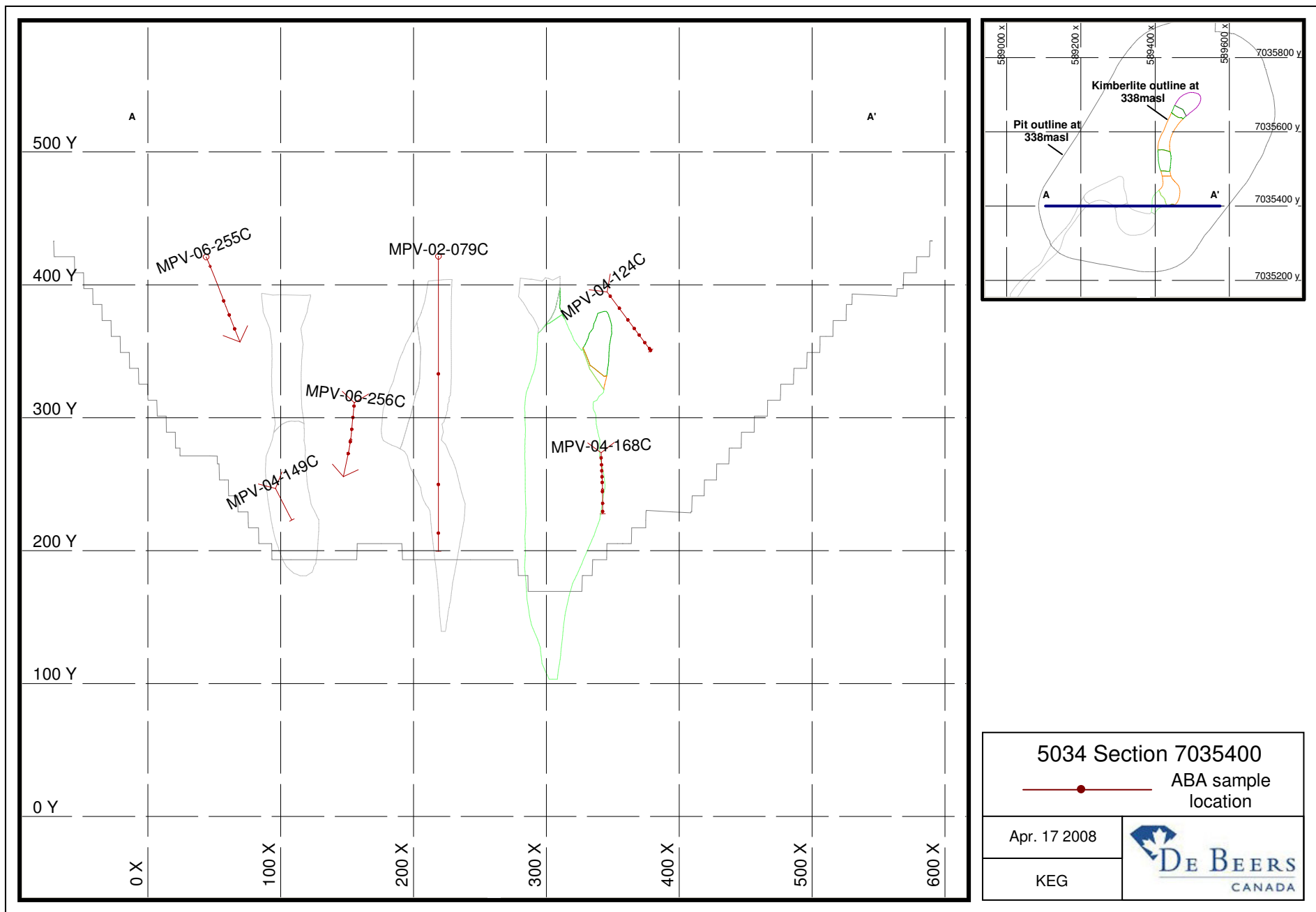
DRILLHOLE LOCATIONS

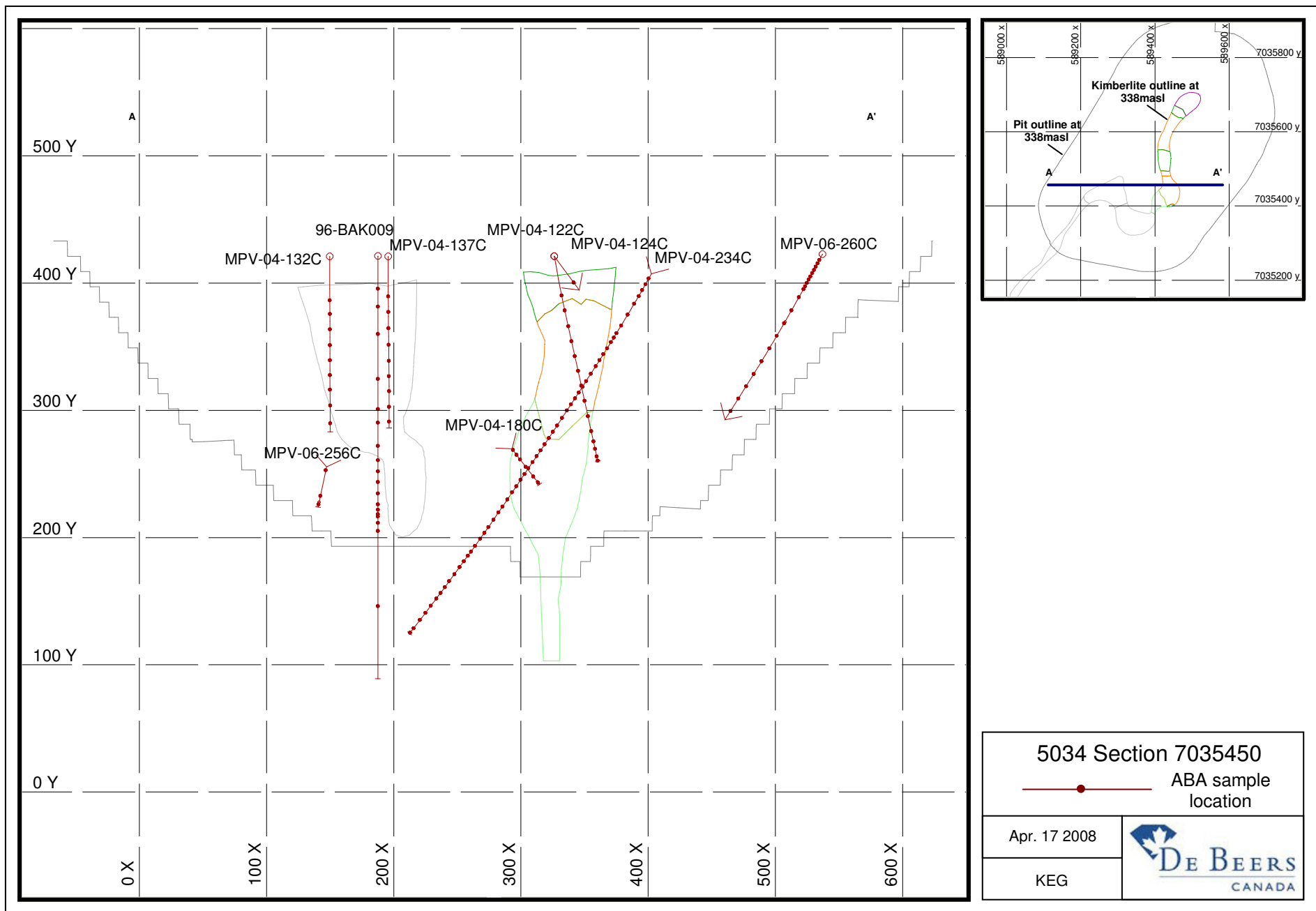
Note: the figures included in this attachment show the pit outlines from a previous iteration of the Project Description. Please consult Figure 8.4-3 for the iteration being assessed in this Environmental Impact Statement (EIS).

