MEMO

To:	Denis Cimon, Canadian Malartic	From:	Ron Nicholson
			Sarah Barabash
Ref:	**Preliminary Review of the Canadian Malartic ABA Geochemistry and Mine Waste Management Plans**	Date:	17 November 2014

EcoMetrix Incorporated was retained by the Canadian Malartic Corporation to provide a third-party independent review of the geochemical conditions of, and management plans for, mine waste at the Malartic mine. The review was planned in 2 phases, with the focus of this memorandum on Phase 1. This initial review phase was intended to provide a preliminary assessment with a focus on high level issues that may be material to risk management and permitting activities that are in progress for the mine expansion.

There are several data sets that begin with the original environmental assessment (EIE) initiated in 2008 for the Malartic mine. A summary of the available data sets is provided in the following table. The Golder (2014 draft report) static data set, including ABA analyses is the most recent and comprehensive with respect to the planned mine expansion and therefore it was the focus of this preliminary data assessment.

Year Initiated	Data Types	Organization
2008	Static Kinetic (Humidity Cells)	Osisko Internal (EIE) SGS (data files)
2008	Static Kinetic (Humidity Cells and Columns)	URSTM (2013 Report)
2014	Static (3 deposits and all important rock types)	Golder (2014 draft report)

Golder Associés Ltée, 2014. Programme De Caractérisation Géochimique 2012-2013, Mine Canadian Malartic, Malartic, Québec, Rapport Préliminaire pour Canadian Malartic.

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This memo represents preliminary considerations on the acid generating potential of mine waste at the Malartic mine based on the static acid base accounting (ABA) data in the Golder (2014) draft report. The kinetic data from the SGS humidity cells were also reviewed at a screening level to estimate metal leaching rates and contact water chemistry, as well as sulphide and carbonate depletion rates. A more detailed assessment of the complete data, including other data files will be addressed within Phase 2 of this review.

Objective

The overall objective of this review is to provide an independent opinion on the risks associated with the management and storage of waste rock and tailings that will be produced from the Malartic mining operation in the context of the acid rock drainage and metal leaching (ARD-ML) potential of these materials. The overall review will address these risks from two perspectives. The first perspective will consider the regulatory requirements, as outlined in Directive 019, in terms of applicable guidelines and engineering controls that may be associated with the mine waste materials. The second perspective will focus on potential water quality effects that represent environmental, as well as financial, risks. The second represents a more holistic approach and will provide an evaluation of potential issues and management strategies in terms of modern standards of practice for mine waste management.

This preliminary assessment considered the second perspective that considers risk associated with waste management and focused on the ABA characteristics of these materials only. The assessment of the ABA data in the Golder draft report is presented in the context of the prescribed criteria in Directive 019 for potentially acid generating wastes, to be consistent with the regulatory jurisdiction. In addition to the Directive 019 results and interpretation, this preliminary review considered more recent approaches being applied in Canada and internationally as presented in the Mine Environment Neutral Drainage (MEND) Prediction Manual (Price, 2009). The professional experience of the authors and the numerous mining projects completed by EcoMetrix was also incorporated as part of this review where relevant.

ABA Data

Waste Rock

A total of 304 samples were submitted for ABA analysis as part of the Golder (2014) draft report. These included 245 waste rock, 41 ore and 18 tailings samples. At a

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screening level, the sampling rationale appears to be appropriate and the samples are considered to be representative of materials that will be mined during the proposed mine expansion. In this preliminary assessment, the ore samples were considered to be reasonable surrogates for "tailings" assuming that sulphide minerals will not be removed from the ore in the mill. Therefore, the following discussion focuses on waste rock and "tailings". The three deposits (Barnat, CM, Gouldie) and several rock types were sampled and considered by rock type and deposit in the Golder (2014) draft report. An overview of all samples is presented herein without consideration of rock type, in order to determine overall trends and issues. Further consideration of the deposits and rock types will be given in the detailed Phase 2 review.

The acid base accounting (ABA) characteristics are intended to provide a screening level assessment of potential risks of acid generation in mine wastes over the long term if materials are stored in conventional land-based facilities with no mitigation. The critical parameters are the acid generating potential (AP) and neutralization potential (NP) of the mine wastes. The AP is typically estimated by the sulphide content assuming all sulphide will oxidize and form sulphuric acid. The sulphide content as %S is converted to AP units by assuming that each mole of S will produce 2 moles of H^+ or acid. Therefore, %S is multiplied by 31.25 to give AP in units of the equivalent $CaCO_3$ that would be needed to consume the acid or as kg-$CaCO_3$ per tonne of mine material (kg-$CaCO_3$/t). If the sulphide content is measured correctly, the estimate of AP is typically considered to be reasonably representative of the long term potential for acid generation.

The NP can be estimated in more than one way. The concept of NP is that any acid produced by sulphide oxidation would be consumed while maintaining a neutral pH of any contact water. A mineral that is very effective at achieving this outcome is calcite ($CaCO_3$), the main component of limestone. Historically, a method to estimate NP was developed for rapid analysis in the lab and is known as the Sobek method and other modifications of the method have been used in ABA assessments since the 1970s. The method consists of the addition of an excess amount of a strong acid to a sample to consume any neutralizing solids, waiting for the reactions to occur and then back-titrating the liquid with a base to determine how much acid was consumed. The acid consumed is converted to the equivalent of $CaCO_3$ and expressed in consistent units of kg-$CaCO_3$/t. The method is relatively simple and provides consistent results.

