APPENDIX II
REVIEW OF FIELD COLUMN KINETIC TEST DATA

Wolfden Resources Inc.

ULU PROJECT

Review of Field Column Kinetic Test Data

FINAL REPORT

Prepared by:

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Project No: 035-001-01
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Project No. 035-001-01

Date: December 29, 2004

Mr. Jim Cassie, M. Sc., P. Eng.
BGC Engineering Inc.
Suite 1170, 840-7th Avenue S.W.
Calgary, AB T2P 3G2

Dear Mr. Cassie,

Re: Ulu Project – Review of Field Column Kinetic Test Data – Final Report

This report is based on a draft report, dated January 13, 2003, that was prepared for Kinross Gold Corporation (formerly Echo Bay Mines Ltd.). At your request, that draft report has been reviewed and finalized for the new site owner, Wolfden Resources Inc. No new data has been added, and no new analyses have been conducted, although editing suggestions have been incorporated for improved clarity.

As requested, I have forwarded 4 hardcopies and one electronic copy to David Stevenson of Wolfden Resources Inc., and one copy to Lorax Environmental Services Ltd in Vancouver, Please find enclosed a hardcopy for your files, and one copy for Gartner Lee Ltd in Calgary, as requested.

We trust this report meets your requirements at this time.

Yours truly,
Mehling Environmental Management Inc.

P. Mehling

Peri Mehling, MSc., P.Eng.
Senior Consultant

Encl. 2 Paper copies of final report

EXECUTIVE SUMMARY

This report provides a compilation and interpretation of data provided by Kinross Gold Corporation from two field columns at the Ulu Mine Project site. The report also compares the field test results with the conclusions presented in the Klohn-Crippen Consultants Ltd. (Klohn) reported entitled "Ulu Project – Kintetic Testing of Sulphide-Rich Material from Ulu" dated April 1998, which considered early results from the two field columns as well as results from a series of laboratory kinetic tests conducted on coarse ore, fine ore (to simulate tailings) and waste rock.

The key findings, and implication for ore and waste rock management, are as follows:

- Klohn's NPR threshold values to avoid acidic drainage of 3 and 7 for 22 ^{o}C and 4 ^{o}C respectively, calculated from humidity cell results on high-sulphide samples of coarse ore, fine ore (simulated tailings), and waste rock, are considered conservative due to the relatively large volumes of water used in a humidity cell test as compared to field conditions. Lag times before the onset of acidic conditions associated with these thresholds are likely to be in the order of decades.
- Results from the field columns tests conducted on coarse ore samples suggest that threshold NPRs to avoid acidic drainage may be as low as 1.3 and 2.0. The reduced threshold NPR values (as compared to the humidity cell test results) are attributed to the reduced NP depletion rate, as a result of lower flushing volumes and frequency under field conditions. However, these field column NPR threshold values should be viewed with caution as all oxidation products may not be released as they are produced, and the sulphate release rates may continue to increase as products build up and become available for release on subsequent flush events. Confirmation and use of these lower threshold NPR values would require continued test work (allowing for stabilization of oxidation rates), or dismantling and analysis of field columns.
- High arsenic concentrations, and elevated zinc concentrations are anticipated from ore located in the active layer on site at neutral pH. These arsenic concentrations may be of concern as they occasionally exceeded the federal *Metal Mining Effluent Regulations* maximum allowable values, particularly in the later stages of the 5 year test.
- Given that ore stockpiles are anticipated to be milled quickly, and are not likely to be stored for more than one year before transport to an offsite mill, the predicted arsenic and zinc concentrations and the predicted delay until the onset of acidic conditions are unlikely to result in significant adverse affects on the environment.
- Minimal metal leaching from waste rock was anticipated by Klohn (1996) based on the geological model (which suggests low levels of mineralization in the waste rock) and the lack of a metal leaching problem associated with the single, high sulphide

waste rock kinetic test sample. However, the limited metal database for waste rock samples precludes a quantitative assessment of metal content in waste materials at this time. Greater clarity of the potential quantity of waste rock that might contain elevated metal levels may be determined by review of the 7305 ICP's referred to the BHP geology report (1993).