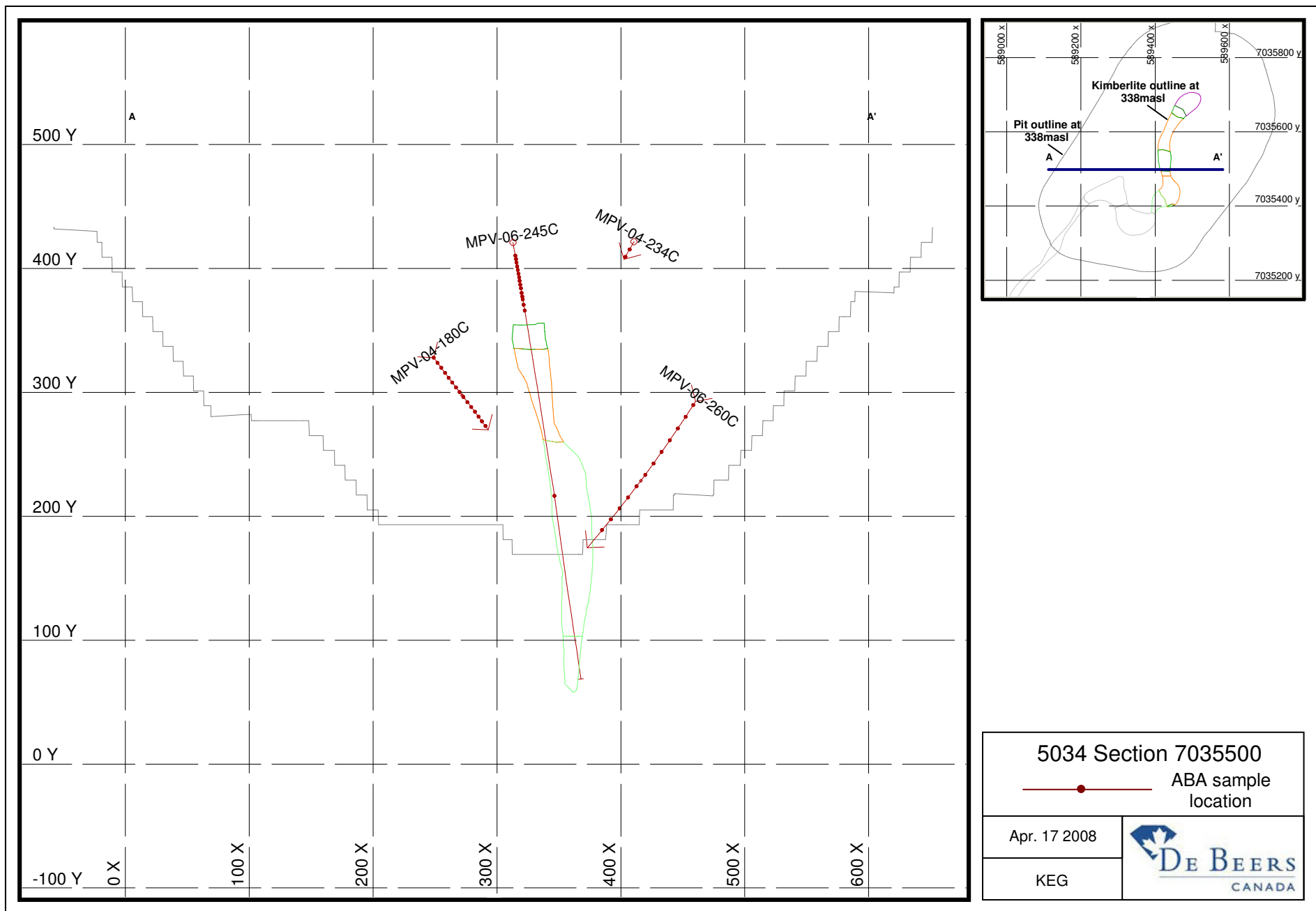


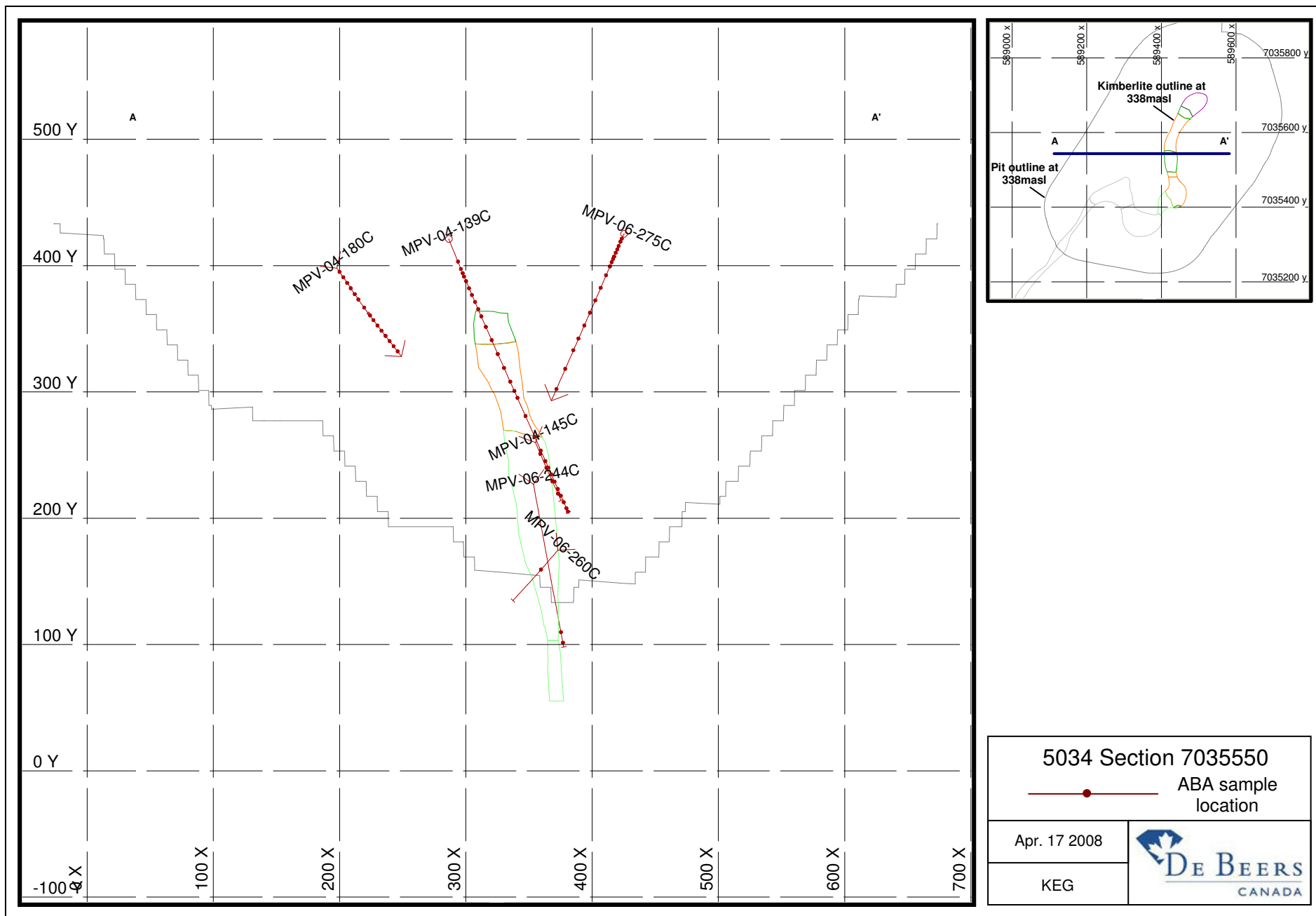


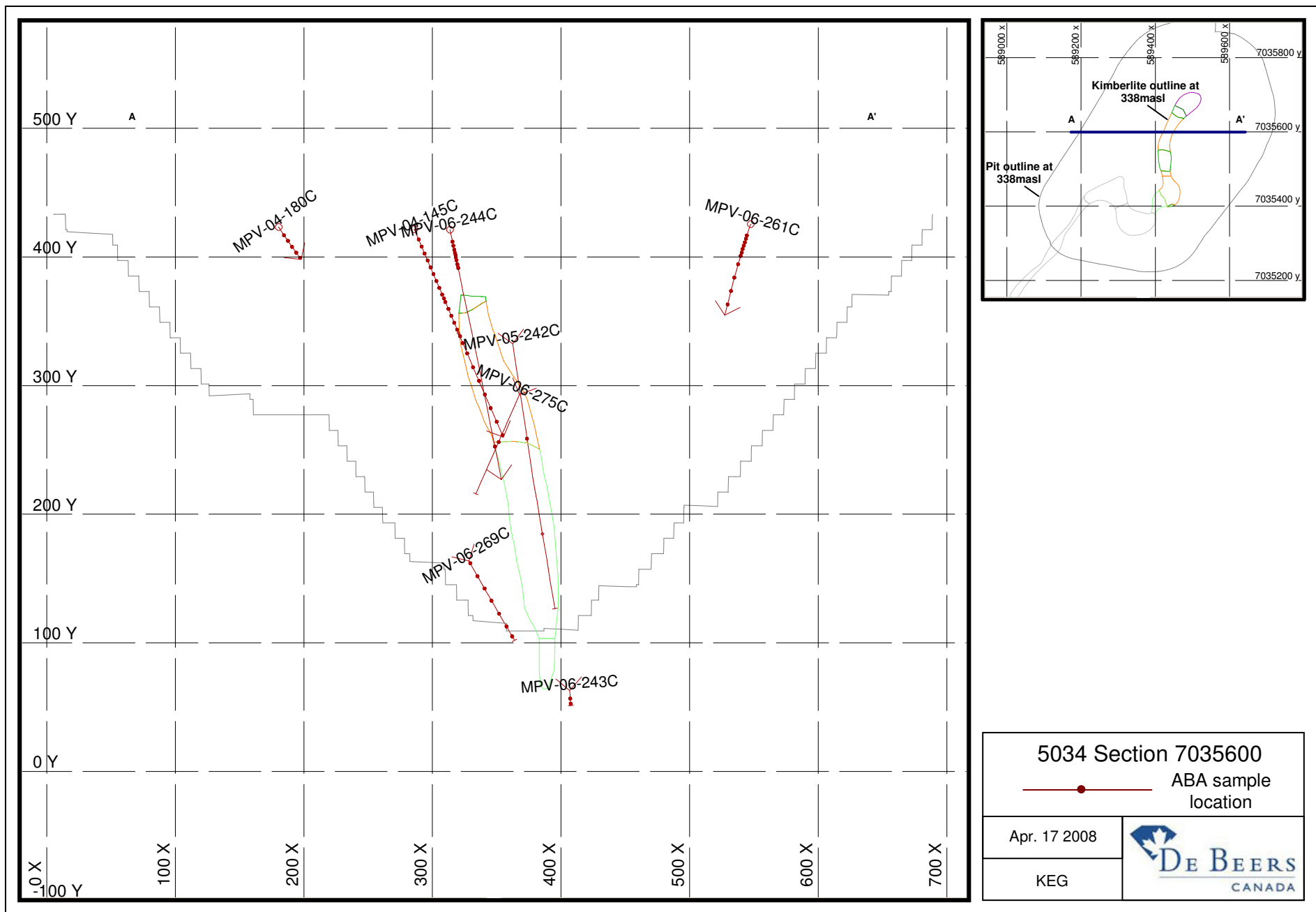


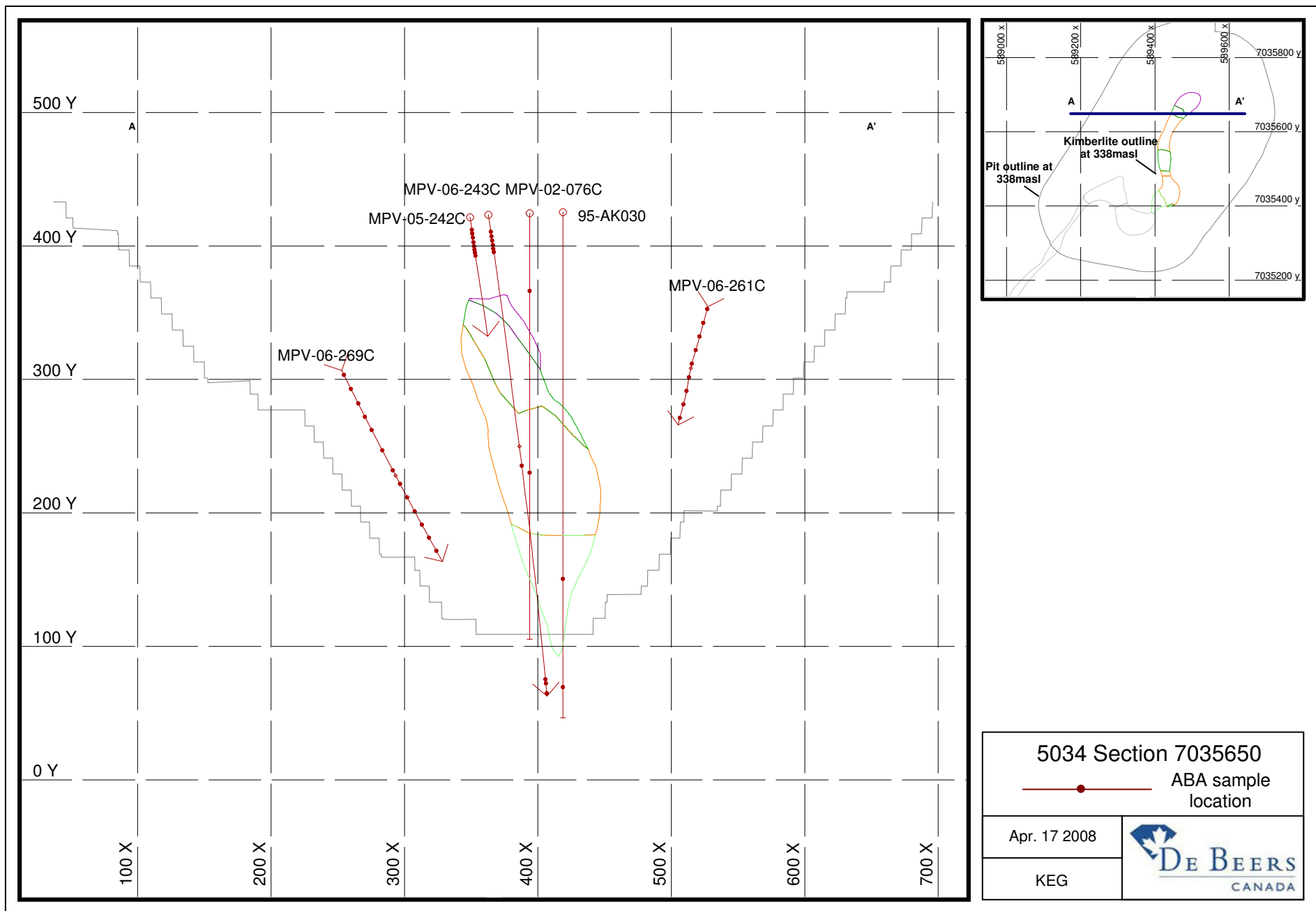


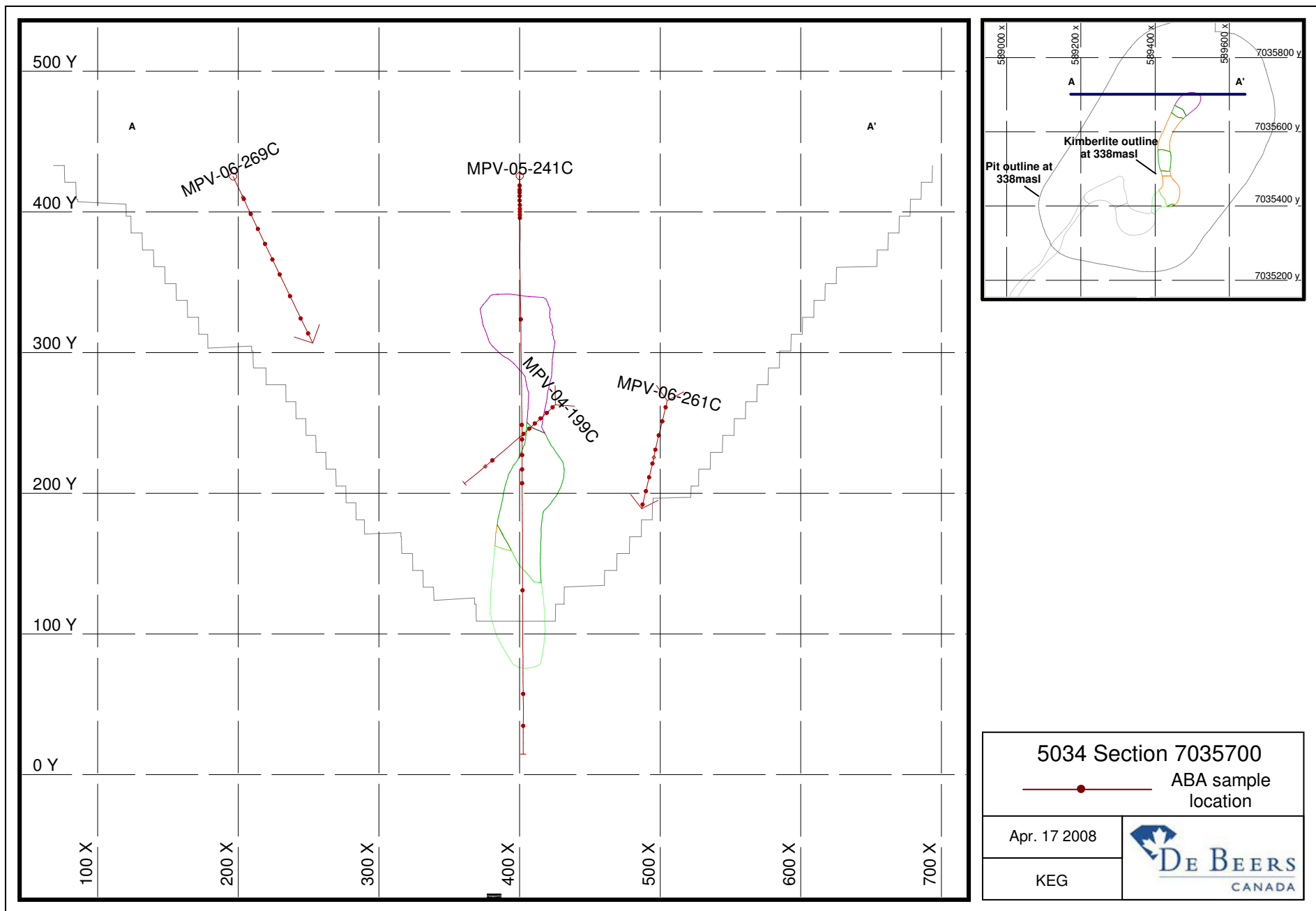


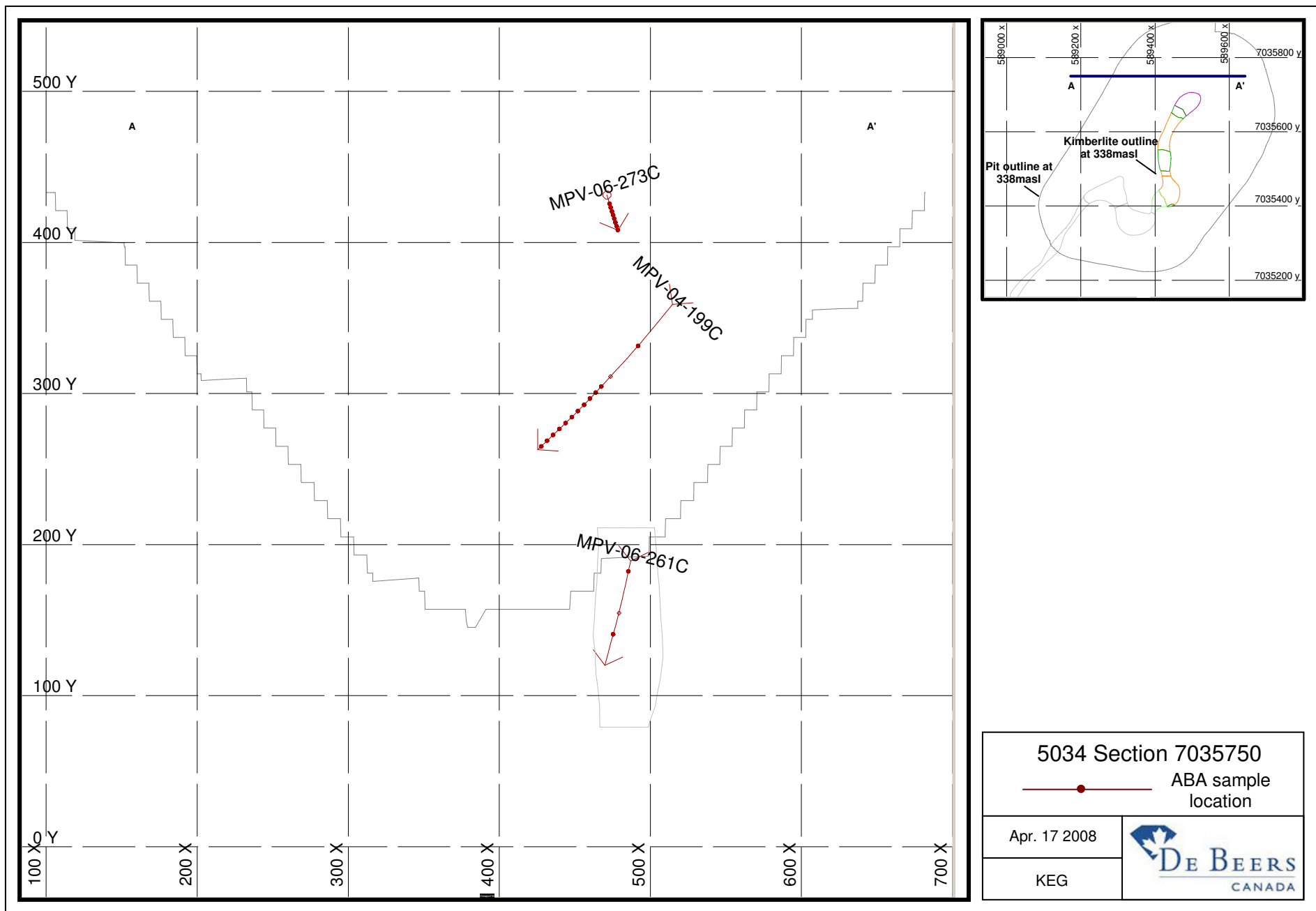


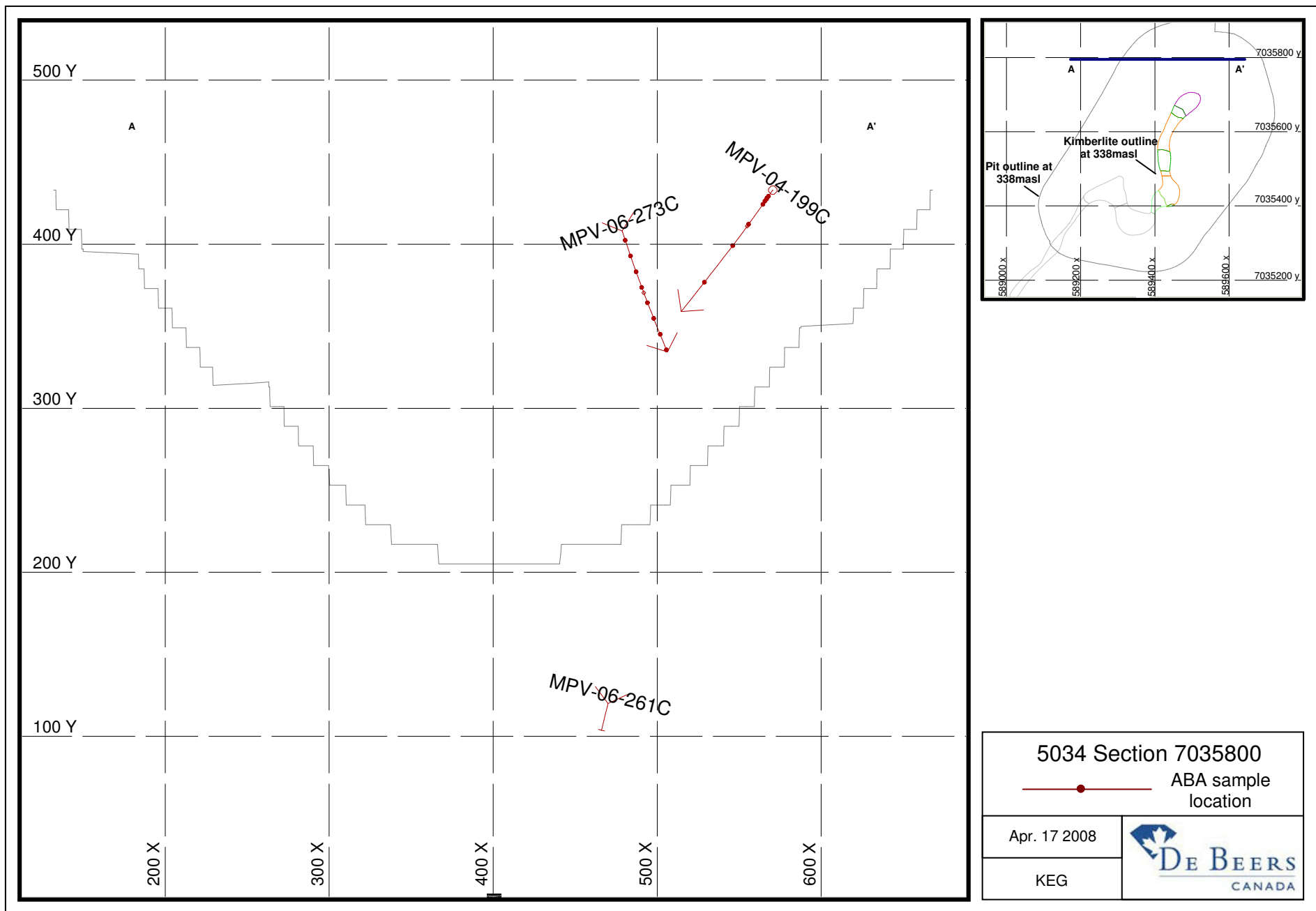


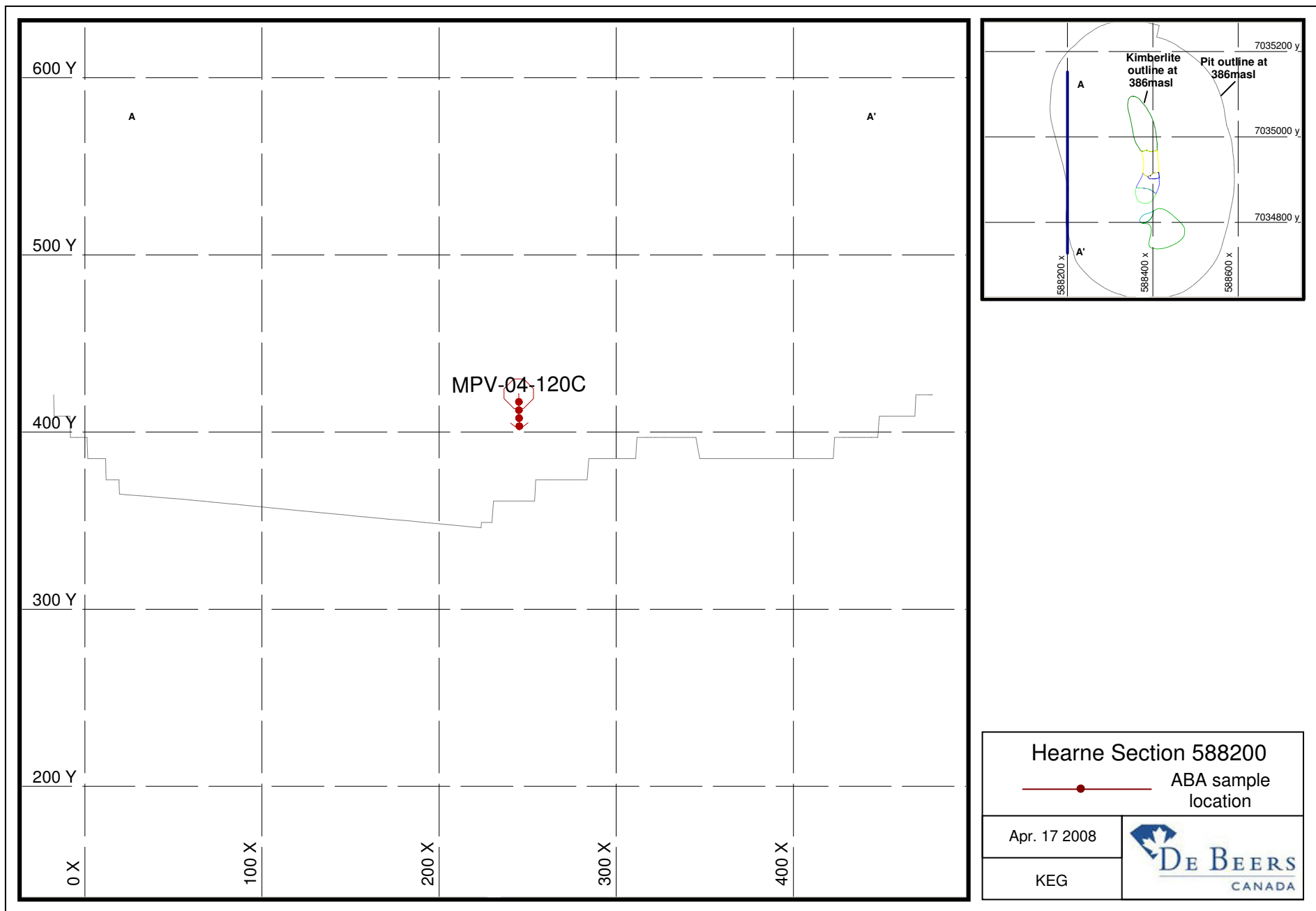


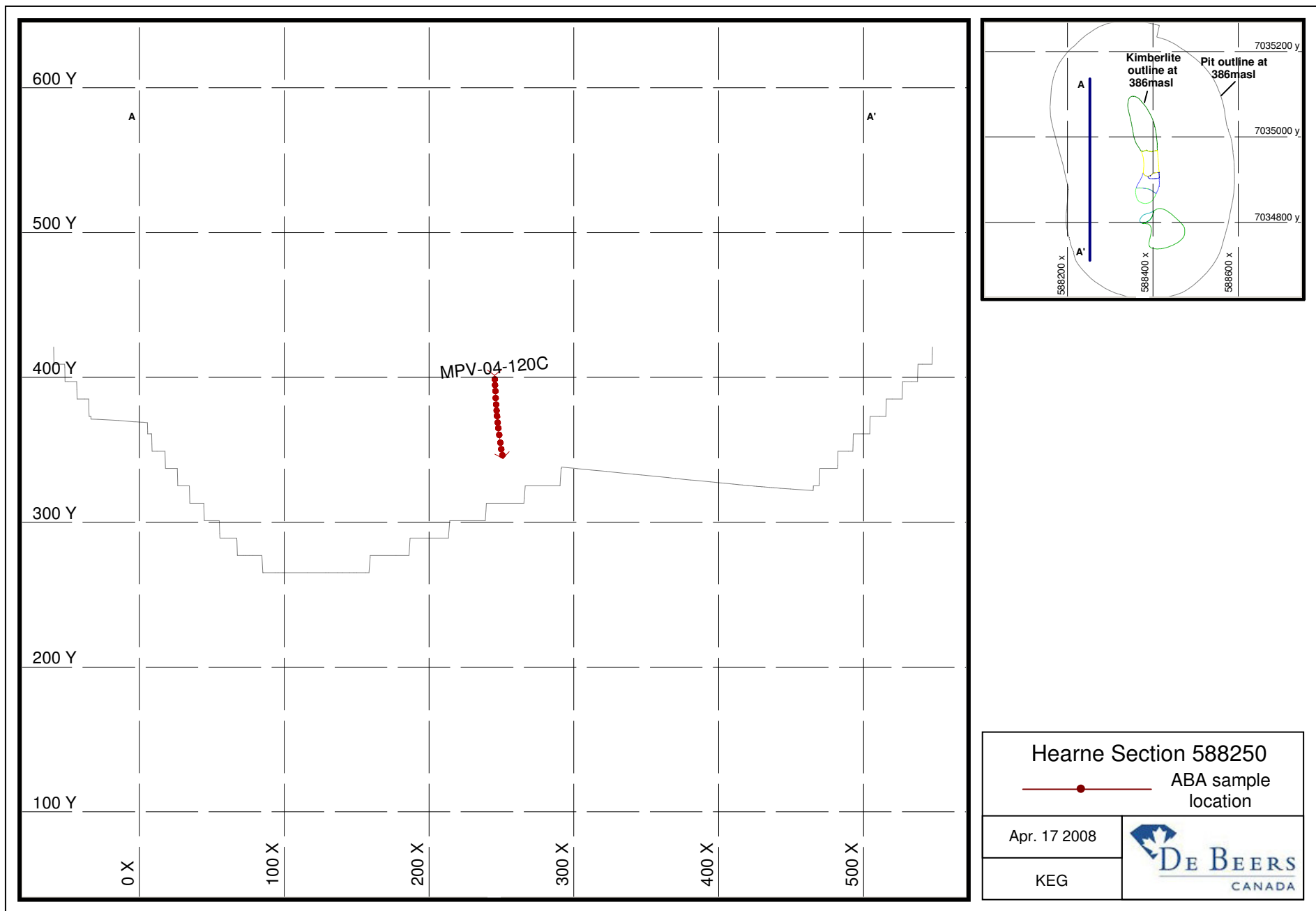


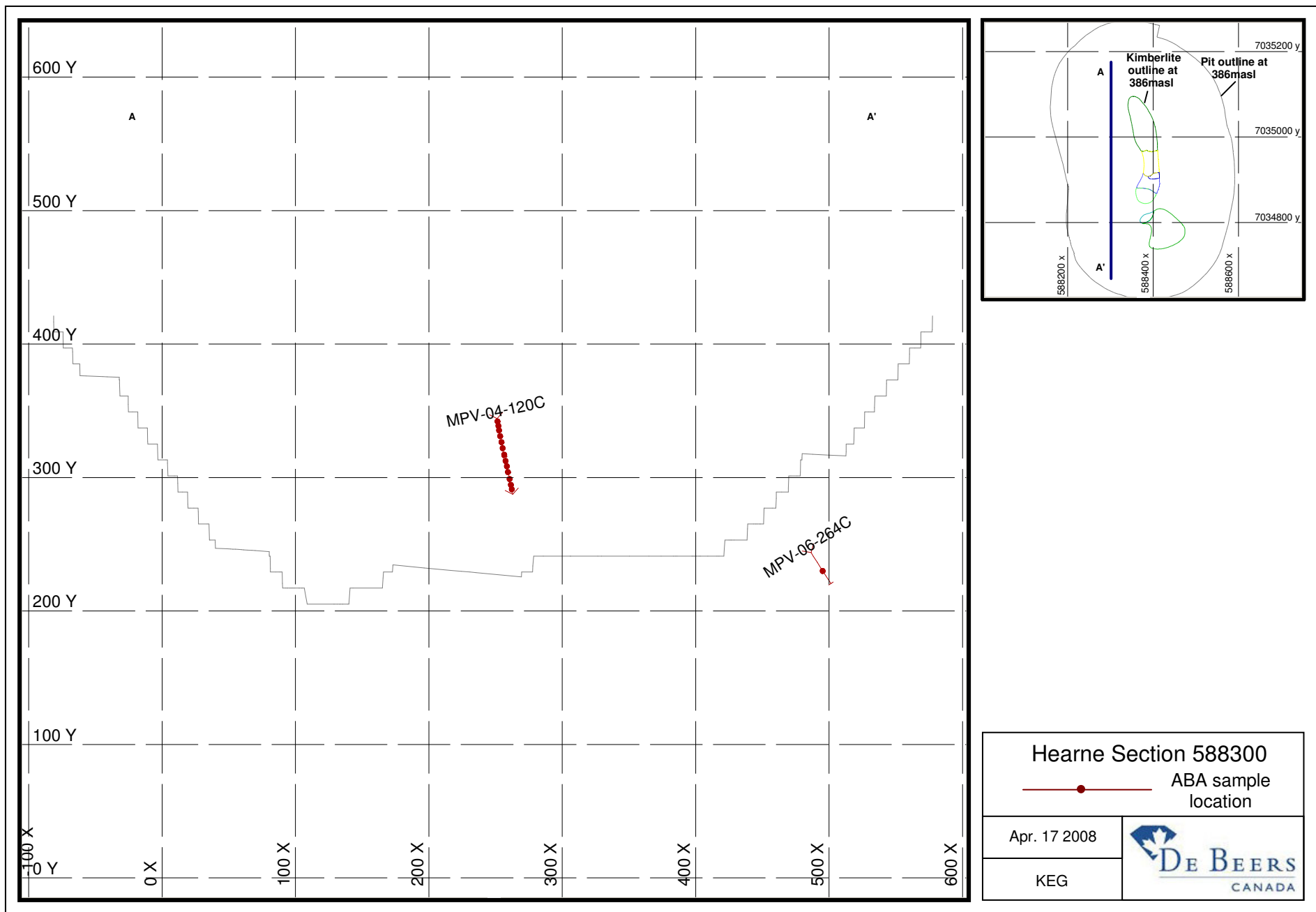


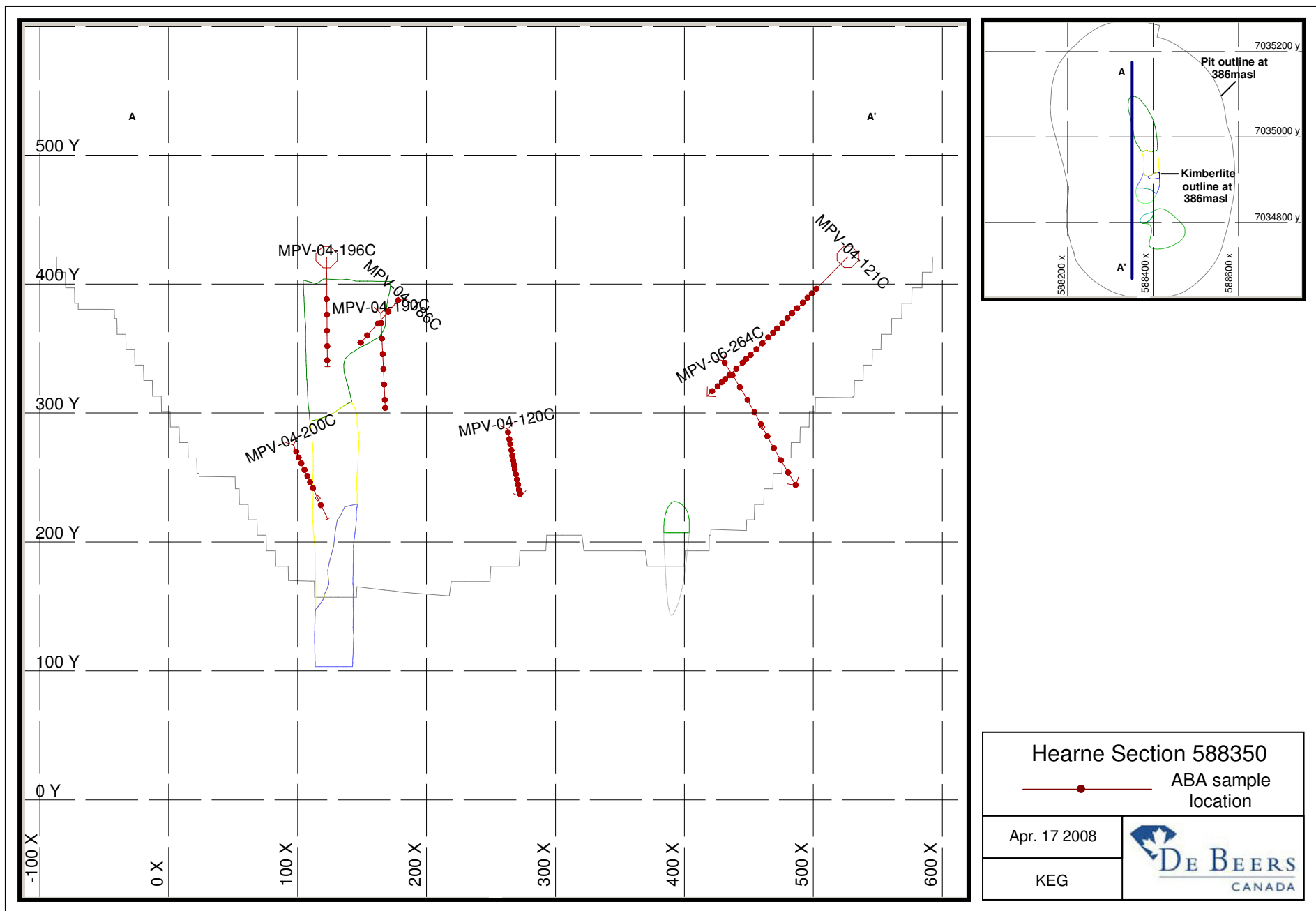


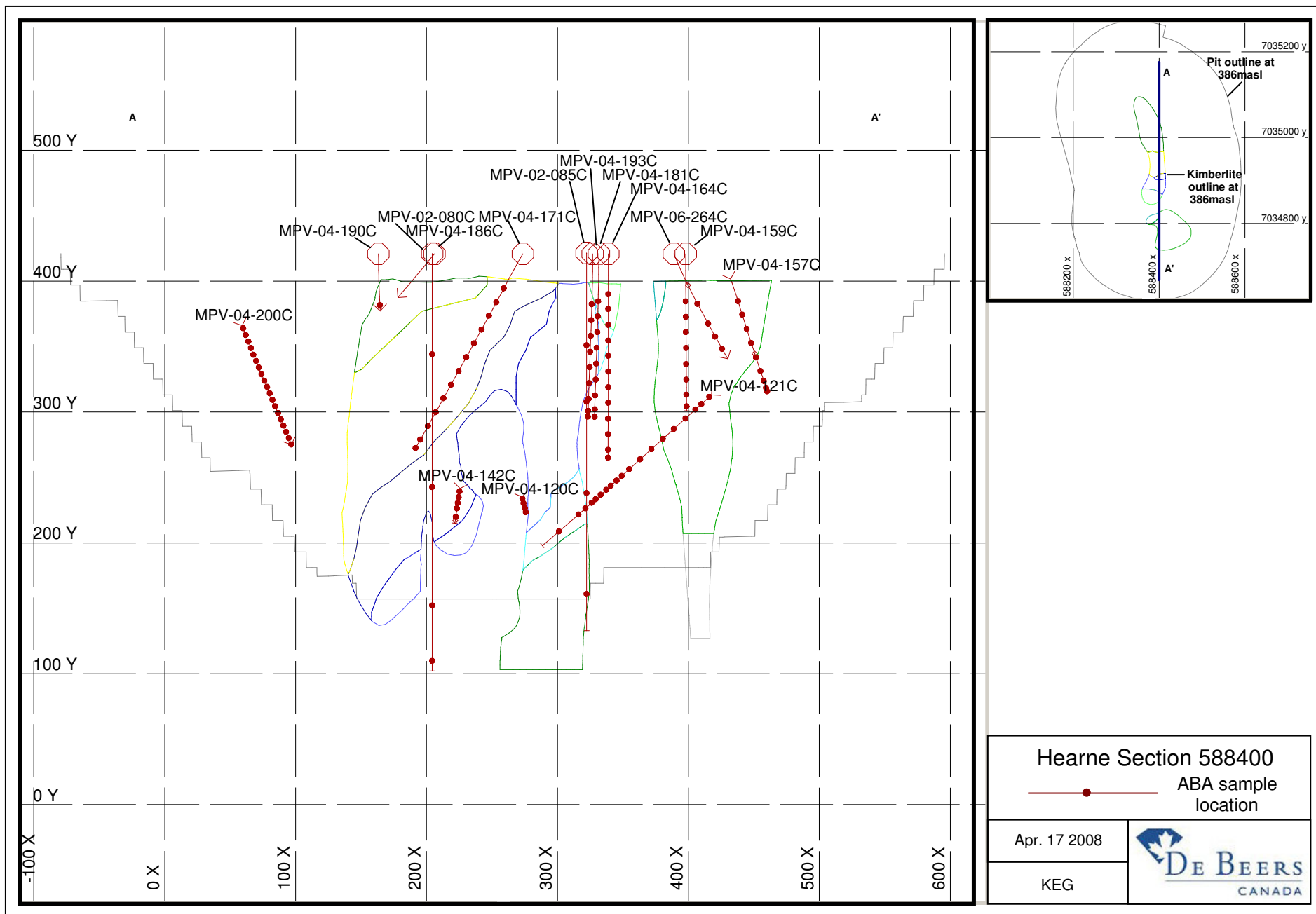


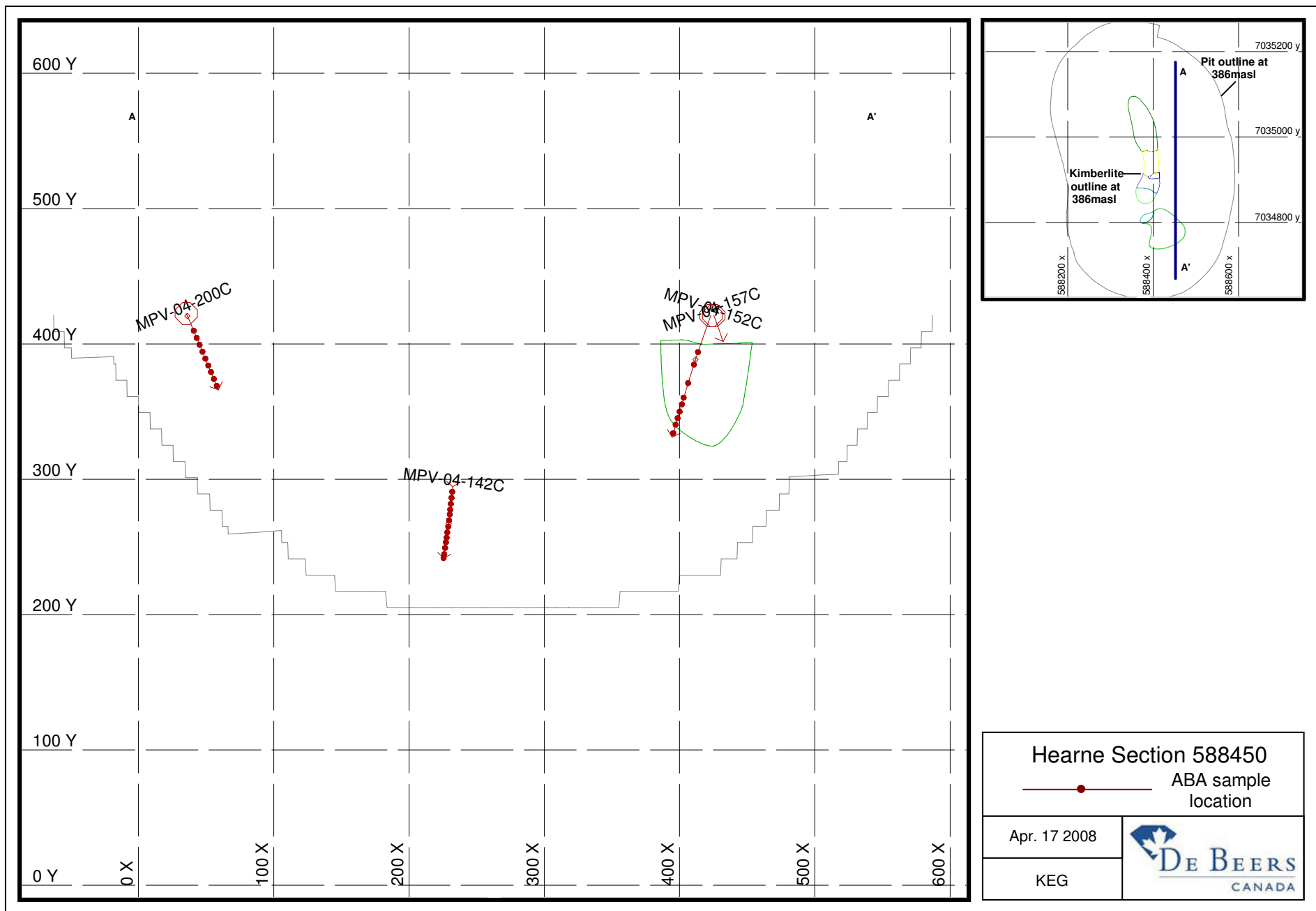


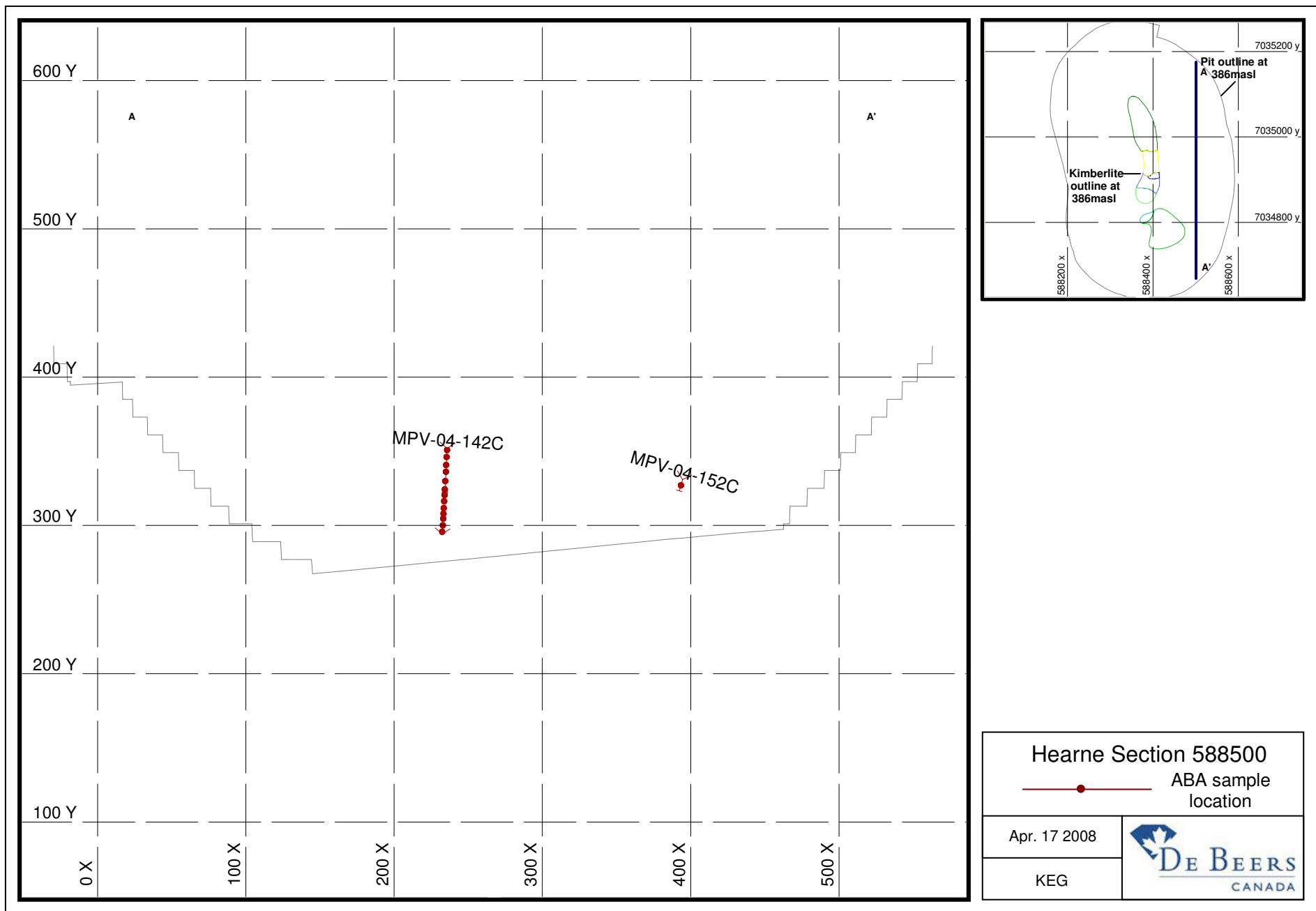


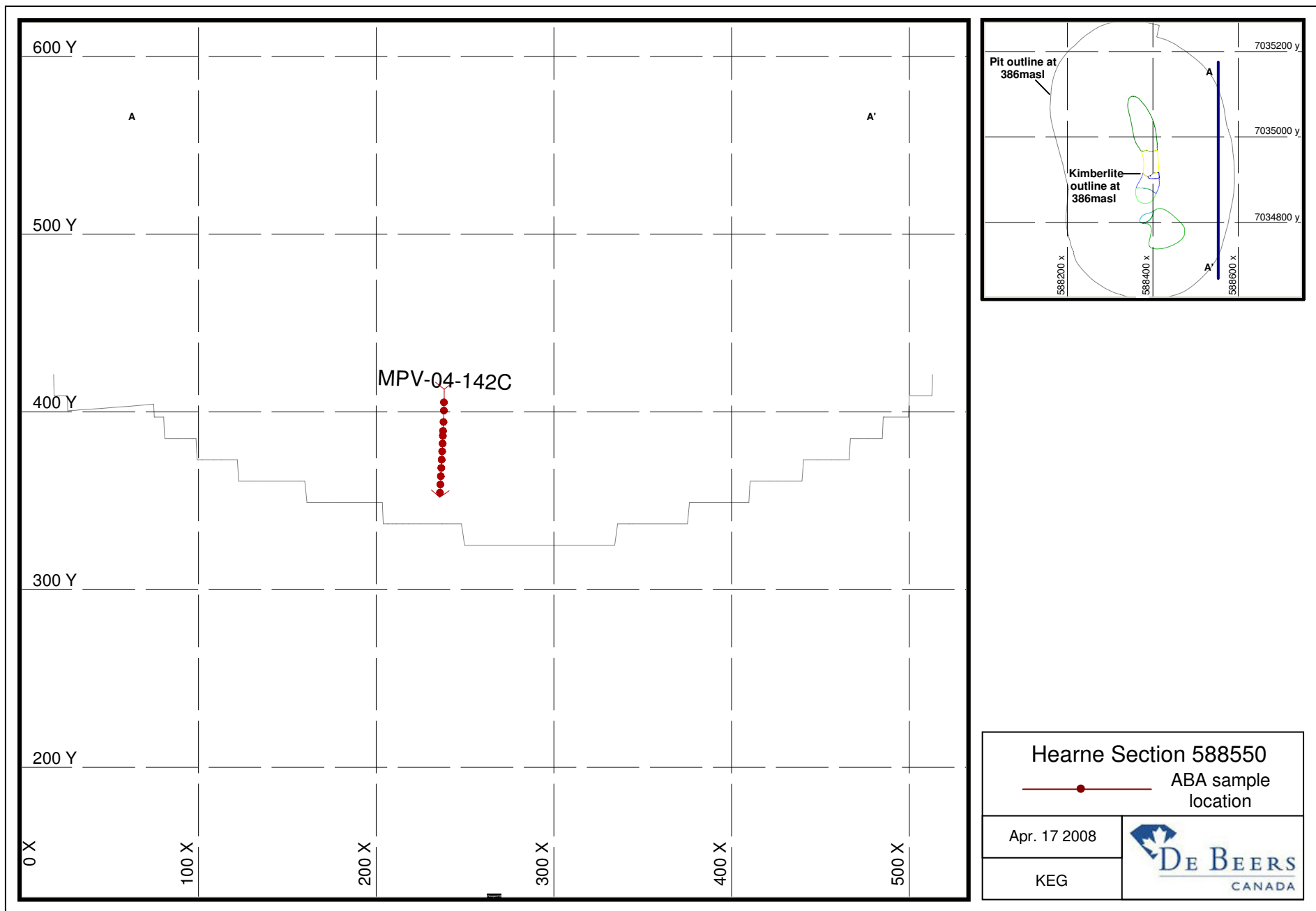


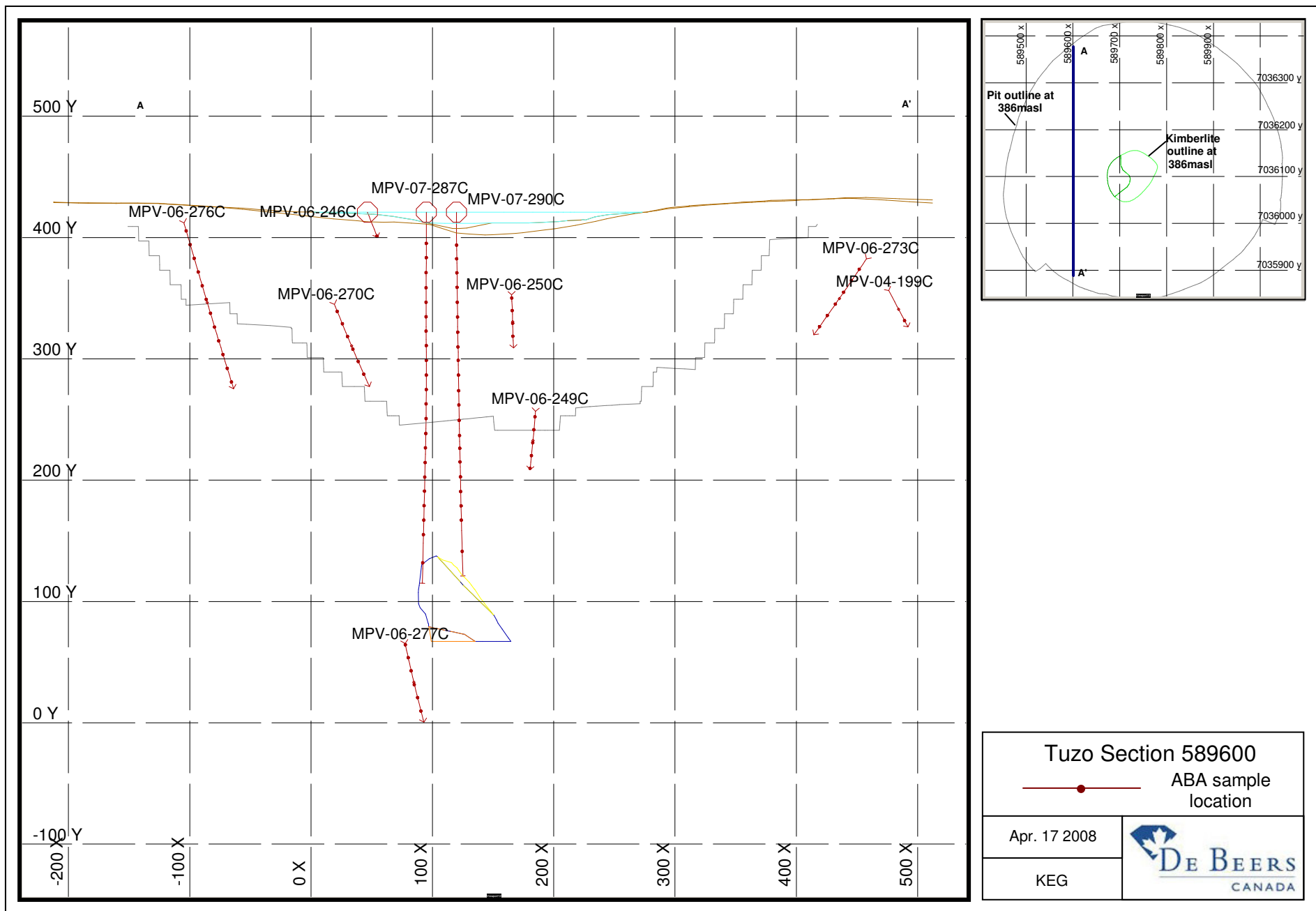


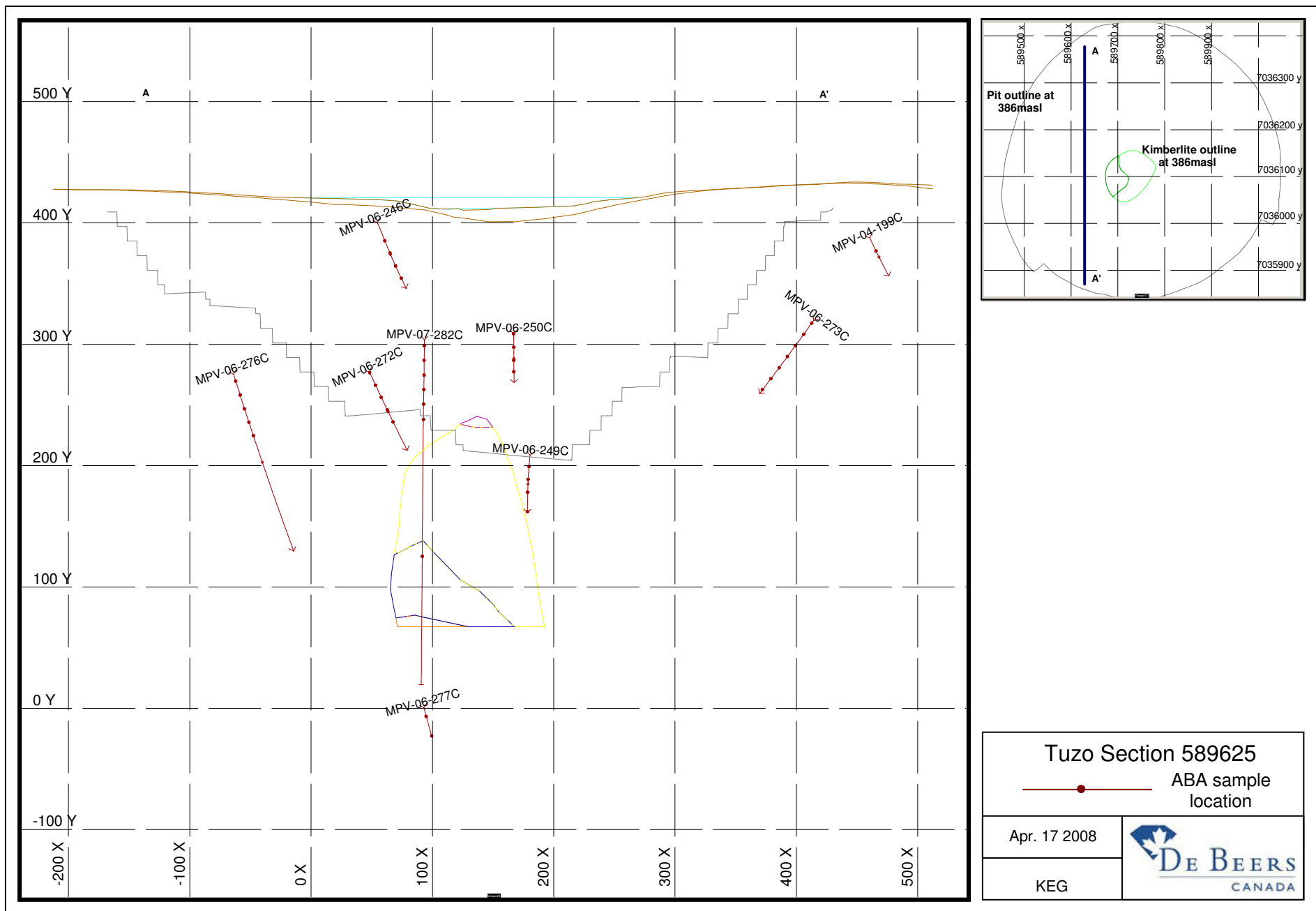


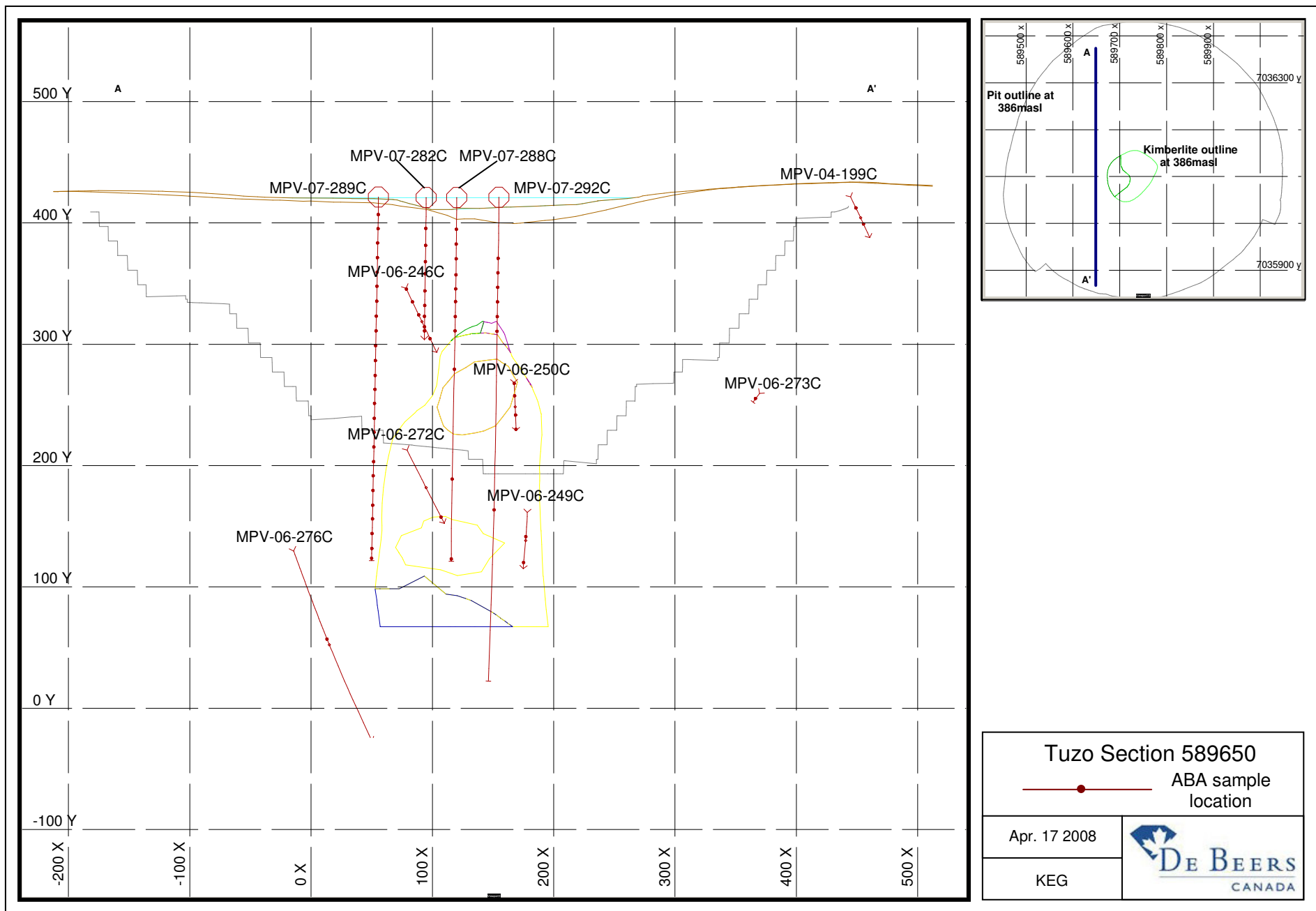


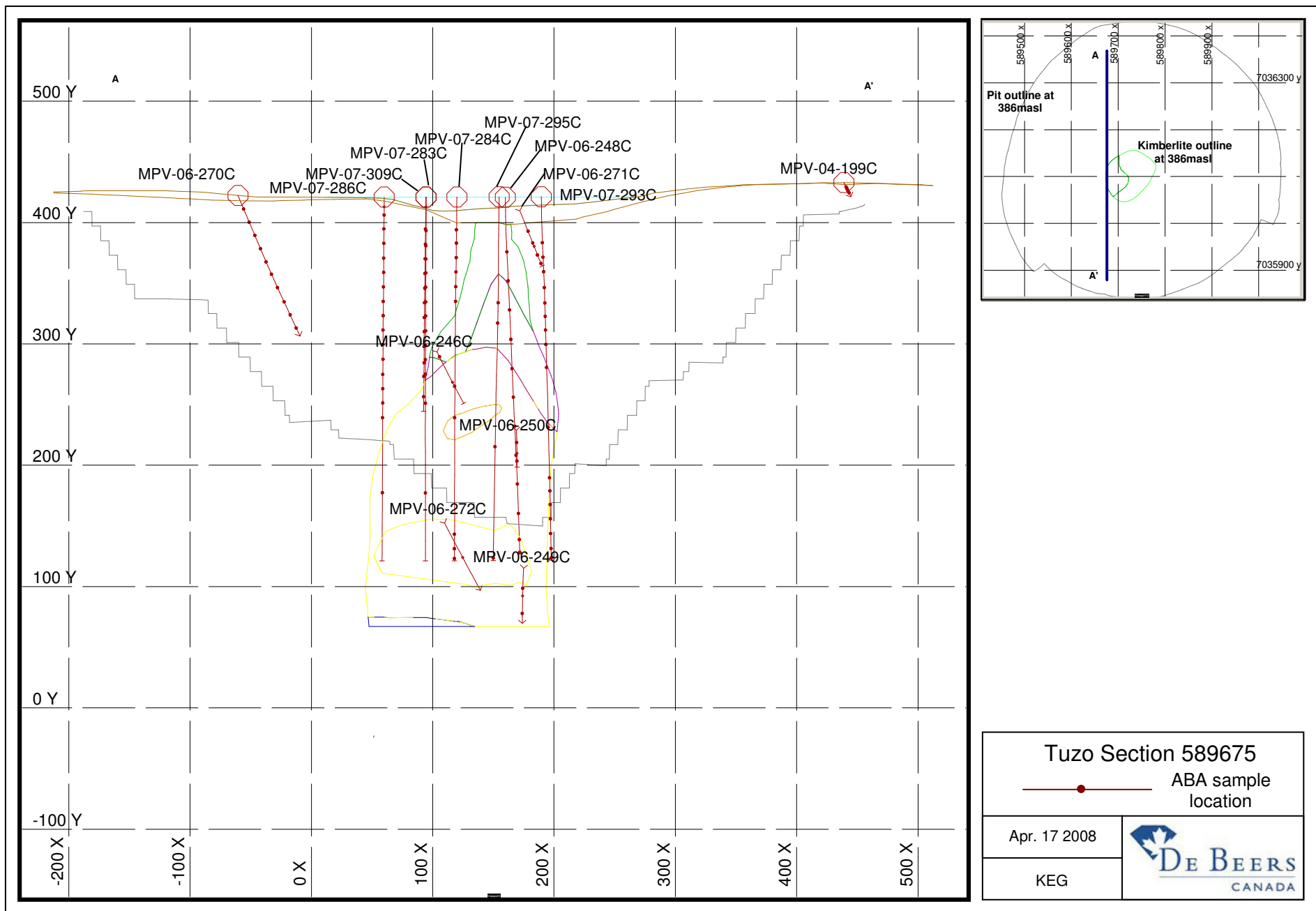


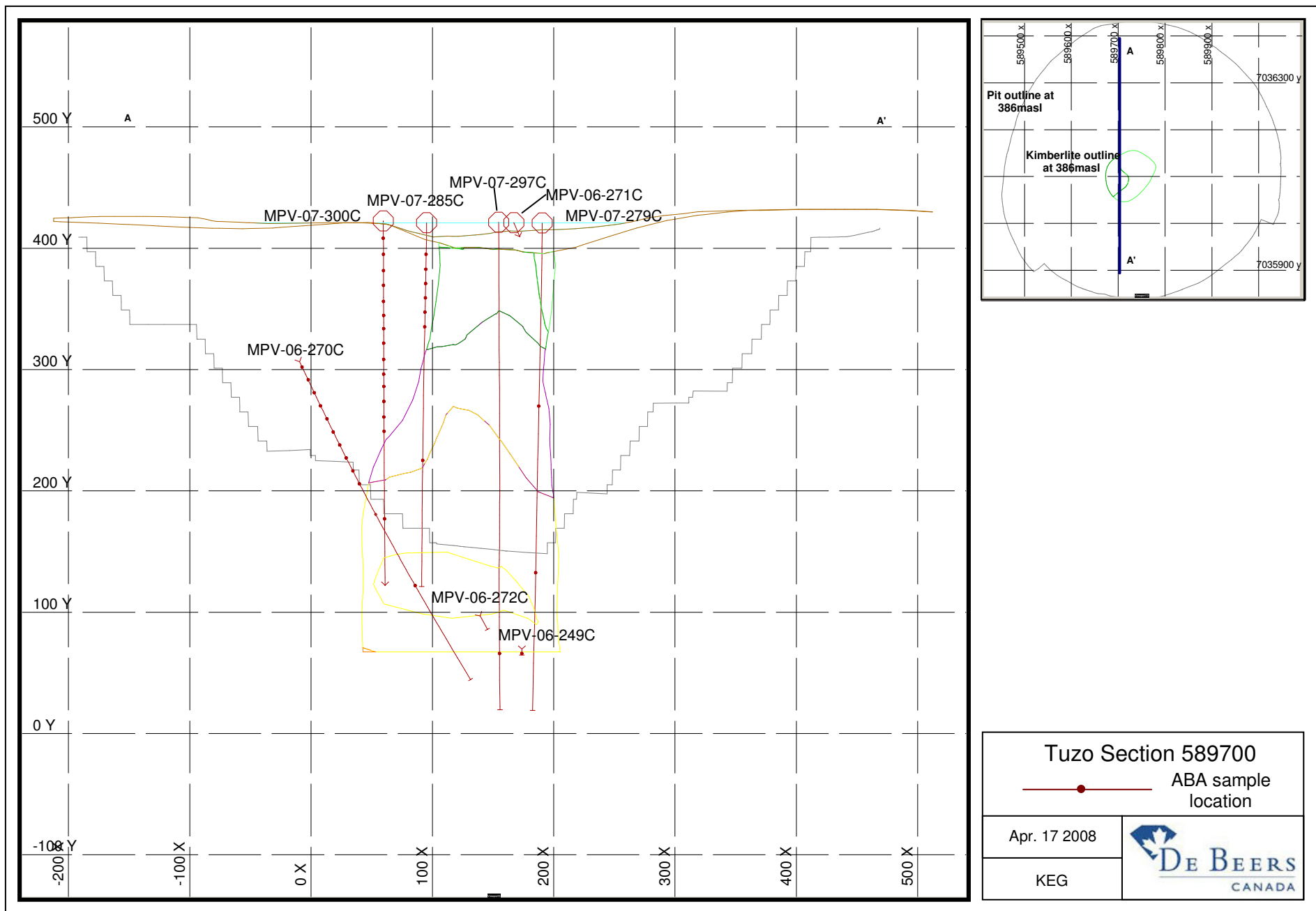


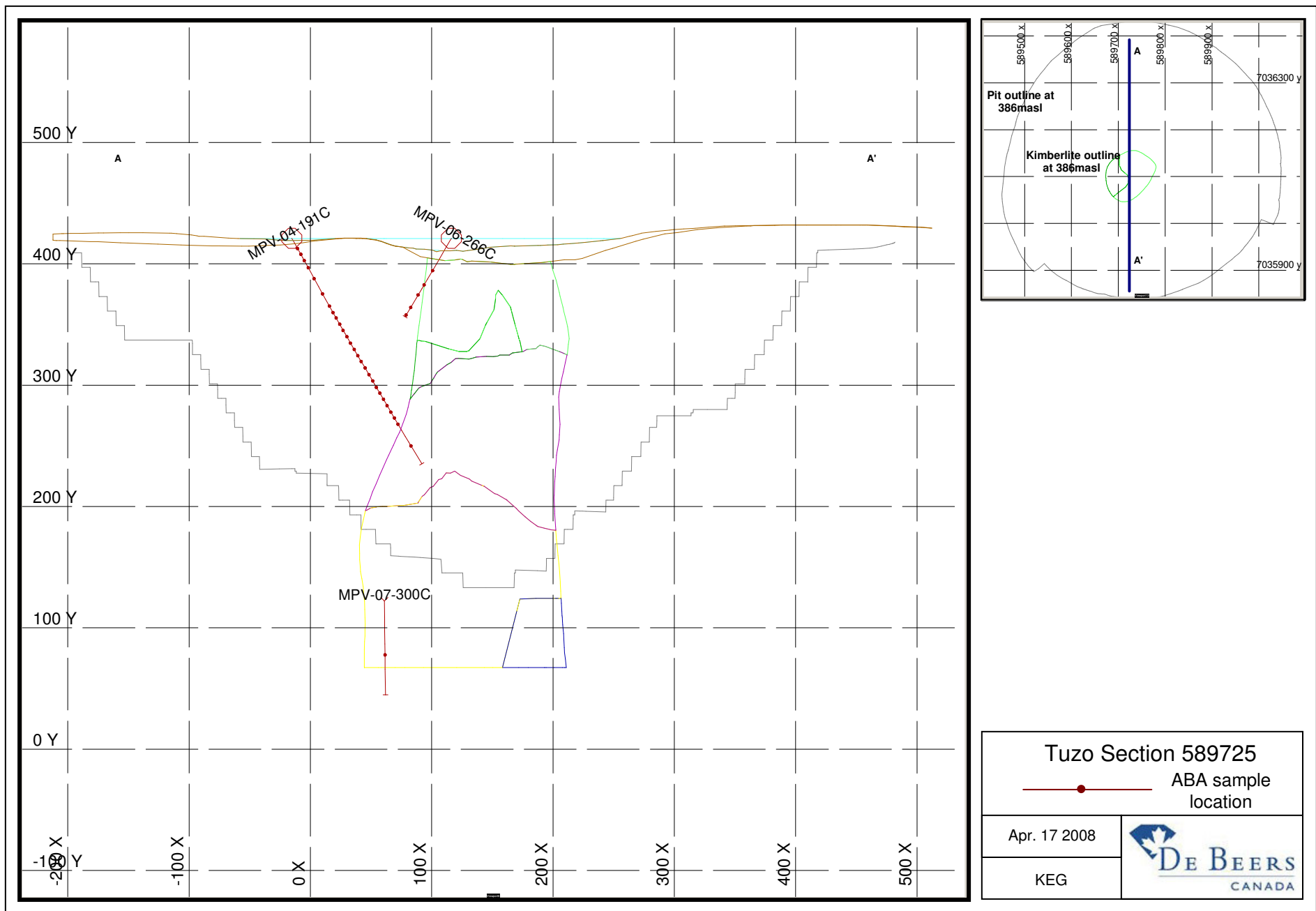


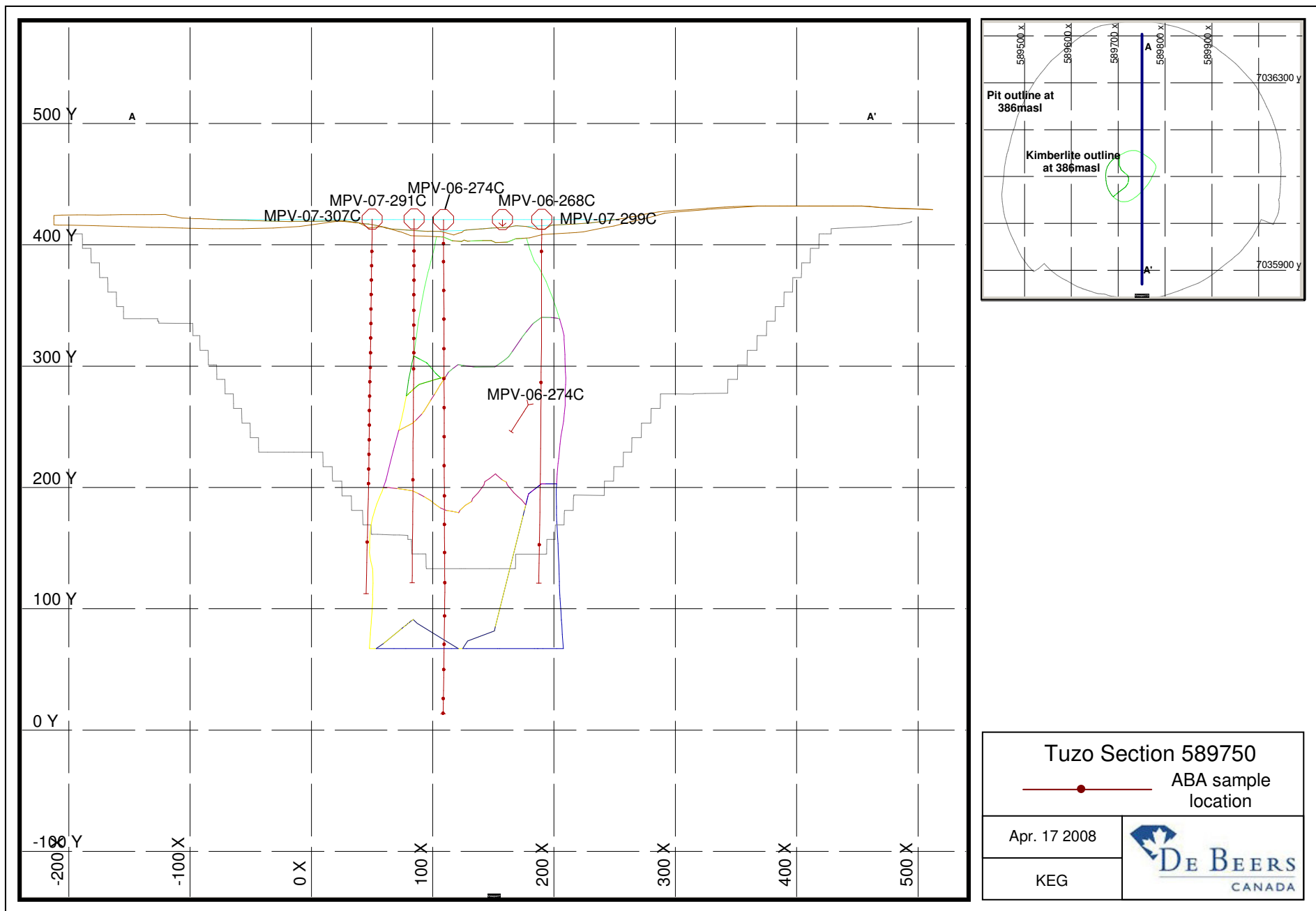


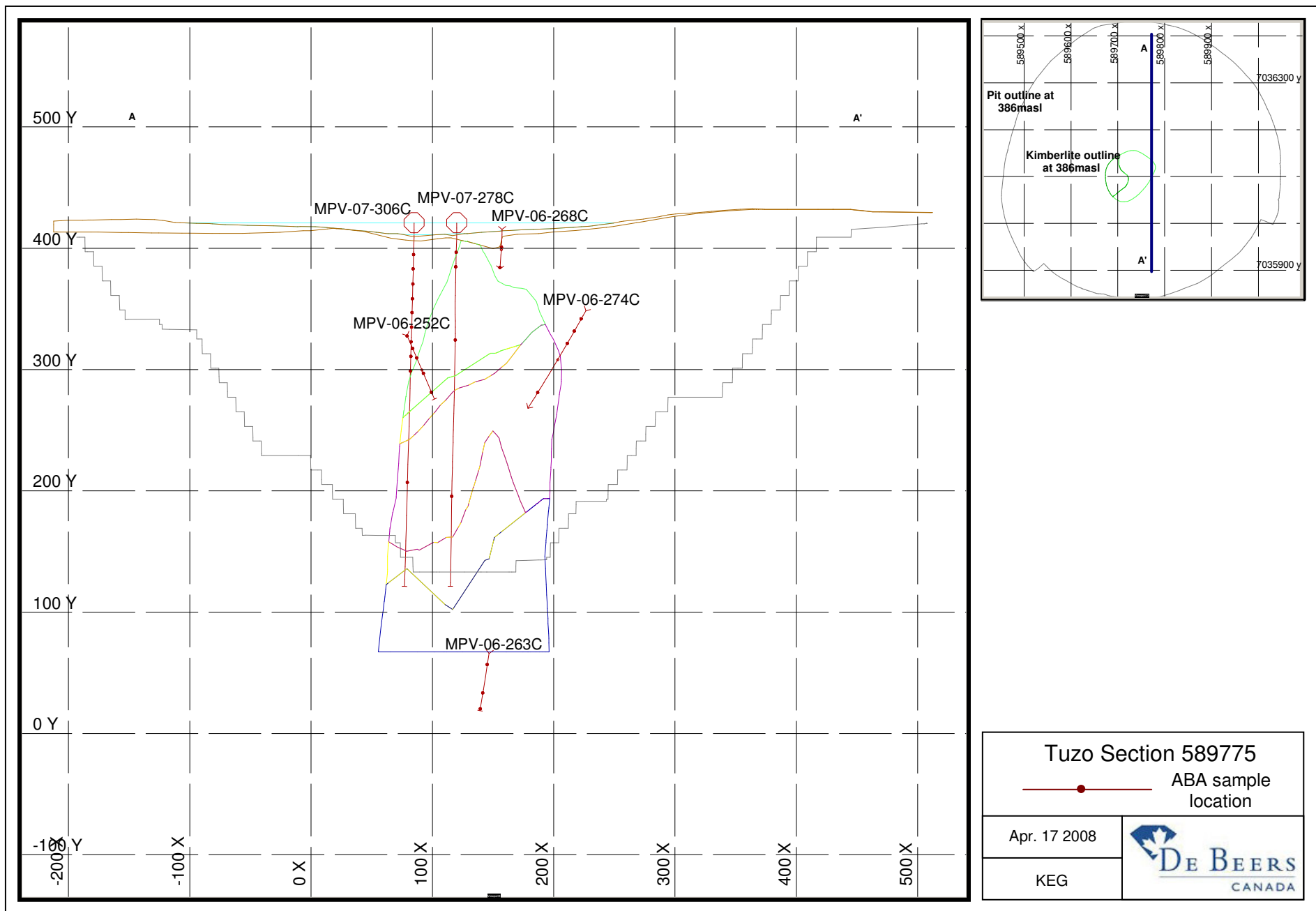


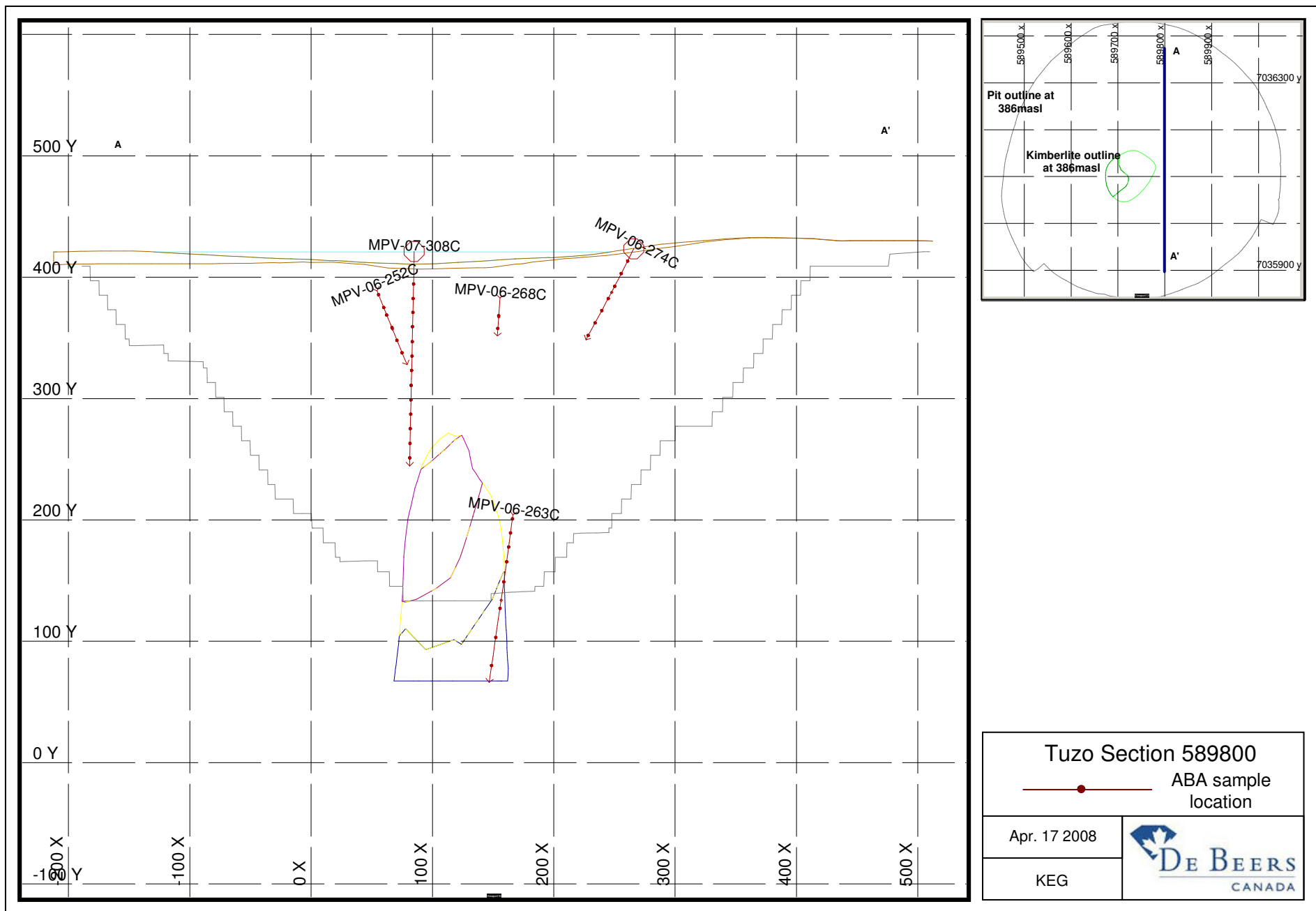


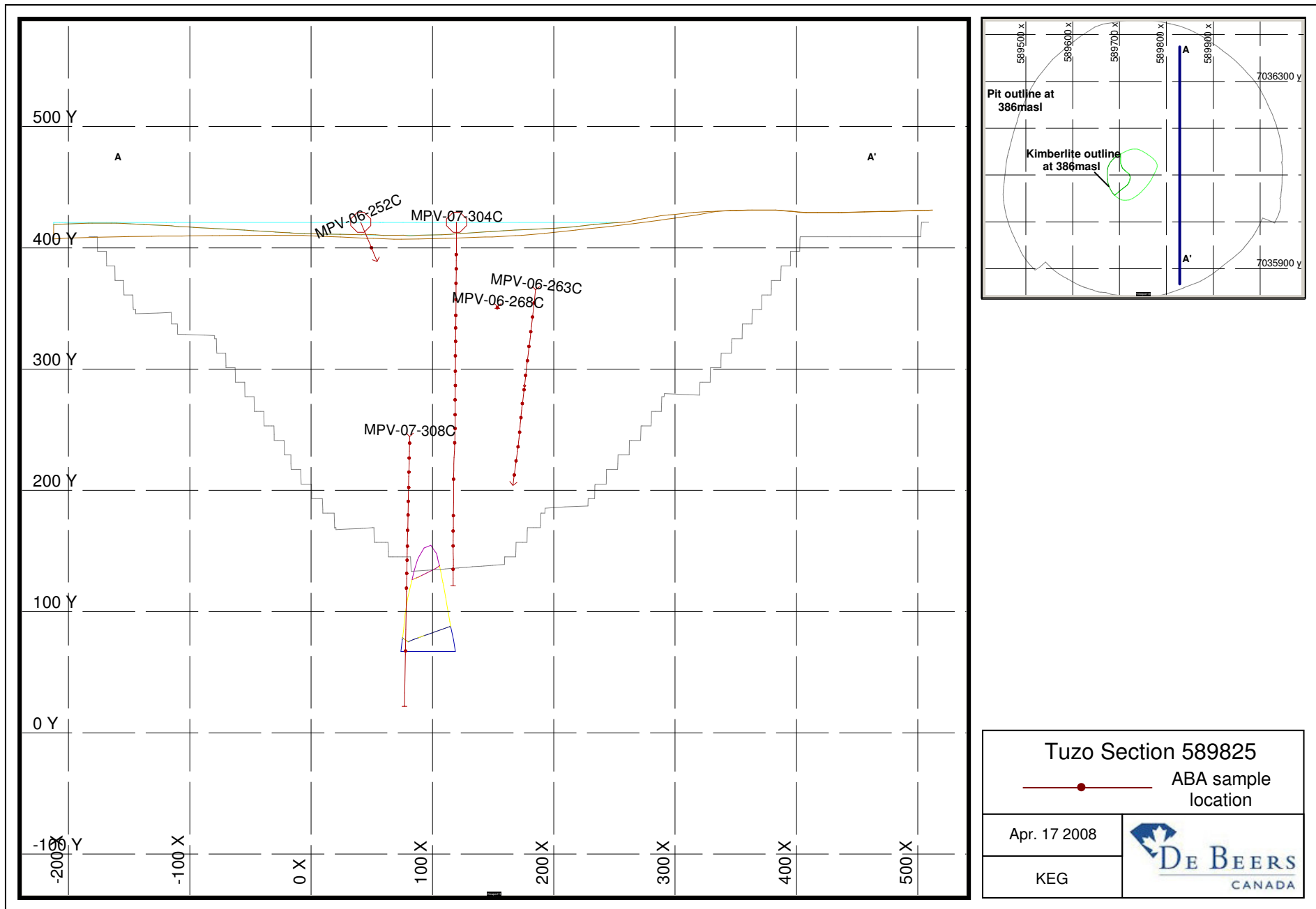












ATTACHMENT 8.III-2
TESTING PROCEDURE

Mineralogical Analysis

Three mineralogical analyses were conducted to identify the major, minor and trace mineralogical assemblages. The 2004 mineralogy report by Petrascience, the 2010 mineralogy report by CEMI and the 2011 report by SGS are attached in Attachment 8.III-3. In 2004, the methodology completed to determine the mineralogical composition of the tailings included qualitative X-ray diffraction (XRD) and optical microscopy of polished thin sections of kimberlite, country rock and processed kimberlite samples. Two processed kimberlite composite samples were analyzed in 2010 using semi-quantitative XRD. In 2011, seven additional processed kimberlite samples were submitted for mineralogical analysis to determine the general mineralogical composition, and identify the source minerals and associations of phosphorous in the PK. Samples were analyzed using semi-quantitative XRD, QEMSCAN and electron microprobe.