However, the Sobek-NP can be a poor estimate for "effective" NP in some materials. There can be complexities for which the Sobek-NP overestimates or underestimates the

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effective NP. Therefore, it is becoming more common to consider the carbonate content in the solids as an estimate of effective NP (assuming that calcium and magnesium carbonates dominate). Results from the URSTM (2013) report confirmed the presence of calcite ($CaCO_3$) in waste rock and tailings samples by XRD analysis. The analysis of carbonate in solids is relatively simple with current technology and carbonate analyses are commonly completed as part of the ABA analysis package. The carbonate content as $\%CO_2$ or $\%CO_3$ is converted to NP units of kg-$CaCO_3$/t and is referred to as Carb-NP. Therefore, one of the first steps in assessing ABA characteristics of mine wastes is to compare Sobek to carbonate NP.

The Carb-NP and Sobek NP of the waste rock samples were compared in **Figure 1**. This plot includes all rock samples that were analysed for carbonate. Samples that were collected by Osisko did not include analysis for carbonate so not all waste rock samples are represented in this plot. Nonetheless, the plot shows that the two methods give well correlated results with a slope of 1 and a negative intercept. The intercept represents the amount of Sobek-NP that is not based on carbonate and that is likely not effective for maintaining neutral pH conditions in contact water. The relationship shows that the Sobek-NP will be approximately 15 kg-$CaCO_3$/t when the Carb-NP is zero. And although the slope is equal to 1, the 1:1 line shown on the plot illustrates that the Carb-NP is less than the Sobek NP on average. This trend was also apparent in the lower range of values, as shown in **Figure 2**, with values of less than 50 kg-$CaCO_3$/t. These figures also demonstrate that there can be a wide range of results for the two methods in spite of the excellent statistical correlation. Differences between Sobek-NP and Carb-NP of 25 kg-$CaCO_3$/t are not uncommon in **Figure 2**. The smaller Carb-NP values in comparison to the larger Sobek-NP values affects the interpretation of the ABA results as discussed in more detail in the following sections.

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Figure 1: Relationship between Carb-NP and Sobek-NP for the waste rock samples.
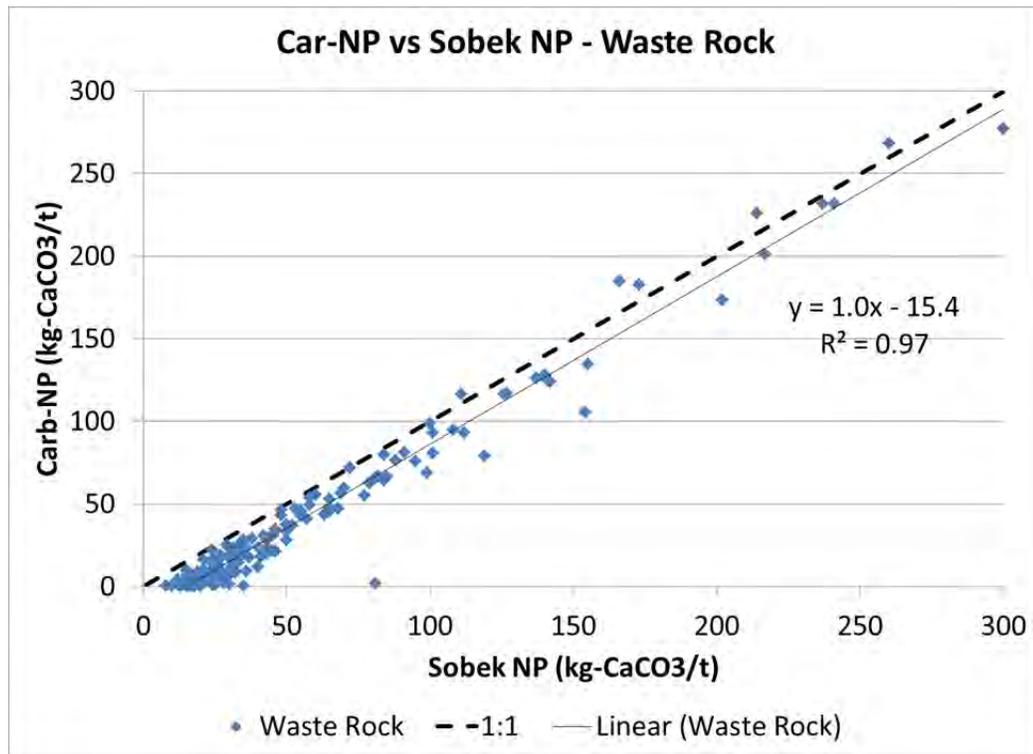
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Figure 2: Relationship between Carb-NP and Sobek-NP for waste rock samples with
Sobek-NP values less than 50 kg-CaCO$_3$/t.
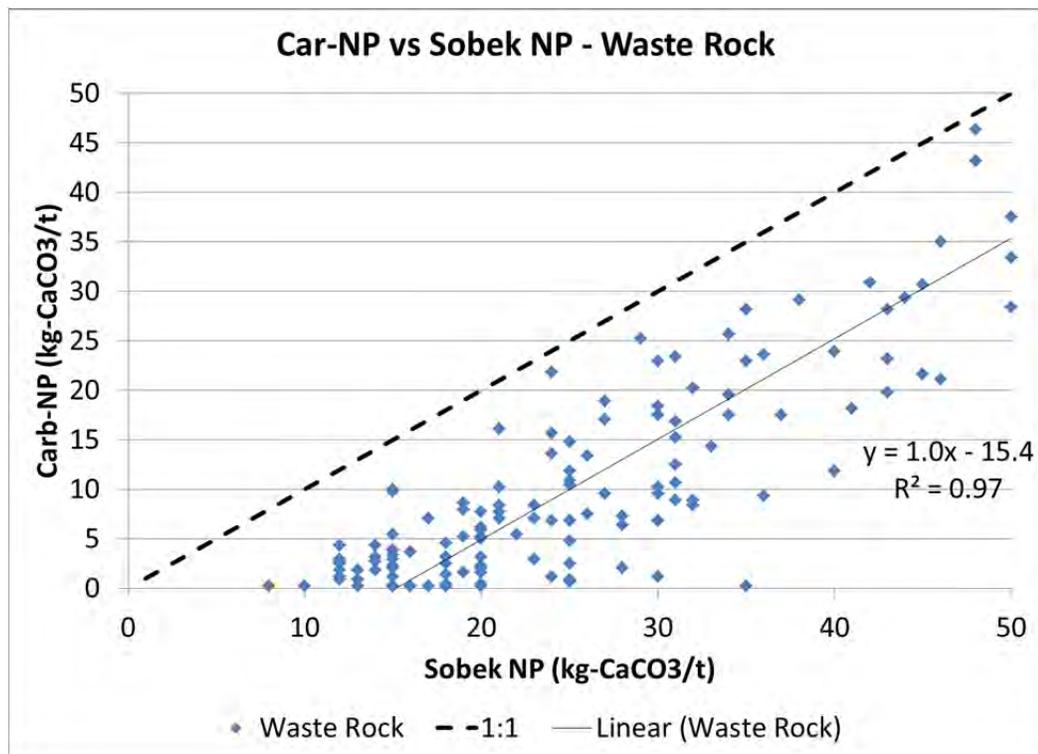
Directive 019 has specific criteria to characterize mine waste as potentially acid
generating. The values are based on guidelines developed by the British Columbia
Ministry of Mines and referred to as the BC DRAFT Guidelines for the Prediction of Acid
Rock Drainage and Metal Leaching (Price, 1997). However, these guidelines were
updated by MEND and published as Price (2009). The 2009 version is typically
considered to supersede the 1997 publication. While Directive 019 references a
neutralization potential ratio (NPR) of less than 3 to represent potentially acid generating
(PAG) materials using Sobek-NP values, the more recent approach utilizes an NPR of
less than 2 to represent PAG materials, if the NP is effective (eg. Carbonate).