- Any waste material that contains arsenic, such as waste rock adjacent to the ore, may have a potential to leach arsenic at elevated concentrations at neutral pH, and should be assessed and/or managed accordingly. Zinc may also be a potential metal leaching concern if present in waste materials in similar quantities and form as the tested coarse and fine ore samples.
- Should acidic conditions eventually develop, leaching of other metals may occur. For example, copper values in the waste rock are noted as being slightly more elevated than ore samples.
- Under field conditions, a threshold NPR of 3 is considered a reasonably conservative means of classifying PAG waste materials to avoid the onset of acid generation. From the existing database, this appears to be consistent with a total sulphur cutoff of 0.2%.
- Based on the ABA database compiled to date, and a threshold NPR of 3 for separating PAG and NPAG material, gabbro and diabase material for the most part are likely to be NPAG, greywacke may be PAG or NPAG depending on the sulphur content, mafic volcanics are likely to be PAG, basalt material is highly variable but generally PAG and all ore and altered material are PAG. Note that the database is dominated by surface samples, and deeper materials may not maintain the indicated trends. Also note that the samples may have been biased to those containing visible sulphides.
- The onset of acidic conditions, and/or predicted metal leaching, may not necessarily result in significant adverse affects on the environment. Impact assessments are required to assess potential impacts, and typically take into account the mass of material maintained in a frozen state, volume and grainsize of the stockpiled material, site temperatures, the tendency for water to flow through channels and bypass many of the rock surfaces potentially holding stored oxidation products, and the volume of runoff and leachate that may contact the stockpile materials. MEMI recommends that impact assessments for specific site conditions be conducted to quantitatively define potential impacts from waste rock storage.

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LIMITATIONS OF REPORT

Mehling Environmental Management Inc. (MEMI) prepared this report for the account of Wolfden Resources Inc. (Wolfden). The material in it reflects the judgement of MEMI staff in light of the information available to MEMI at the time of draft report preparation in January 2003. Any use which a Third Party makes of this report, or any reliance on decisions to be based on it, is the responsibility of such Third Parties. MEMI accepts no responsibility for damages, if any suffered by any Third Party as a result of decisions made or actions based on this report.

As mutual protection to our client, the public, and ourselves, all reports and drawings are submitted for the confidential information of Wolfden. The authorization for use and/or publication of data, statements, conclusions or abstracts from or regarding our reports and drawings is reserved pending written approval by Wolfden and MEMI.

1.0 INTRODUCTION

Mehling Environmental Management Inc. (MEMI) was originally retained by Kinross Gold Corporation (Kinross), formerly Echo Bay Mines Ltd. (Echo Bay), to summarize the field column test work for the Ulu Mine Project and compare the field test work with the conclusions presented in the Klohn-Crippen Consultants Ltd. (Klohn) report entitled "Ulu Project – Kinetic Testing of Sulphide-Rich Material from Ulu" dated April 1998. The 1998 Klohn report considered early results from the same two field columns, as well as results from a series of laboratory kinetic tests conducted on coarse ore, fine ore (to simulate tailings) and waste rock. A draft report was produced on January 13, 2004, but was not finalized.

At the request of BGC Engineering Inc., Calgary, Alberta, the draft report has been reviewed and finalized for the new site owner, Wolfden Resources Inc. No new data has been added, and no new analyses have been conducted, although editing suggestions have been incorporated for improved clarity.

The scope of work for this project included:

- A review of reports, data and study information related to Acid Rock Drainage/Metal Leaching (ARD/ML) as provided by Kinross, including site geology, rock types, rock characteristics and kinetic tests;
- Compilation and interpretation of data from two field columns collected and provided by Kinross. The interpretation was to focus on comparison of field leach rates to sulphate production and neutralization depletion rates estimated in the preliminary assessment undertaken by Klohn-Crippen Consultants Ltd. (Klohn); and,
- Completion of a column test report, including discussion of potential implications for mine waste management.

Specific reports provided by Kinross and reviewed for acid base accounting (ABA) data and kinetic test results were:

- "Ulu Project, Northwest Territories, Environmental Overview" prepared for BHP Minerals Ltd. of Vancouver, B.C. by Rescan Environmental Services Ltd. (Rescan) of Vancouver, B.C., dated December 1991;
- "Ulu Project, Preliminary Assessment of Acid Rock Drainage Potential" prepared for Echo Bay Mines Ltd. – Lupin Operation (EBM-Lupin), by Klohn-Crippen Consultants Ltd. (Klohn) of Calgary, Alberta, dated October 1996; and,
- "Ulu Project, Kinetic Testing of Sulfide-Rich Material from Ulu" prepared for Echo Bay Mines Ltd., by Klohn, dated April 1998.