Note that the mineralogical quantities that are reported in Attachment 8.III-3 are largely based on results of XRD and may not fully represent the mineralogical compositions of the samples. XRD cannot identify amorphous phases, and therefore semi-crystalline precipitate minerals may not be fully represented by the results of XRD. In addition, trace concentrations of minerals are difficult to identify due to the limitations of the analytical method: generally, the minimum detection limit for XRD is approximately 1%.

Whole Rock and Trace Metal Chemistry

Major oxide and trace metal composition of a sample are determined using whole rock chemical analysis. Whole rock analysis (WRA) was assessed by a combination of X-ray fluorescence (XRF) and trace metal analysis using aqua regia digest followed by inductively coupled plasma (ICP) atomic emission instrumental analysis. Global Discovery Labs of Vancouver, British Columbia conducted the whole rock and trace metals analysis for all samples collected in 2008 under sub-contract to Vizon SciTech (now Maxaam Analytics) of Vancouver, British Columbia. Processed kimberlite studies in 2010 and 2011 were conducted by SGS laboratories in Vancouver.

Acid Base Accounting and Net Acid Generation Tests

The acid base accounting (ABA) analysis determines and balances the amount of acid potential (AP) with the amount of acid neutralizing potential (NP) that may be generated by a sample. ABA testing was conducted by Vizon SciTech (now Maxaam Analytics) (Vancouver, British Columbia) prior to 2010, and SGS laboratories (Vancouver, British Columbia) in 2010 and 2011 using the modified Sobek methods (Sobek et al., 1978) as recommended by Price (1997). Specific analyses included for ABA determination are paste pH, sulphur species, acid

potential (AP), neutralization potential (NP) and carbon species (total carbon, carbonate content and organic carbon content).

Acid Potential (AP)

The acid potential (AP) represents the bulk amount of acidity that can be produced, if all the sulphide minerals in the sample were oxidized. In the evaluation in this report, AP is calculated from total sulphur content. This was a conservative assumption carried forward from AMEC (2008). Total sulphur concentrations include but sulphur from sulphide minerals and often includes amounts of oxidized, non-reactive forms of sulphur, such as sulphate. Although the dissolution of sulphate minerals can contribute some AP in the short-term, sulphate minerals do not generally contribute to the long-term acid generation potential of a material.