For reference here, the plot of Sobek-NPR versus sulphide content is shown in **Figure 3**.
This plot is similar to that in the Golder (2014) report without specifying rock type. The

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horizontal line with an NPR value of 2 is included for reference. By definition, samples
with NPR values less than 1 are almost certainly PAG materials. Samples with NPR
values greater than 2 would be classified as non-PAG if the NP is all usable or effective.
Samples with NPR values in between 1 and 2 have some uncertainty. Using these
criteria, only 4% of the rock samples would be classified as PAG and another 22% would
have an uncertain classification. As discussed above, however the Sobek-NPR may not
be a good estimator of PAG material with these rock materials.

Figure 3: Relationship between Sobek-NPR and sulphide content for all rock samples.
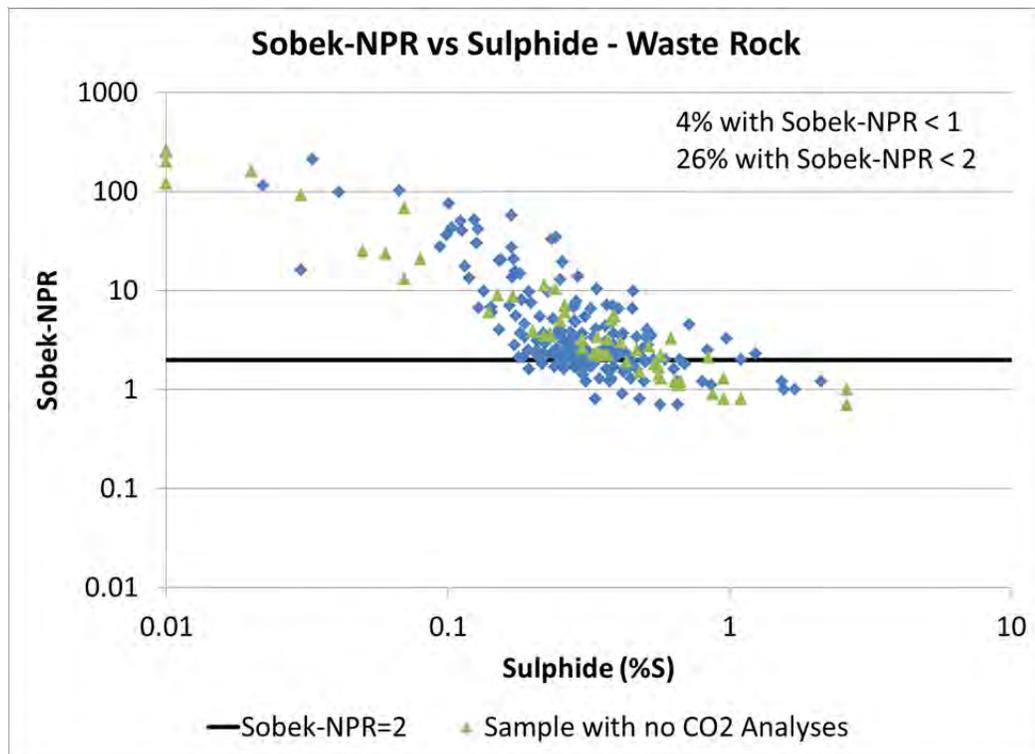
Figure 4 illustrates the relationship between Carb-NPR values and sulphide sulphur
contents for all rock samples that were analysed for carbonate. This plot is quite
different from the Sobek-NPR plot. By applying the Carb-NPR criteria, almost 50% of
the samples would be classified as PAG, with NPR values of less than 1. Another 20%
would be classified as uncertain and only 35% will be non-PAG. The relative proportions

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of PAG and uncertain material is somewhat lower than that identified in the Golder (2014) draft report using Directive 019 criteria, however the conclusions are similar in that a substantial quantity of the rock is at risk of being PAG in the long term.