2.0 BACKGROUND

The following project description was taken from Klohn, 1998:

> "The Ulu property is located 45 km north of the Arctic Circle and 135 km north of the Lupin Mine in the Mackenzie Mining District, Northwest Territories. Echo Bay Mines – Lupin Operation acquired the property from BHP Minerals Canada Ltd. in 1995, intending to develop it to provide ore for milling at the Lupin Mine. The tentative mine plan involves stockpiling ore materials at the Ulu site year-round and transporting them to the Lupin Mine when winter roads are operational. Waste rock excavated to reach the orebody is used for construction of ore pads for temporary ore storage and camp pads at the Ulu site."

2.1 Deposit Geology and Mineralogy

The following geological description is from Klohn, 1996:

> "The Ulu deposit is an Archean epigenetic lode-gold occurrence located within the High Lake greenstone belt of the north-central Slave Province. Pillowed to massive mafic volcanic rocks and co-magmatic gabbro sills are interlayered with greywacke-mudstone turbidite sequences that form a tight north-trending anticline bound on all sides by late Archean granite. Mineralization is hosted in discordant quartz veins concentrated along the axial trace of the anticline. Regional metamorphism to the lower amphibolite facies has converted the sedimentary package largely to biotite schist. Mafic metavolcanic and metagabbro rocks proximal to mineralization are similar in mineralogy and bulk chemistry and are classified as sub-alkaline, high-iron tholeiites (Carpenter, 1994). Gold mineralization is commonly hosted in metavolcanics (e.g., the Flood Zone), less commonly in metagabbro (e.g., the Gnu Zone) and rarely within metasediments (e.g. the Sediment Core Zone).
>
> In the Flood Zone, where most recent work has been focused and where initial mining development will probably commence, the ore mineralization is associated with pervasive silicification and feldspar alteration. Gold occurs adjacent to acicular arsenopyrite in the silica-feldspar altered mafic metavolcanic wallrock and breccia. Pyrrhotite occurs as late anhedral grains that may be found vein-forming and cross-cutting the arsenopyrite-gold mineralization. Pyrite with or without trace amounts of chalcopyrite occurs in late quartz stockwork selvage and fractures. Marcasite, goethite and limonite are present as late weathering products. The hangingwall metavolcanic show retrograde metamorphism and propylitic alteration characterized by actinolite, epidote and minor chlorite, quartz and sericite. Late quartz-actinolite-carbonate veins are occasionally found overprinting the metamorphic assemblages. The footwall rocks exhibit pervasive biotite and albite alteration with quartz, epidote and chlorite as minor constituents."

3.0 PREVIOUS ARD ASSESSMENTS

3.1 Static Test Results (Klohn, 1996)

Klohn (1996) reviewed previously available data and furnished new field observations and an interpretation of static test data, incorporating acid-base accounting (ABA) test results from a new suite of 32 samples collected by Klohn staff and Echo Bay geologists. Conclusions and recommendation for further work were made based on a synthesis of all acquired data.

The ABA testwork conducted prior to Klohn's participation consisted of

- 1990 testing performed as part of the environmental overview by Rescan (1991), which attempted "...to characterize the ARD potential of the various lithologies occurring in the Ulu property through the analysis of 15 samples"; and,
- 14 samples analyzed in 1992 by BHP Minerals (1993), which "...specifically addressed the ARD characteristics of the ore material and rocks in the hanging wall exposed in a trench in the NW Flood Zone."

ABA methods used in these studies were not specified in Klohn (1996), or in the referenced reports.

Klohn (1996) noted the following conclusions from the previous work:

> "...the ore material is potentially acid-generating while most barren rocks are not. Rocks in the contact zones with ore mineralization generally have a lower NP/AP [Neutralization Potential/Acid Potential] ratio. The sulfide content appears to be the primary factor determining whether or not the ratio is to fall below the safety threshold values recommended by the regulatory agencies (NP/AP = 3/1 according to the U.S. Environmental Protection Agency; and NP/AP = 4/1 according to the B.C. ARD Guidelines)"

Klohn (1996) also noted that these results were consistent with Klohn's preliminary ARD assessment developed on the basis of the deposit geology and prevalent mineralogy, as follows:

> "Mesothermal lode gold deposits are ranked low in overall susceptibility to give rise to ARD problems among the seven common deposit types investigated by Kwong (1993). In the Ulu deposit, with the possible exception of metasediment-hosted mineralization, the basic to ultra-basic character of the barren host rocks is likely to render prospective waste rock not susceptible to acid generation in spite of the scarcity of carbonate minerals. Due to pervasive silica and feldspar alteration and the presence of pyrrhotite in the mineralized zones, however, the ore material is likely to be net acid-generating. Whether or not an ore stockpile would generate acid in the temporary storage pad will depend on the pyrrhotite oxidation rate under climatic conditions at the site. To avoid contaminating benign waste rock that can be used for construction purposes, care should be taken to characterize and isolate sulphide-bearing sub-ore material that may be net acid-generating."

Klohn (1996) supplemented the previous ARD testwork with the ABA analysis of 32 samples, using ABA procedures modified from the Coastech Research (1990) method (Modified ABA). The 32 samples included:

- "16 composite chips samples of the portal under construction, including 4 collected by Klohn-Crippen personnel while working on the site (Ulu-KC-1 to 4), 4 previously collected by an EBM-Lupin geologist (Ulu KC-5 to 8), and 8 subsequently collected by an EBM-Lupin geologist from the camp pads (Ulu KC-25 to 32);
- 8 composite pulp samples covering two mineralized zones encountered in diamond drill hole 96UL-20; both the ore material and its immediate wallrock alteration were included (Ulu-KC-9 to 16);
- The fresh interior (KC-Ulu-17) and 1 alteration rind (KC-Ulu-18) of a grab sample collected by an EBM-Lupin geologist from the Ore Zone Surface;
- 6 barren country rocks (3 gabbro, 2 biotite schist, and 1 mafic volcanic rock) samples from drill cores 96-UL-1 to 4 by a mine geologist (Ulu-KC-19 to 24)"

Klohn (1996) drew "... the following conclusions with regard to the acid rock drainage potential of rocks hosting the gold mineralization at Ulu:

1. With few exceptions, most rocks in the Ulu property do not contain any significant carbonate content but mafic silicates may contribute a neutralization potential in the order of 20 kg $CaCO_3$ equivalent/tonne.
2. Regardless of rock type and extent of mineralization, the total sulfur content is the most important parameter determining whether or not a sample is classified as potentially acid-generating (PAG).
3. Because the apparently very slow sulfide oxidation rate occurring at the site, a threshold total sulfur content of 0.9 wt.% and a NPR [Neutralization Potential Ration, or NP/AP] of >1 are recommended as appropriate discriminators to differentiate PAG from non-PAG rocks. [These parameters were revised following kinetic tests as reported in Klohn, 1998, see below.]
4. Both PAG and non-PAG rocks occur in the vicinity of the portal under construction. Care should be taken to isolate sulfide-rich rocks and not use them for construction purposes.
5. Based on the apparent paucity of sulfide-rich material and very slow sulfide-oxidation rate, the waste rock [that had been] used in construction of camp pads from underground is unlikely to be acid generating, especially if the waste rock was well mixed in the process."

Klohn (1996) recommended the following work be undertaken "... to confirm the preliminary ARD assessment based on the results of ABA testing as well as to identify and help avoid potential metal leaching problems:

1. Design and conduct kinetic tests to substantiate (a) the slow sulfide oxidation rate apparently occurring at the site; and (b) the appropriateness of using a

lower than recommended NPR as a PAG discriminator for the site [i.e. an NPR of 1]; as well as elucidate potential metal leaching problems, especially arsenic. [Arsenic was noted as being potentially mobile even under non-acidic conditions.]

2. Involve field geologists in ARD assessment in this case, especially utilize their expertise in mineral identification to avoid employing rocks with more than 2.5% pyrrhotite or 2% pyrite or 4.5% arsenopyrite by volume or their combined equivalents in the construction of the prospective ore pad. [These specific values were selected as equivalent to a threshold value of 0.9% sulphur, consistent with a NPR value of 1. Material identified as sulphide-rich was to be "... stockpiled on a low permeability structure and later capped in-situ or utilized as an ore dilutent in the milling process." Klohn noted that a low permeability structure was to be present for ore stockpiling, and that a neutralization pond was to be available to address low pH leachate, should it occur.]
3. Continue to collect samples for ABA analysis as the project progresses until a database is built up that will allow the identification and application of more readily acquirable surrogate parameters for ARD assessment."