Neutralization Potential (NP)

The neutralization potential (NP) represents the bulk amount of acidity that the sample can potentially consume or neutralize. The NP was determined by acidifying the sample with sulphuric acid. Following the acidification of the sample, the amount of acid that is consumed during the test period is determined by a reverse titration. Negative NP values indicate that samples contained stored acidity in the form of soluble phases that contribute acidity on dissolution.

The carbonate neutralization potential (CaNP) is a calculated value that represents the bulk amount of acidity that the sample can potentially consume through the dissolution of carbonate minerals. Carbonate NP was calculated using carbon dioxide concentrations for all samples analyzed prior to 2010. Carbon dioxide concentrations were not reported in 2010 and 2011 processed kimberlite samples, therefore total inorganic carbon concentrations were used to calculate the carbonate NP.

Calculated CaNP values assume that all of the measured carbon in the sample is contained in carbonate minerals that contribute fully to acid neutralization. General limitations of using total carbon include the presence of organic carbon (coal, peat, etc.) and the presence of carbonate minerals that release net acidity on dissolution, such as siderite. These general limitations were not an issue for the lithologies evaluated as part of this project since appreciable amounts of siderite or organic carbon were not observed.

NP and CaNP are typically compared for the purpose of evaluating the mineralogical source of neutralization potential in a sample. In addition to the consumption of acid by readily soluble carbonate minerals, the 'bulk' NP could include neutralization potential released by the dissolution of aluminosilicate, silicate and/or other minerals