Figure 4: Relationship between Carb-NPR and sulphide contents for rock samples with carbonate analyses.
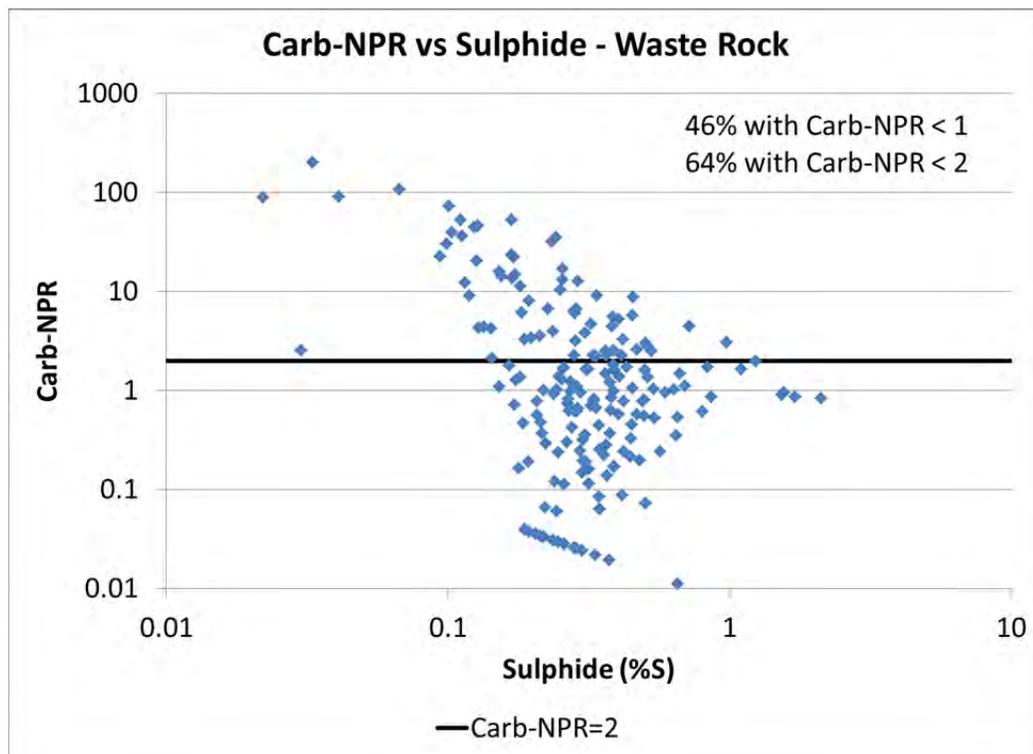
Tailings

A similar analysis was completed for the tailings, using the ore samples as a surrogate for the tailings. Once again, the Carb-NP was compared to the Sobek-NP as illustrated in **Figure 5**. The results are very similar to those observed for the waste rock. The Carb-NP values are lower that the Sobek-NP values for the majority of samples, with the slope of the correlation equal to one and the intercept equal to 16 kg-CaCO$_3$/t. Sample results from the tailings impoundment and the concentrator were also included in **Figure 5** and were not significantly different from those of the ore. As indicated previously for

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the waste rock, the Sobek-NP test results likely overestimate the effective NP of the tailings.

Figure 5: Relationship between Carb-NP and Sobek-NP for tailings and ore samples.
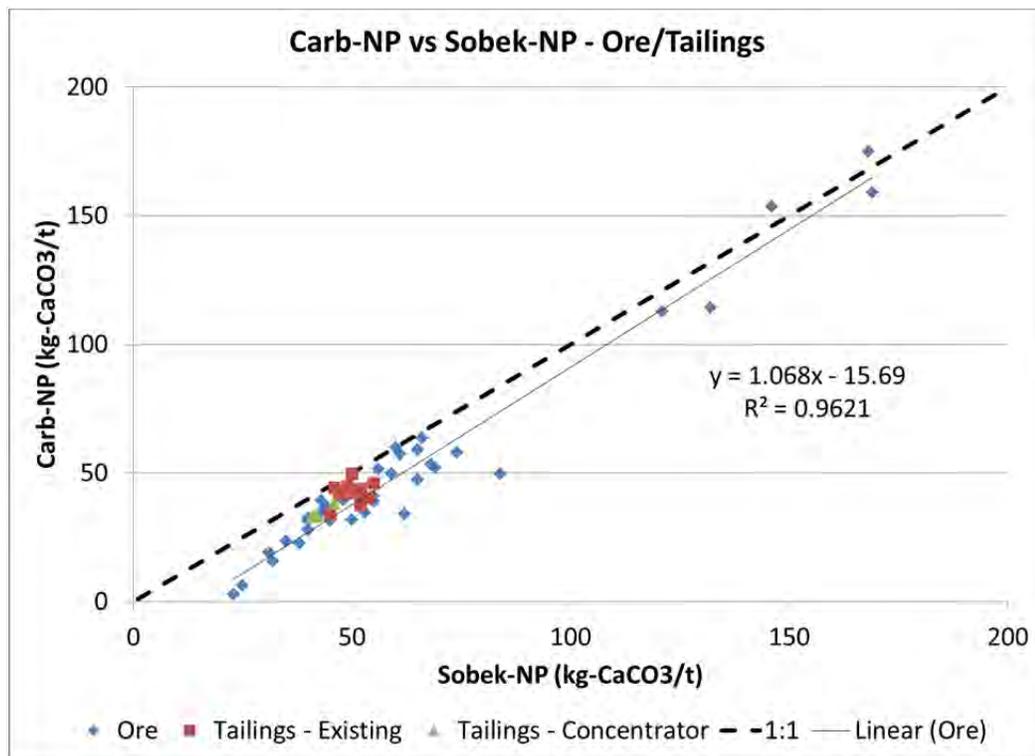
The relationship between the Sobek-NPR values and the sulphide contents is shown in **Figure 6** for reference to the Golder (2014) draft report. The majority of samples have NPR values of less than 2 and would therefore be classified as PAG or uncertain.