3.2 Kinetic Tests (Klohn, 1998)

On behalf of Echo Bay, Klohn designed and conducted a kinetic test program to investigate the possibility of ARD/ML resulting from stockpiling ore at Ulu prior to its transport by winter-road to Lupin for processing. The test program (Klohn, 1998) involved:

- humidity-cell tests on the coarse fraction (>1.5 mm) of a crushed composite ore sample at both $4^{o}C$ and $22^{o}C$ (i.e. room temperature);
- field-column tests on two duplicate samples of the same coarse ore fraction as used in the above tests;
- a humidity-cell test on the <1.5 mm fraction of the same crushed composite ore sample used in the above test at $22^{o}C$. This fine fraction accounted for about 16% by weight of the composite sample, and was labeled 'tailings' as it was apparently considered likely to represent the tailings that would be produced by processing the ore through a mill; and,
- humidity-cell tests on a waste rock composite sample at both $4^{o}C$ and $22^{o}C$ (i.e. room temperature).

Grain size effects, temperature control of reaction rates and influence of flushing events on leachate chemistry were considered in the interpretation of test results (Klohn, 1998). All samples were described as being "sulphide-rich", and presumably were selected to represent relatively reactive material for the site, although there was no discussion of the kinetic test samples relative to the overall characteristics of the site (See Section 3.1.1 for further discussion).

Klohn (1998) noted significant differences in mineralogy between the ore and waste rock composites, as follows:

> "The ore composite contains more quartz and biotite and less hornblende and plagioclase than the waste rock. Although the total sulfide content of the two composites is similar (i.e. within the error of visual estimates), pyrrhotite and arsenopyrite are the dominant sulphide minerals in the ore composite while pyrite predominates in the waste rock tested. All sulphides are fresh and carbonate is rare in all of the test composites."

The similarity in sulphide content between the ore and waste rock sample, the low carbonate-NP content of all three test materials, and the lack of arsenopyrite in the specific waste rock sample submitted for kinetic testing were supported by the metals and ABA analyses conducted by Klohn on the test samples, as summarized in Tables 1 and 2 below

The analytical data also indicated that similar NPR pre-test values existed in all 3 samples, and that there was virtually no sulphate-sulphur in any of the samples. Also sulphide and arsenic appeared to report preferentially to the fine (tailings) fraction of ore, as compared to the coarse fraction of the ore.

Table 1: Solids Metals Analyses (Klohn, 1998)

Sample	As (ppm)	Ca (%)	Cr (ppm)	Cu (ppm)	Mg (%)	Pb (ppm)	Zn (ppm)
ORE							
pre-test	7780	1.03	38	60	0.68	2	86
post-test @ 4^{o}C	9590	1.06	50	60	0.72	<5	65
post-test @ RT	9870	1.09	60	75	0.75	5	90
WASTE ROCK							
pre-test	556	1.07	59	103	1.16	<2	44
post-test @ 4^{o}C	90	1.07	60	110	1.11	<5	40
post-test @ RT	90	1.04	80	125	1.11	<5	40
TAILINGS							
pre-test	>10000	1.17	47	75	0.75	6	84
post-test @ RT	10670	1.07	50	80	0.72	10	90

Note: RT = room temperature of approx. 22 ^{o}C

Table 2: ABA Data (Klohn, 1998)

Sample	Paste pH	% Total S	% S (Sulfate)	AP kg/t	NP kg/t	NNP kg/t	NP/AP (NPR)	Carb-NP kg/t
ORE								
pre-test	8.70	1.14	<0.01	35	32	-3	0.9	6
post-test @ 4°C	9.21	1.14	<0.01	35	31	-4	0.9	5
post-test @ RT	8.97	1.22	<0.01	38	25	-13	0.7	5
WASTE ROCK								
pre-test	9.32	1.17	<0.01	36	28	-8	0.8	4
post-test @ 4°C	9.31	1.19	<0.01	37	28	-9	0.8	6
post-test @ RT	9.16	1.17	<0.01	36	25	-11	0.7	4
TAILINGS								
pre-test	8.12	1.63	<0.01	51	49	-2	1.0	9
post-test @ RT	8.56	1.55	<0.01	48	45	-3	0.9	8

Notes: AP = Acid Potential in kg $CaCO_3$/tonne
NP = Neutralization Potential in kg $CaCO_3$/tonne
NNP = Net Neutralization Potential in kg $CaCO_3$/tonne = NP – AP
Carb-NP = Carbonate NP in kg $CaCO_3$/tonne, calculated from carbonate analysis

The two ore, two waste rock and one tailings humidity cells were run for either 40 or 41 weeks. The two field column tests were run for one complete cycle of changing seasons, yielding three data points. Results as reported in Klohn (1998) are summarized below.