that do not typically dissolve until / unless acid generating conditions are achieved. If the NP is approximately equal to the CaNP, the NP is likely attributable to the dissolution of carbonate minerals. In cases where the NP is significantly greater than CaNP, the NP could be overestimated due to the partial dissolution of silicate minerals. The rate of aluminosilicate or silicate mineral dissolution is kinetically limited and generally too slow to provide effective neutralizing capacity under ambient field conditions; silicate minerals predominantly provide NP if (and when) acidic conditions are achieved, or where water-rock interaction times are very long.

Interpretation of Acid Base Accounting Results

Acid Base Accounting results for some samples were below analytical method detection limits. For calculation of summary statistics, results at or below the method detection limit were replaced with one half the value of the lower detection limit for calculation purposes. The acid rock drainage (ARD) classification of samples was based on **Aboriginal Affairs and Northern Development Canada (now AANDC)** (DIAND 1992) criteria presented in "Guidelines for ARD Prediction in the North." The guide was developed to "assist the Department of Indian Affairs and Northern Development in predicting the potential in active and inactive hardrock mines in the Yukon and Northwest Territories." The acid generation potential guide is summarized in the table below:

Interpretation of Acid Base Accounting Results

Acid Generation Potential	Criteria	Comments
Potentially Acid Generating (PAG)	$NP/AP < 1$	Potentially acid generating unless sulphide minerals are non-reactive.
Uncertain	$1 < NP/AP < 3$	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides.
Non-Acid Generating (Non-AG)	$3 < NP/AP$	Not expected to generate acidity.

(INAP, 2009)

Note: For tailings material (i.e., processed kimberlite) a lower NP/AP ratio may be acceptable as the material is more homogenous and reactive due to comminution, and should be evaluated within the context of material placement and processing.

The criteria listed in the table above are consistent with the recommendations in MEND (2009) and INAP (2009). However, it should be noted that for several reasons, no single NP/AP ratio or sulphur concentration is universally applicable with respect to acid generation prediction. The actual threshold values for a particular test sample are material specific, and could depend on several factors,