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Figure 6: Relationship between Sobek-NPR values and sulphide contents for tailings and ore samples.
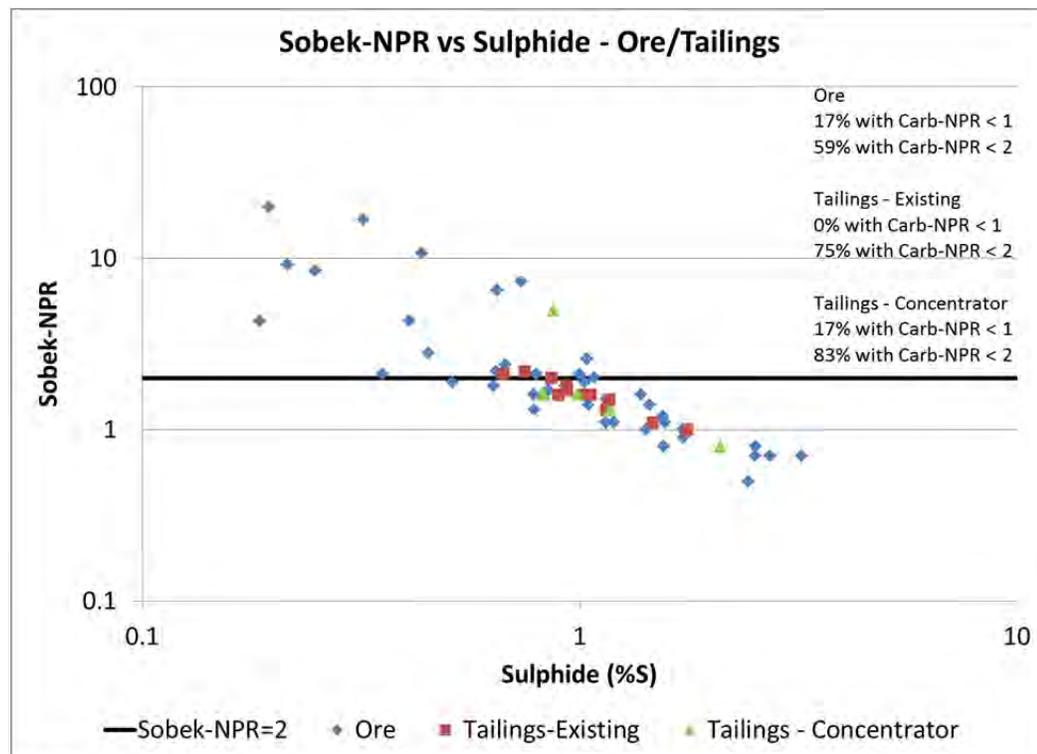
The relationship between Carb-NPR values and sulphide contents for the ore and tailings samples is presented in **Figure 7**. Approximately 80% of the ore samples and 100% of the tailings samples have Carb-NPR values less than 2 and would be classified as PAG or uncertain.

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Figure 7: Relationship between Carb-NPR and sulphide contents for the ore and tailings samples.
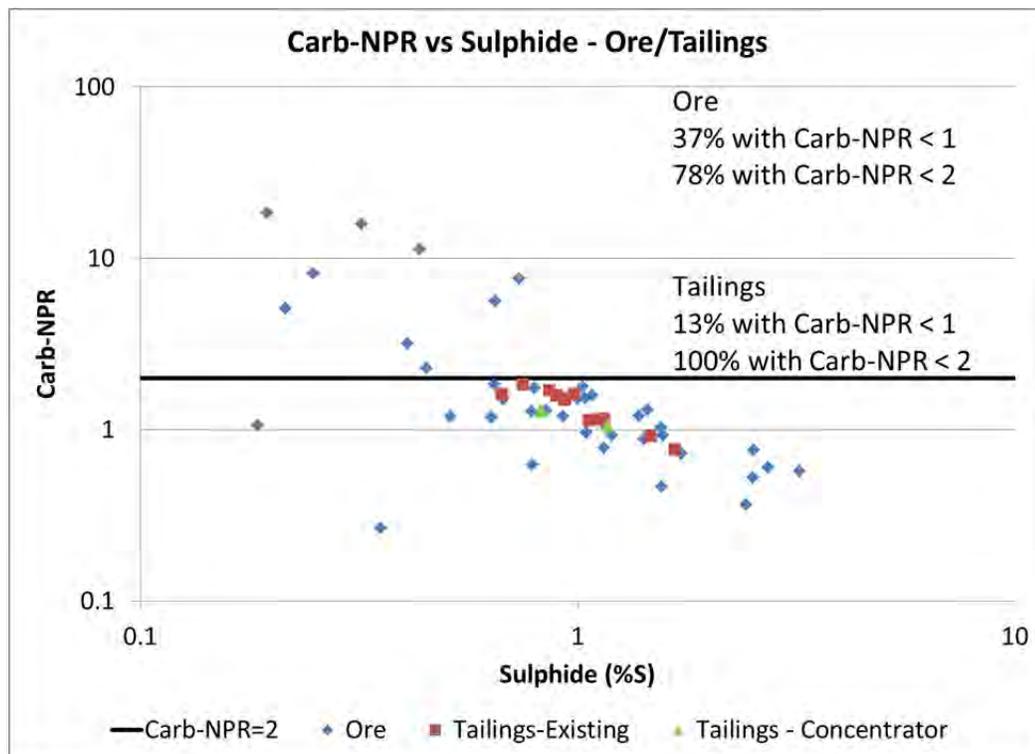
Carbonate and Sulphide Depletion Times

As sulphide minerals oxidize, the sulphide is depleted and the local acid produced is neutralized by the dissolution of carbonate minerals. Even for PAG materials, the pH of the rock drainage or contact waters should remain near neutral until the carbonate is depleted in the solids. The rates of sulphide and carbonate depletion can be estimated from the humidity cell data and the initial mineral contents of the solids. The sulphide depletion rates were calculated from the sulphate loading rates given by the humidity cells and adjusted to field conditions. Similarly, the carbonate depletion rates were estimated from the alkalinity loading rates given by the humidity cells. For these calculations, it was conservatively assumed that only 20% of the total sulphide and carbonate contents in the waste rock were available for reaction and that the remaining

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80% will remain locked into the larger rock fragments and unavailable for weathering reactions.