3.2.1 Summary of Coarse Ore Kinetic Test Results

Table 3 compares the results of weathering of Ulu ore under different conditions, as provided in Klohn, 1998:

Table 3: Results of Weathering of Ulu Ore under Different Conditions
(from Klohn, 1998)

	Cell @ 4°C	Cell @ 22°C	Field Column #1	Field Column #2
S depletion rate (mM/kg/week)	0.012	0.052	0.004	0.004
NP depletion rate (mM $CaCO_3$/kg/week)	0.060	0.116	Not calculated due to remnant salt	
Time for S depletion (years)	563	132	1707	1726
Time for total NP depletion (years)	102	53	Not calculated	
As loading rate (mg/kg/week)	0.01 to 0.063 decreasing with time	0.01 to 0.153 decreasing with time	0.001 to 0.004	0.001 to 0.003
Zn loading rate (mg/kg/week)	0.01 to 0.0961 erratic	0.0006 to 0.1061 erratic	0.0002 to 0.0009	0.0002 to 0.0004

Klohn, 1998 stated that "the sulphide-sulphur depletion rate for the humidity cells was calculated based on the average sulfate release rate measured between weeks 10 and 30 and since the sulphate production rates appear to slowly decrease with time this may have resulted in an underestimate of the time to deplete all sulphides. For the field columns, the sulphide sulphur depletion rate was obtained by dividing the cumulative sulphate release rate by 52 weeks. The NP depletion rate was calculated from the total weekly release, on a molar basis, of Ca+Mg+0.5Na+0.5K." It was noted that salt water had been used as a drilling fluid which apparently contaminated the ore sample (Klohn, 1998). For the humidity cell, the NP depletion rates were measured from weeks 10 to 30 when all the remnant salts had been leached, however, the field columns still contained remnant salts, therefore NP depletion rates could not be calculated.

Both humidity cell tests, at 4°C and 22°C, suggested that the coarse ore sample would eventually become acidic, with NP being depleted prior to sulphide, although the lag times for these samples to produce acidic drainage were estimated to be lengthy (50 to 100 years).

Metal loading or leaching rates from the coarse ore were noted as being much lower in the field tests as compared to the humidity cell tests. This was attributed to the lower average reaction temperature and the lower frequency of flushing events under field conditions. Arsenic and zinc loading rates were highlighted.

3.2.2 Summary of Fine Ore Kinetic Test Results

Table 4 shows the results of humidity cell testing of prospective Ulu tailings (fine-grained portion <1.5 mm fraction of bulk ore composite) at 22 ^{o}C as presented in Klohn, 1998:

Table 4: Results of Weathering of Prospective Ulu Tailings (Fine-Grained Ore) at Room Temperature (Klohn, 1998)

	Cell @ 22^{o}C
S depletion rate (mM/kg/week)	0.119
NP depletion rate (mM $CaCO_3$/kg/week)	0.305
Time for S depletion (years)	82
Time for total NP depletion (years)	31
As loading rate (mg/kg/wk)	0.28 – 0.61 (decreases slightly)
Zn loading rate (mg/kg/wk)	0.001 – 0.209 (erratic)

The following summary of the results of weathering of Ulu tailings at room temperature were extracted from Klohn 1998:

> "Compared to the weathering of Ulu ore under the same conditions, the sulfate depletion rate is twice as fast and the NP depletion rate nearly three times faster. Thus even though the tailings contains more sulfides and has a higher NP than the Ulu ore, it takes less time for the tailings to exhaust its sulphide content and NP than the coarser-grained ore. It is estimated that net acid generation will occur in about 30 years if the tailings is subjected to weathering at room temperature. The calculated As loading rates are at least four times higher than those calculated for the Ulu ore while the erratic Zn release rates are only two times higher. Evidently, grain size plays a significant role in mineral weathering and associated metal leaching."

