D11 SURFACE WATER QUALITY EFFECTS ASSESSMENT UPDATE

MARATHON PALLADIUM PROJECT – WATER QUALITY ASSESSMENT UPDATE

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MARATHON PALLADIUM PROJECT – WATER QUALITY ASSESSMENT UPDATE

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EXECUTIVE SUMMARY

Ecometrix Incorporated (Ecometrix) was retained by Generation PGM (GenPGM) to provide an updated water quality assessment for the Marathon Palladium Project (the "Project"). This updated water quality assessment has been completed to inform the Addendum to the Marathon Palladium Environmental Impact Statement (EIS Addendum) as input to the Joint Review Panel process.

The quantitative approach to the assessment of potential surface water quality effects uses numerical modeling to predict water quality (that is, the concentrations of individual water quality constituents) in water courses and water bodies that receive Project related discharges. The water quality model integrates, and was developed in consideration updated information pertaining to background water quality in the study area, existing hydrological conditions, the Project water balance and the results of geochemical testing and modelling that characterize the geochemical source terms and loadings profiles that are associated with mine components.

The key results of the updated water quality analysis are as follows:

- Construction
  - Per the site water balance, contact waters associated with site aspects will be managed through site water management infrastructure during construction. No routine direct discharges to local subwatersheds, Hare Lake or the Pic River are planned during construction. The focus of water management during construction, will be the mitigation of the potential for mobilization of suspended material into natural surface water features as the result of land disturbance and clearing.
- Operations
  - During operations the primary potential water quality effect from the Project is the discharge of excess water from the site water management system to Hare Lake. No other routine discharges from the site are planned during operations. For planning purposes, the water balance has assumed discharge will occur between April and November. Rates of discharge vary within and among years according to the development of the site and Process Plant needs. In general, it is expected that between ~1 and 2 * 10^6 m^3 of treated mine water will be discharged from the site to Hare Lake per year of the operations phase of the mine.
  - Maximum predicted concentrations are not expected to exceed relevant water quality benchmarks in Hare Lake during operations. In many cases constituent concentrations are not predicted to change from background levels. In some cases (e.g., molybdenum, nitrate) constituents in Hare Lake show small

incremental increases in predicted concentrations relative to background during periods of discharge but, as indicated the concentrations remain below water quality benchmark values. For a small number of constituents (e.g., iron, aluminum), it is noted that background concentrations exceed the water quality benchmark values upon which the water quality assessment is based. For each of these constituents no change, or a reduction from background levels is predicted.

  - Based on the nature of the treated effluent to Hare Lake, no effects on the normal seasonal mixing, nor thermal regime of the lake are expected.

  - The incremental increases predicted in sediment constituent concentrations in Hare Lake are generally within the background variability seen for individual constituents in Hare Lake based on baseline data and therefore are essentially indistinguishable from existing constituent levels. The exceptions to this pattern are molybdenum and vanadium, for which greater relative increases in concentrations are predicted than for other constituents; however, no Project effects on aquatic biota would be expected.

  - No risks to ecological receptors in Hare Lake are predicted.

- Initial phase of closure

  - At the cessation of operations routine discharge of water from the site to the local environment are not planned. All contact water on the site will be managed within the water management pond and conveyed to the open pit for storage to ensure care and control while active rehabilitation of the site is underway. For planning purposes it is assumed this period will last 5 years.

- Long-term closure

Following the initial 5 year period, natural pre-mining drainage patterns will be restored to the extent possible. Water quality predictions extending over the long term indicate water quality in Hare Lake, the Pic River and local site-associated subwatersheds (e.g., subwatersheds, 101, 106) will meet relevant water quality benchmarks for the protection of aquatic life.

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1.0 INTRODUCTION

Generation PGM Inc. (GenPGM) proposes to develop the Marathon Palladium Project (the "Project"), which is a platinum group metals (PGM) and copper (Cu) open pit mine and milling operation near the Town of Marathon, Ontario. The Project is being assessed in accordance with the Canadian Environmental Assessment Act (2012) and Ontario's Environmental Assessment Act (EA Act) through a Joint Review Panel (the Panel) pursuant to the Canada-Ontario Agreement on Environmental Assessment Cooperation (2004).

Ecometrix Incorporated (Ecometrix) has been retained by GenPGM to provide an updated water quality assessment Project. This report provides an update to the water quality assessment as described in the information currently on the record.

This updated water quality assessment has been completed to inform the Addendum to the Marathon Palladium Environmental Impact Statement (EIS Addendum) as input to the Joint Review Panel process. It has been prepared pursuant to the Canadian Environmental Assessment Act, 2012 and in consideration of the Guidelines for the Preparation of an Environmental Impact Statement – Marathon Platinum Group Metals and Copper Mine Project (EIS Guidelines) (Canadian Environmental Assessment Agency (CEAA) and Ontario Ministry of Environment (MOE) (2011).

1.1 Marathon Palladium Project

The Project is located approximately 10 km north of the Town of Marathon, Ontario (Figure 1-1). Marathon is a community of approximately 3,300 people (Statistics Canada, 2017) located adjacent to the Trans-Canada Highway (Highway 17) on the northeast shore of Lake Superior approximately 300 km east of Thunder Bay and 400 km northwest of Sault Ste. Marie. The centre of the Project footprint sits at approximately 48° 47′ N latitude, 86° 19′ W longitude (UTM Easting 550197 and Northing 5403595). The footprint of the proposed mine location is roughly bounded by Highway 17 and the Marathon Airport to the south, the Pic River and Camp 19 Road to the east, Hare Lake to the west, and Bamoos Lake to the north. Access is currently gained through Camp 19 Road.