The sulphide and carbonate contents in the waste rock solids represent the median values given by the ABA test results. Depletion time calculations are summarized in **Table 1** and are organized by rock type to reflect the associated variations in the sulphide and carbonate contents. The depletion times should be considered as order of magnitude estimates and that local conditions within the rock materials may result in shorter or longer depletion times.

Table 1: A summary of median sulphide and carbonate contents and their estimated depletion times based on humidity cell results adjusted for field conditions.

Percentage of Rock Inventory	Material	Total Sulphide	Total CaCO3	Available Sulphide	Available CaCO3	Sulphide Depletion Time	CaCO3 Depletion Time
%		mg/kg	mg/kg	mg/kg	mg/kg	(a)	(a)
48	AGR	2980	3636	596	727	1021	24
16	CGR	3750	29318	750	5864	1285	197
5	CPO	2810	23636	562	4727	963	159
7	CUM-CCH	1690	80000	338	16000	579	538
1.5	IMF	5280	76364	1056	15273	1809	514
3	SCH	2420	126136	484	25227	829	848
2	SGR	6410	33182	1282	6636	2197	223
5	SPO	3740	25455	748	5091	1282	171
11	UM	1670	72955	334	14591	572	491
	TAILINGS	9580	40568	9580	40568	259	99

The results in **Table 1** show that sulphide depletion times in waste rock are on the order of hundreds to thousands of years and therefore sulphide depletion cannot likely be considered in any mitigation strategies. The shortest carbonate depletion times are on the order of 20 years for the Greywacke (ARG). This means that even though the rock is expected to produce acid in the long term, we can expect large lag times to the onset of acidification. If more than 20% of the carbonate is available, the lag times will be proportionally greater. The depletion times for carbonate in the other rock types ranges from 150 to several hundred years. Therefore we may not expect to observe the effects of net acid generation in waste rock during the mining operation or perhaps for a long period after closure for materials that are stored on land surface in traditional stockpiles.

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It was assumed that 100% of the carbonate and sulphide minerals will be available in the tailings because of the fine particle size in tailings. The leaching rates are higher in the tailings than those in waste rock. Consequently the depletion times tend to be shorter, on average, even though proportionally more sulphide and carbonate is available for reaction. As discussed in more detail in the following sections, the oxidation and depletion of sulphide and carbonate in tailings only applies to the near surface material.

The sulphide depletion time in tailings is on the order of hundreds of years (**Table 1**). The depletion of carbonate in tailings will be on the order of 100 years. Therefore, there is a long lag time expected before the potential onset of acid conditions at the surface of the tailings if placed in a typical impoundment with beached material at surface. The large lag times provide ample opportunity to implement management strategies for the tailings before acidification can occur.

Metal Leaching

The SGS humidity cell data were reviewed for this preliminary assessment. The SGS humidity cells included 3 tailings tests and 7 tests on the various waste rock and low grade ore types. These included samples of a Greywacke composite (GRWC), a low grade ore composite (LGOC), low grade Pontiac ore (LGPPC), a porphyry waste rock composite (POWC), an ultramafic waste rock composite (UMWC2), a waste rock composite (WC) and a Pontiac waste rock sample (WP). The majority of the waste rock humidity cells were in operation for a period of about 5 years. The leachate samples were analysed for a large number of constituents of potential concern (COPC), including mercury (Hg) and other constituents that can be helpful for the interpretation of results.

The results exhibited neutral pH values throughout the test period. The leachate had measureable concentrations of sulphate and alkalinity that are consistent with results for sulphide bearing waste rock containing carbonate minerals. The concentrations of many constituents were given as less that the reporting (detection) limits and the limits for most constituents were as good as or better than typical industry standards (**Table 2**). Leachate samples associated with values of less than the reporting limit values represent a complication in the interpretation of the data as will be discussed below.

As a screening method, it is useful to calculate the potential concentrations in contact water or drainage from a waste rock pile. As a first step, this was completed by assuming a configuration of the waste rock stock pile as it will be at closure. This represents a maximum loadings condition. The chemistry of the drainage is then calculated from the loadings or leaching rates from the humidity cell, adjusted for field

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conditions, and an estimated infiltration rate based on precipitation that is adjusted for evaporation and runoff. This approach assumes that the loadings of constituents mix with the infiltrating water with no other chemical processes controlling concentrations. This approach is extremely conservative but provides a preliminary basis for assessing risks to water quality. In this case, the very small concentrations in the humidity cell leachate translate to larger concentrations in the drainage water as a result of the large mass of waste rock in the stockpile (**Table 2**).

Table 2 summarizes the humidity cell results and adjusted field rates together with the calculated concentrations in the contact water for the final stockpile configuration with 750Mt of rock. The table also includes a reference to the number of leachate samples with concentrations reported as less than the detection limit and comments on probable solubility controls that will override the calculated concentrations. The Directive 019 and Metal Mining Effluent Regulation (MMER) effluent limits are also included for reference. The MMER limits include the current values on the left and proposed updated values on the right. New constituents that are being considered for effluent limits but have not yet had values proposed are noted as to-be-determined (TBD). Solubility controlled constituents are considered to be low risk if the contact water remains at neutral pH.