3.2.3 Summary of Waste Rock Kinetic Test Results

Table 5 compares the results of weathering of Ulu waste rock under different conditions (from Klohn, 1998):

Table 5: Comparison of the Results of Weathering of Ulu Waste Rock Under Different Conditions (Klohn, 1998)

	Cell @ 4^oC	Cell @ 22^oC
S depletion rate (mM/kg/week)	0.010	0.044
NP depletion rate (mM $CaCO_3$/kg/week)	0.079	0.087
Time for S depletion (years)	698	159
Time for total NP depletion (years)	68	62

No significant release of trace elements was detected in the waste rock leachates (Klohn, 1998). Klohn (1998) states that "similar to what has been observed in the weathering of Ulu ore samples, temperature does not greatly affect the NP depletion rate but the sulphide-S depletion rate at room temperature is four times as high as that obtained at 4^oC. On a molar basis, NP depletion proceeds faster than sulfide oxidation under both temperature conditions. Thus, although the waste rock composite has a NPR of about 1, sustained weathering will eventually lead to net acid generation. This will occur in about 60 years with weathering at room temperature and about 70 years at 4^oC."

3.2.4 Conclusions from Kinetic Test Results

The following conclusions arising from the kinetic tests was taken from Klohn, 1998:

> "From the weathering of the Ulu composites [in humidity cells] under different settings, it is evident that temperature affects the rate of sulfide oxidation more than that of the depletion of neutralization potential (NP) in a sample. Since NP depletion has invariably occurred faster than sulfide oxidation, only materials with a neutralization potential ratio (NPR) of greater than 3 will not lead to net acid generation with prolonged weathering at 22^oC. Under colder conditions, the NPR required to eliminate the possibility of ARD can be as high as 7. However, in the latter case, the amount of acid released on an annual basis is so low that it should not cause any significant impact.
>
> A lower average reaction temperature and a lower frequency of flushing events account for the relatively low sulfide oxidation and metal leaching rates observed with the field-column testing of the Ulu ore compared to the humidity cell testing results. Metal leaching with the Ulu waste rock is largely insignificant but variable amounts of As and Zn can be leached from the Ulu ore depending on the grain size of the test sample, the ambient temperature for reaction and the frequency of flushing. Based on the kinetic test results, it is estimated that stockpiling of coarse ore at the Ulu site up to 50 years will not lead to net acid generation or intense metal leaching. To avoid unnecessary metal leaching problems, however, it is

recommended that ore temporarily stockpiled at the Ulu site should not be pulverized to less than 1.5 mm in diameter."

Recommendations for further work included:

- Extension of the field test program for another two years, since insufficient data was collected from the field columns to establish long-term trends.
- That additional samples be collected from the deeper parts of the deposit for testing (including kinetic tests), as testing had been limited to samples collected from the shallow parts of the Ulu deposit.

3.3 Discussion of Previous ARD Assessments

3.3.1 Representativeness of Kinetic Test Samples

MEMI reviewed the Klohn 1996 static test database to compare ore and waste rock characteristics to the materials selected for the humidity cell and field column tests discussed above. The 1996 database contained 10 samples described as ore or as being from a mineralized zone, and 37 samples that could be classified as waste rock. The range and average of these materials are shown on Table 6. Humidity cell sample characteristics are also shown in Table 6, and in more detail on Table 2.

Table 6 indicates that the total sulphur content of the coarse ore sample used in the kinetic tests was higher than the mean of the 10 samples from the ore or mineralized zone database. This confirms Klohn's 1998 contention that the humidity cell test samples can be considered 'high sulphide' samples, although several individual ore samples displayed higher sulphide content. As well as displaying higher sulphur content, the coarse ore sample also displayed slightly higher NP than the mean of the 10 ore samples in the database. The NNP result of -3 kg/t and NPR of 0.9 for the ore sample was the same or similar to the mean result of -3 kg/t NNP and 0.8 NPR for the 10 ore and mineralized zone samples in the database.

The fine ore or tailings sample also displayed similar NNP and NPR values. However, the sulphur content was at the higher end of the ore database range, at 1.63%, and the NP was greater than the ore database range, at 49 kg/t.

Given the characteristics of the coarse ore and fine ore or tailings samples, the humidity cell and field tests are likely to provide reasonable worst case results, rather than average or expected results.

The waste rock composite used in the kinetic tests had a total sulphur content of 1.17% which was significantly higher than the mean of 0.68% for 37 waste rock sample results presented in Klohn 1996. This again confirmed Klohn's 1998 contention that the humidity cell test samples can be considered 'high sulphide' samples, although several individual waste rock samples displayed higher sulphide content. The NP of the waste