including chemical and mineralogical composition (i.e., presence and amounts of acid generation and neutralization minerals), morphology (i.e., grain size, texture and crystallinity) and site-specific exposure conditions.

Net Acid Generation (NAG) Testing

Processed kimberlite samples collected in 2010 were submitted for Net Acid Generation (NAG) testing, conducted according to the protocols in AMIRA (2002) and Miller *et al.* (1997). The purpose of the NAG test is to evaluate potential for acid generation following complete oxidation of all sulphide minerals within the sample. During the NAG test, hydrogen peroxide is added to a sample in quantities sufficient to completely oxidize all sulphide minerals. The pH of the oxidized solution was measured after the completion of the reaction to determine the NAG-pH, followed by titration of the solution to a pH of 4.5 with sodium hydroxide. Back-titration to a pH of 7 was completed to provide added information on buffering capacity.

The results of the NAG test were used to provide an initial indication of the propensity of a material to produce acidity after a period of exposure and weathering. The NAG pH is a useful indicator of whether a sample contains sufficient internal buffering capacity to neutralize the acidity produced through sulphide oxidation. A NAG-pH value of less than 4.5 is indicative that insufficient NP exists in the tailings to buffer the acidity generated by the complete oxidation of sulphide minerals, however rates of mineral dissolution are not evaluated by the NAG testing.

Shake Flask Extraction Testing

Short-term static leachate extraction tests are used to determine the readily-soluble component of a sample. These tests, commonly known as shake flask extractions (SFE), are useful for indicating the short-term leaching characteristics and potential for metal release from a sample. SFE tests do not assess long-term processes, such as dissolution of refractory minerals and sulphide oxidation. A modified version of the British Columbia solid waste extraction procedure (SWEP) using distilled water as the leaching agent and a 3:1 mass ratio (750 millilitres [mL] of water with 250 grams [g] of rock) was conducted by Vizon SciTech (Vancouver, British Columbia) in 2004 and SGS (Vancouver, British Columbia) in 2010 and 2011.