There is some uncertainty for many of the constituents that are dominated by detection limit values. For example, copper had almost 90% of the analyses reported at less than the detection limit of 0.0005 mg/L with a resulting calculated concentration in contact water of 0.85 mg/L. If the actual copper concentrations in the leachate samples were equal to one-tenth of the detection limit or 0.00005 mg/L, the calculated concentration in the contact water would be 0.085 mg/L, a value that is less than the Directive 019 and current MMER value of 0.3 mg/L, and therefore could be considered as a low to moderate risk for water quality at the site. It should also be noted that Directive 019 and MMER values may not apply after mine closure and lower values may be required in site runoff.

The calculated contact water concentrations presented in **Table 2** suggest that there may be a few constituents that represent a moderate risk to water quality and those are shown as light shaded values in the table. Some of these constituents such as zinc, that were dominated by detection limit values in the humidity cell leachate samples may also represent some risks but it is difficult to define this risk based on the available data. These risks relate to closure conditions and not necessarily to operating conditions.

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Table 2: Summary Humidity Cell Concentrations, Field Loading Rates and Calculated Concentrations in Contact Water for Waste Rock Contained Within Rock Stockpiles.

Constituent	Humidity Cell mg/L	Estimated Field Rate g/t/a	Estimated Contact Water mg/L	Dir 019 (Effluent) mg/L	MMER mg/L	Less than Detection Limit %	Comments
Sulphate (SO4)	0.53	1.9	752				
Alkalinity (as CaCO3)	9.0	32	12767				Solubility Controlled
Calcium (Ca)	2.8	10	3951				Solubility Controlled
Aluminum (Al)	0.022	0.08	31		-/TBD	0%	Solubility Controlled
Antimony (Sb)	0.00068	0.002	0.97			27%	
Arsenic (As)	0.00037	0.001	0.5	0.2	0.5/0.1	49%	Detection Limits
Cadmium (Cd)	0.00001	0.00003	0.01			70%	Detection Limits
Chromium (Cr)	0.0005	0.002	0.7			99%	Detection Limits
Cobalt (Co)	0.00007	0.0002	0.10			16%	
Copper (Cu)	0.0006	0.002	0.8	0.3	0.3/0.05	89%	Detection Limits
Iron (Fe)	0.003	0.01	4.3	3	-/TBD	96%	Solubility Controlled
Lead (Pb)	0.00003	0.0001	0.04	0.2	0.2/0.05	35%	Solubility Controlled
Manganese (Mn)	0.009	0.03	13			0%	
Mercury (Hg)	0.00001	0.00004	0.02			96%	Detection Limits
Molybdenum (Mo)	0.0003	0.001	0.4			2%	
Nickel (Ni)	0.0001	0.0005	0.2	0.5	0.5/0.25	49%	
Selenium (Se)	0.001	0.004	1.4		-/TBD	100%	Detection Limits
Vanadium (V)	0.0001	0.0004	0.2			0%	
Zinc (Zn)	0.002	0.007	3	0.5	0.5/0.25	88%	Detection Limits
Notes:							
low risk at netral pH							
Moderate risk							
MMER shown as current value/proposed value (0.5/0.25)							
TBD - to be determined - Values are being considered for revised MMER							

The loadings from the waste rock contact waters that are transported by infiltration and drainage through the rock will be somewhat proportional to the mass of rock in the stockpile for those constituents that do not have solubility controls or that will not be chemically attenuated within the rock pile or along the drainage pathway. The calculated concentrations in the contact water can be prorated to the inventory of rock during the operation. During operations, the mine will be producing waste rock at a rate of approximately 50 Mt per year. Therefore, the calculated concentrations can be compared to the effluent limits over time to assess potential risks as the waste rock accumulates. The calculated concentrations in the contact water for the waste rock stockpile over time are summarized in **Table 3**.

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If arsenic and copper are considered as water quality risks, these results suggest that concentrations may approach the Directive 019/MMER values near year 6 of the operation with about 300 Mt of rock stockpiled. In reality, the stockpile will require time to wet up to field capacity (the moisture content that allows gravity driven drainage) and there is typically a delay in water flow as drainage from waste rock stockpiles and therefore the actual effects on the site runoff may be delayed beyond that time. Nonetheless, the conservative estimates suggest that there may be requirements to manage water from the stockpile during the operation.

Table 3: Calculated Concentrations in Waste Rock Contact Water During Operations.

Waste Rock (Mtonnes)	54	161	321	482	643	750
YEAR	1	3	6	9	12	14
Constituent	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
SO4	54	161	322	483	644	752
Alkalinity (as CaCO3)	912	2736	5472	8207	10943	12767
Ca	282	847	1693	2540	3387	3951
Aluminum (Al)	2	7	13	20	27	31
Antimony (Sb)	0.07	0.2	0.4	0.6	0.8	1
Arsenic (As)	0.04	0.1	0.2	0.3	0.4	0.5
Cadmium (Cd)	0.001	0.003	0.005	0.008	0.01	0.01
Chromium (Cr)	0.05	0.2	0.3	0.5	0.6	0.7
Cobalt (Co)	0.007	0.02	0.04	0.06	0.08	0.1
Copper (Cu)	0.06	0.2	0.4	0.5	0.7	0.8
Iron (Fe)	0.3	0.9	2	3	4	4
Lead (Pb)	0.003	0.008	0.02	0.02	0.03	0.04
Manganese (Mn)	0.9	3	6	8	11	13
Mercury (Hg)	0.001	0.003	0.007	0.01	0.01	0.02
Molybdenum (Mo)	0.03	0.1	0.2	0.3	0.4	0.4
Nickel (Ni)	0.01	0.04	0.08	0.1	0.2	0.2
Selenium (Se)	0.1	0.3	0.6	0.9	1	1
Vanadium (V)	0.01	0.04	0.08	0.1	0.2	0.2
Zinc (Zn)	0.2	0.6	1	2	2	3

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Discussion

Waste Rock

It is clear that management and mitigation strategies should be considered for waste rock at the Malartic mine in order to avoid future water quality effects. The first aspect relating to these management strategies is related to ABA characteristics and the potential onset of acid generation and the second is related to metal leaching. The large proportion of potentially acid generating waste rock will focus mitigation strategies to methods amenable to these large tonnages contained within the stockpile.

Segregation of rock types with PAG criteria can be useful when there are options for selective placement of materials. For example, PAG materials can be placed in mined-out pits if pit storage is available during mining of other deposits on-site and should be considered for Malartic. Identification of PAG material is straight forward and practical and can therefore be aligned with assay procedures on the blast hole cuttings. Simple criteria can be based on total sulphur and total carbon contents using an on-site induction furnace analyzer that can provide results in the same time frame as the ore assays. Regardless of the plans to segregate waste rock into PAG and non-PAG classes, the on-site analysis of sulphur and carbon should be considered in order to further define the characteristics of the materials being stockpiled. This information may be useful in developing future management strategies and is more cost-effectively obtained during the mining operation than at a later date when drilling and sampling of these materials, as placed within the stockpile, will be required.

In the absence of other mitigation strategies, a "dry" cover may be applicable to the waste rock stockpile. The cover can be designed to limit oxygen access to the rock as well as to minimize infiltration. A cover will likely require modification to side slopes on the rock pile.

One option for cover material is low sulphur tailings (discussed below). Typical mining plans include milling of stockpiled ore at the end operation. This results in tailings production after waste rock production has ceased. The excess tailings could be directly deposited on the rock stockpile. If thickened, tailings tend not to segregate upon deposition and can have excellent moisture retaining characteristics.

Options to manage metal leaching may also be available. However, the data used to assess metal leaching is limited to a few humidity cells and required some uncertain scaling adjustments to reflect field conditions. It is therefore highly recommended that

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the operation consider field test cells with run-of-mine waste rock in order to obtain more robust data in order to evaluate metal leaching and potential contact water quality under field conditions. An example of field test cells with approximately 100 tonnes of waste rock included within each cell is shown in **Figure 8**. These can be constructed on site and managed by on-site personnel. Test cell design, standard operating procedures (SOP) and interpretation can be provided.

Figure 8: Example of One-Hundred Tonne Waste Rock Test Cells with Leachate Collection Tanks.

During operation, there may be opportunities for limiting the available sulphide material and the degree of metal leaching by controlling the fines in the waste rock. As discussed in the section on sulphide and carbonate depletion times, not all of the sulphide or carbonate is expected to be available in the waste rock. It is understood that the rock materials at Malartic are very hard and competent. This implies that larger fragments will not break down physically during or after placement or as a result of weathering. That means that sulphide minerals in larger fragments of rock may be naturally isolated from weathering by the rock and that only a small fraction of the sulphur in the large fragments will be susceptible to oxidation. This can limit the loadings and acid production rates even if materials do generate acid because the finer fractions are responsible for controlling leaching rates and therefore the loadings of acidity and metals as well. If water management is required, minimizing loading rates can have important implications for operating costs. Minimizing the fines in a waste rock stockpile can act to minimize leaching and loading rates.

One strategy for managing fragment size is blast control. If practical, blast fragmentation of waste can be adjusted to minimize the production of fines. Controlling the formation

Reference: Preliminary Review of the Canadian Malartic ABA Geochemistry and Mine Waste
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of fines either by adjusting blast procedures or during material handling can have a substantial effect on leaching and therefore also on the concentrations in contact waters during operations and in the long term.

Tailings

The tailings represent a risk of generating acid if stored in a conventional impoundment without any mitigation. However, because of the nature of tailings weathering and an acid base balance that is not greatly skewed, there are several mitigation options to manage the tailings. The aspect of timing is also reasonable because mitigation may only be required for the topmost few metres of tailings that are susceptible to oxidation and therefore to acid generation. Tailings are self-isolating with respect to oxygen and the material below a few metres is typically not subject to oxidation because of the oxygen-barrier effect of the elevated moisture content in tailings. This is especially evident in thickened tailings that do not segregate by grain size during deposition and that have the ability to retain very high moisture contents.

One option is to add a sulphur removal circuit to the mill. Sulphur removal by flotation is a practical and efficient method of reducing the sulphide content and producing a non-PAG tailings. Because of the need for this material on the top few metres of tailings but not necessarily in the deeper tailings, the circuit could be constructed and commissioned during operation allowing for sufficient tailings production to have an adequate layer of low-sulphur tailings on the surface. Testing and further evaluation would be required to determine the level of sulphur removal required and the thickness of the top layer of low sulphur tailings needed to prevent oxidation. Experience shows that the sulphur concentrate would likely represent about 10% or less of the total tailings and would be managed as a separate stream. The concentrate could be stored to be permanently under water either in a pond, such as a flooded pit, or under the water table below low sulphur tailings.

Another option that may be considered without sulphur removal is an NP amendment to the tailings in the mill. This could be accomplished by adding crushed limestone to the tailings before discharge. The limestone amendment would be designed to provide an acceptable Carb-NPR value to the tailings. With the average characteristics of the tailings assessed in this review, about 40 kg-$CaCO_3$/t would be required to get the Carb-NPR to a value of one and 90 kg-$CaCO_3$/t would be required to attain a value of 2. In this case, only the top 1 metre or less of tailings will require the NP amendment. It has been shown that only the very top of the tailings requires protection from acidification if

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there is sufficient carbonate at depth to consume any acid that migrate downward with infiltration. The amendment at surface protects the runoff from becoming acidic and therefore protects the quality of runoff. If small amounts of acid are produced below the amended layer, the downward moving infiltration will encounter excess carbonate in the underlying tailings and will be neutralized. The details of such a design would need to be developed in detail, but this is a practical approach that has been proposed or used at several other sites.

Closure

I trust that this preliminary assessment of the Canadian Malartic mine wastes meets your immediate needs. Please do not hesitate to contact either of us with any questions or comments you may have.