SFEs results represent metal release due to the dissolution of readily soluble minerals such as carbonates and salts. The SFE tests do not simulate site drainage chemistry. Results at or below the analytical detection limits were replaced with one half the value of the lower detection limit for calculating summary statistics.

Chemical Analysis of Process Water

Process water represents the water used in the process plant during the recovery of diamonds. This water is in contact with PK, and ultimately is discharged as a component of the PK fines slurry. Samples of process water were collected by De Beers during metallurgical testing conducted in 2010; samples were collected after each sample had gone through the process plant. A total of 9 samples of process water were provided to SGS (Vancouver, British Columbia) for chemical analysis.

Kinetic Testing

Kinetic tests are repetitive leaching tests designed to simulate enhanced weathering and provide rates for acid generation, acid neutralization, and metal and major element leaching under laboratory conditions. Kinetic tests were conducted using several methodologies, to evaluate the variability in sample reactivity in different exposure conditions, including:

- Humidity cell tests (HCT) carried out using the standard humidity cell test (HCT) approach described in ASTM D 5744-96, 1996
- Column cell testing, as described by Price (1997)
- Submerged column tests as described in the following section

The results of HC testing are particularly suited for the development of reaction rates, and can also be used to make inferences with respect to long-term water chemistry. The column cell data can provide an understanding of the secondary geochemistry and may simulate of potential drainage chemistry characteristics. Submerged column tests were initiated to provide an indication of leachate concentrations that could be produced by PK submerged under a column of water over time.

In scaling up kinetic test results to field conditions a number of factors including the greater particle size of country rock compared to kinetic tests, potential for preferential exposure of acid producing or acid neutralizing minerals during mining, climate conditions, and limitations in the scale of laboratory based tests need to be considered. However, as discussed in Price (1997), results from kinetic tests can be used as “analogue” inputs for contact water in the absence of site specific data.

Humidity Cell (HC) Testing

Laboratory humidity cell testing (HCT) of kimberlite, country rock and processed kimberlite samples was conducted in 2004, and additional humidity cell testing on processed kimberlites is currently underway. The kinetic tests are being performed according to the ASTM D5744-96 Standard Test Method for Accelerated Weathering

of Solid Materials Using a Modified Humidity Cell (ASTM, 2001). A humidity cell is a weathering chamber designed to provide simple control over air, temperature and moisture, while allowing for the removal of weathering products (principally oxidation products) in solution. Country rock and PK HCTs initiated in 2004 consist of a 1-kg sample (dry equivalent) of sample which was pre-leached (Cycle 0) with 1 L of de-ionized water, after which weekly leaching cycles were initiated. The weekly cycles include a 3-day period where dry air is circulated in the cell followed by a 3-day period where humid air is circulated in the cell and a final leach day when the cell is flooded with 1 L of distilled water (1:1 liquid to solid ratio by weight). After 1 hour of retention, the leach water is drained from the bottom of the cell, filtered (0.45 µm filter) and collected for analysis. The same testing methodology was applied to the PK HCTs initiated in 2010, only the sample charge was limited to 0.5 kg owing to sample availability.

Humidity cell leachate compositions were used in conjunction with ABA data to calculate sulphide and neutralization potential (NP) depletion. Depletion calculations, based on the relative rate of production of sulphate and alkalinity, are a useful method of predicting the time to onset of acid generation. Sulphide and NP depletion calculations were conducted to evaluate the rate of depletion of acid producing (i.e., sulphide) and acid neutralizing (i.e., carbonate) minerals in the tailings. Empirical rates of NP depletion were calculated according to the recommendations in Price (1997), which assume that the NP depletion is equivalent to the rate of sulphate production (i.e. acid production) and the rate of alkalinity production / acidity consumption. If acid producing minerals are depleted from the tailings prior to soluble, neutralizing minerals, it is unlikely that acid generating conditions will be realized. However, if the rate of dissolution of carbonate minerals exceeds the rate of oxidation of sulphide minerals, acid generation could occur.

Humidity Cell Testing of Pre-Leached Samples

Four samples of granite were submitted for “pre-leached” HCT to evaluate the long-term geochemical characteristics of granite after the complete reaction of NP (HC-28, HC-29, HC-30, HC-31). Samples were “pre-leached” using hydrogen chloride. The effectiveness of removing NP using hydrogen chloride was confirmed by ABA. Samples were pre-treated with a 6 normal hydrochloric acid solution, which removed both the carbonate NP and bulk NP, leaving the AP in the sample intact. After the pre-leaching of the samples, HCT was carried out according to the method outlined in the previous section.

Column Testing

Ten columns were set up in January 2005 at Vizon SciTech (Vancouver, BC, Canada), with the week 0 flush commencing on 31 January 2005, and leachates were analyzed for metals and pH.

Submerged Column Tests

Supplemental testing was initiated in May 2010 for PK and spring and summer of 2011 for PK and country rock to address the possible influence of submerging PK and country rock in post-closure mine waste facilities. Composite samples of fine PK and coarse PK, respectively, were used as charges for the column tests. Country rock samples were collected from drill core adjacent to the core used to construct the 2008 humidity cells. Sample charges with a weight of 3 kg were placed in a PVC column, which was inundated with an initial volume of distilled water (de-oxygenated by bubbling with nitrogen gas) of approximately 2.5 L. The water columns are kept under a nitrogen gas head to limit exposure to the atmosphere.

Each week, samples of water are collected from the base ("bottom") of the column and the water overlying the top of the column ("top"). Additional distilled water is added to the top of the column to replace the volume of water collected each week.

ATTACHMENT 8.III-3
MINERALOGICAL ANALYSIS

**QUANTITATIVE PHASE ANALYSIS OF TWO POWDER SAMPLES USING THE
RIETVELD METHOD AND X-RAY POWDER DIFFRACTION DATA.**

(Project: 1042 DeBeers – PO# 42191)

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August 9, 2010

EXPERIMENTAL METHOD

The two samples “**PK – Coarse Composite**” and “**PK – Fines Composite 2**” of **Project 1042 DeBeers** were reduced to the optimum grain-size range for quantitative X-ray analysis (<10 µm) by grinding under ethanol in a vibratory McCrone Micronising Mill for 7 minutes. Step-scan X-ray powder-diffraction data were collected over a range 3-80°2θ with CoKα radiation on a Bruker D8 Focus Bragg-Brentano diffractometer equipped with an Fe monochromator foil, 0.6 mm (0.3°) divergence slit, incident- and diffracted-beam Soller slits and a LynxEye detector. The long fine-focus Co X-ray tube was operated at 35 kV and 40 mA, using a take-off angle of 6°.

RESULTS

The X-ray diffractograms were analyzed using the International Centre for Diffraction Database PDF-4 and Search-Match software by Siemens (Bruker). X-ray powder-diffraction data of the samples were refined with Rietveld program Topas 4.2 (Bruker AXS). The results of quantitative phase analysis by Rietveld refinements are given in Table 1. These amounts represent the relative amounts of crystalline phases normalized to 100%. The Rietveld refinement plots are shown in Figures 1 – 2.

Both samples contain a significant amount of clay, likely a member of the smectite-group (confirmed by glycolation). As these disordered clays do not have predictable crystal structures, we have used an empirical structure model for montmorillonite. Therefore the determined amounts of all phases are semi-quantitative. Any error (plus or minus) in the amount of smectite causes the total amount of other phases to be renormalized. As the smectite structure model is not constrained by atomic information, it fits all parts of the pattern not adequately fitted by other phases, nanoscale or amorphous components, or background model. Thus the error in determining the amount of smectite is likely on the side of over-estimation. In addition, small amounts of chlorite, if present, are obscured by the broad smectite and serpentine peaks and cannot be accounted for.

Table 1. Results of quantitative phase analysis (wt.%)

Mineral	Ideal Formula	PK-coarse Composite	PK-fines Composite 2
Quartz	SiO ₂	10.7	5.1
Biotite	K(Mg,Fe) ₃ (AlSi ₃ O ₁₀)(OH) ₂	13.4	9.3
Montmorillonite model	(Na,Ca) _{0.3} (Al,Mg) ₂ Si ₄ O ₁₀ (OH) ₂ ·nH ₂ O	27.4	49.5
Talc	Mg ₃ Si ₄ O ₁₀ (OH) ₂	12.4	11.1
Lizardite	Mg ₃ Si ₂ O ₅ (OH) ₄	5.4	4.1
Jarosite ?	K ₂ Fe ₆ ³⁺ (SO ₄) ₄ (OH) ₁₂	0.4	0.5
K-Feldspar	KAlSi ₃ O ₈	8.8	6.6
Plagioclase	NaAlSi ₃ O ₈ – CaAl ₂ Si ₂ O ₈	12.7	6.4
Calcite ?	CaCO ₃	0.4	0.8
Dolomite	CaMg(CO ₃) ₂	0.9	1.4
Diopside	CaMgSi ₂ O ₆	1.9	1.7
Magnetite	Fe ₃ O ₄	1.3	1.1
Forsterite	Mg ₂ SiO ₄	4.2	2.4
Total		100.0	100.0

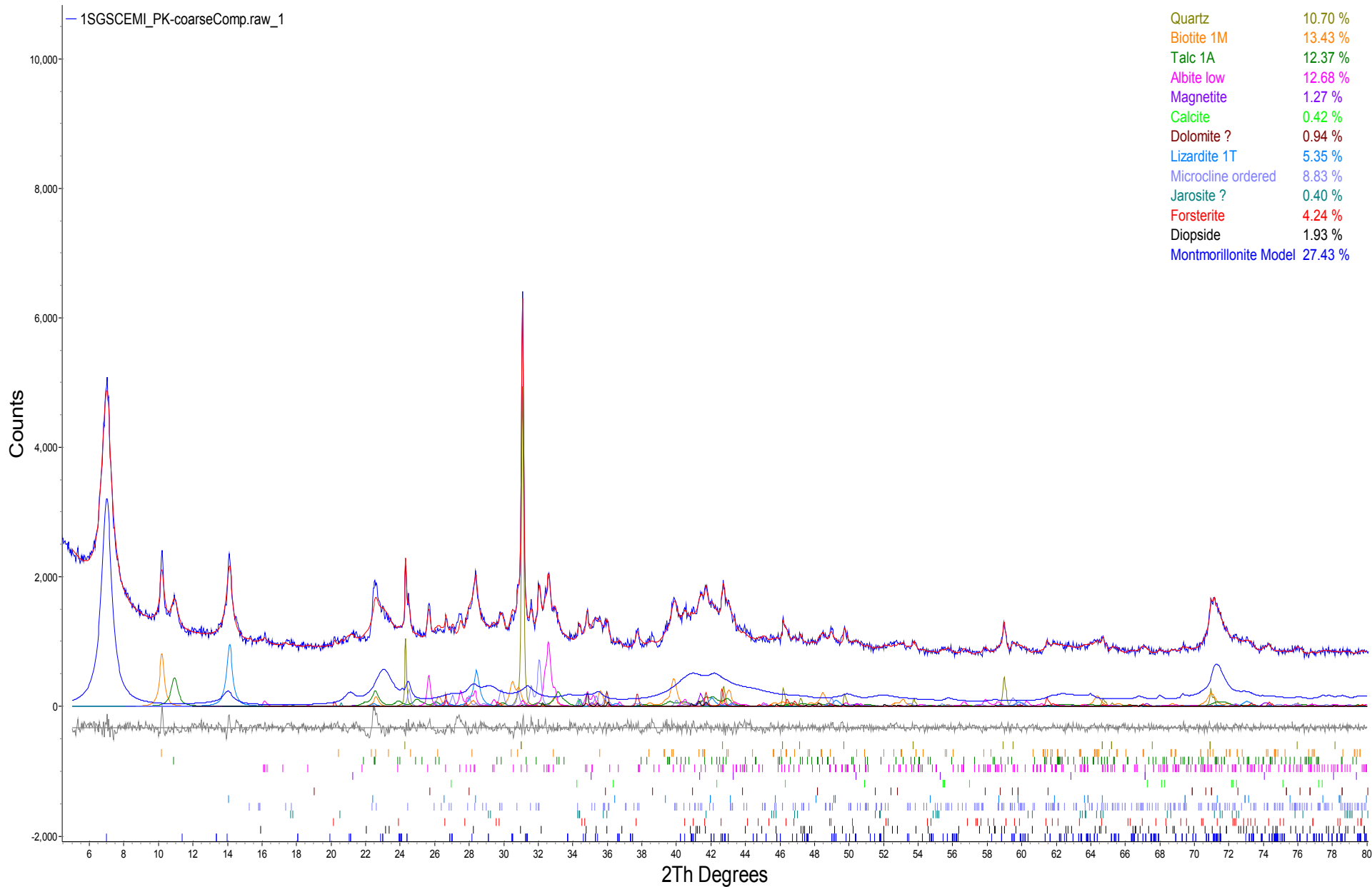


Figure 1. Rietveld refinement plot of sample **SGS CEMI “PK-coarse Composite”** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below – difference between observed and calculated intensities; vertical bars, positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.

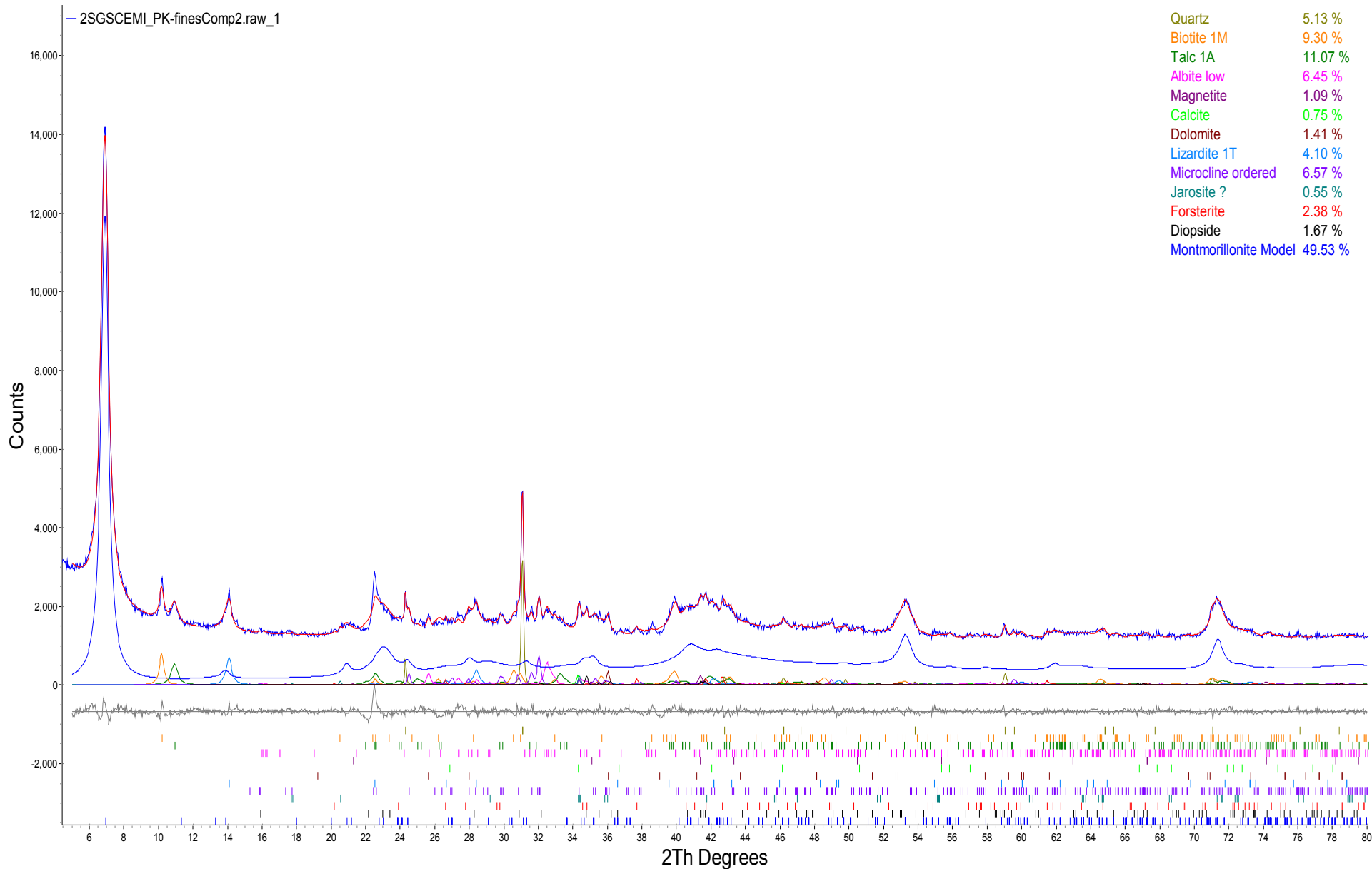


Figure 2. Rietveld refinement plot of sample **SGS CEMI "PK-fines Composite 2** (blue line - observed intensity at each step; red line - calculated pattern; solid grey line below – difference between observed and calculated intensities; vertical bars, positions of all Bragg reflections). Coloured lines are individual diffraction patterns of all phases.