The Project is proposed within an area characterized by relatively dense vegetation, comprised largely of a birch and spruce-dominated mixed wood forest. The terrain is moderate to steep, with frequent bedrock outcrops and prominent east-west oriented valleys. Several watercourses and lakes traverse the area, with drainage flowing either eastward to the Pic River or westward to Lake Superior. The climate of this area is typical of northern areas within the Canadian Shield, with long winters and short, warm summers.

The Project is proposed on Crown Land, with GenPGM holding surface and/or mineral rights for the area. Regional land use activities in the area include hunting, fishing, trapping and snowmobiling, as well as mineral exploration (and mining) and forestry. Other localized land uses in the area include several licensed aggregate pits, the Marathon Municipal Airport, the Marathon Landfill, a municipal works yard and several commercial and residential properties.

The primary industries in the area have historically been forestry, pulp and paper, mining and tourism. Exploration for copper and nickel deposits in the area extend as far back as the 1920s. A large copper-PGM deposit was discovered in 1963. Advanced exploration programs have continued across the site since then. These programs have been supported by various feasibility studies to confirm the economic viability of extracting the deposits.

Several Indigenous communities and Métis groups were originally identified as having a potential interest in the Project based on Treaty Rights, asserted traditional territory and proximity to the Project. Traditional uses which they have identified as occurring in the area include hunting, trapping, fishing and plant harvesting, with activities generally focused on the larger waterways, such as the Pic River, Bamoos Lake and Hare Lake.

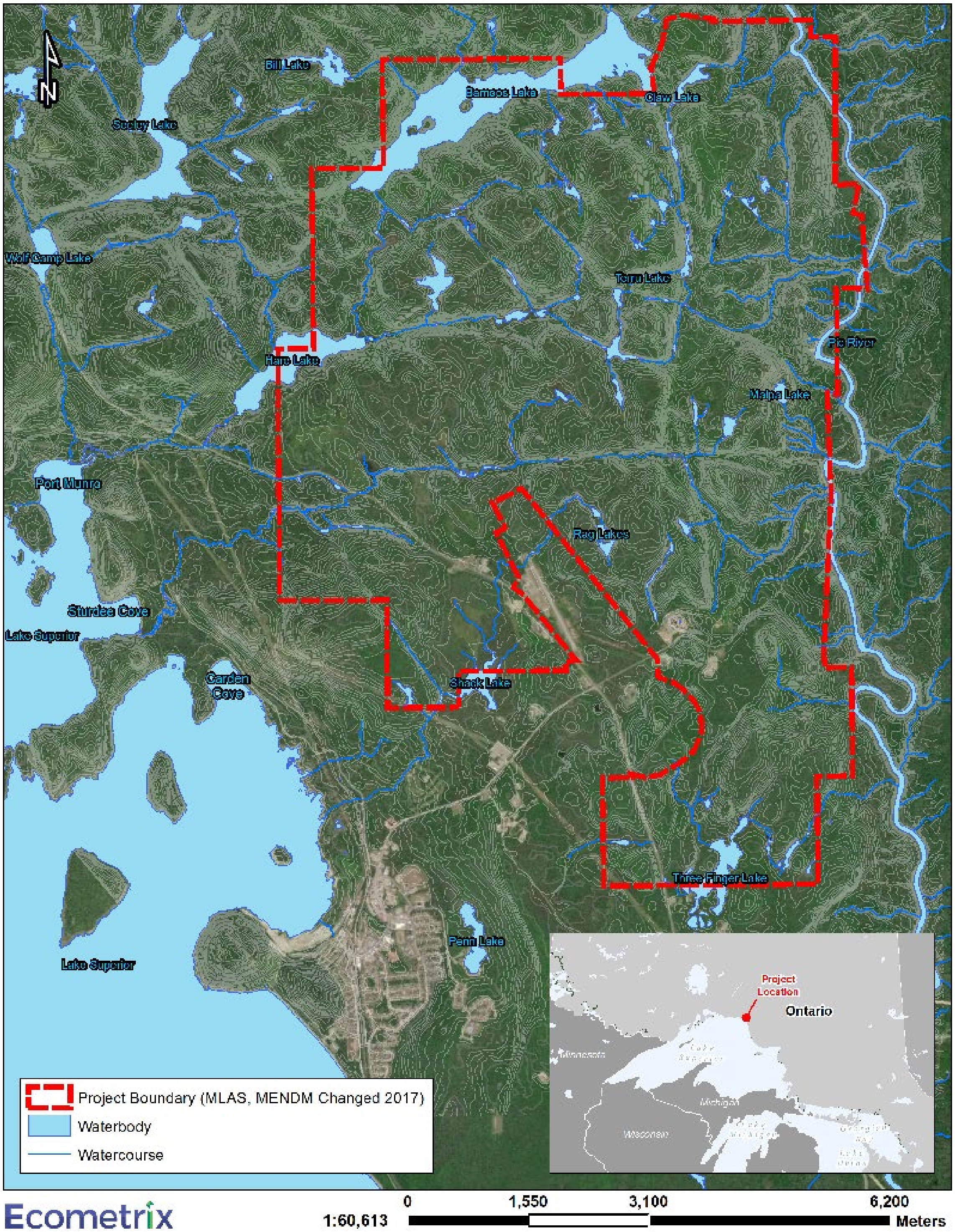

Figure 1-1: Regional Project Location

The Project is based on the development of an open pit mining and milling operation for copper and platinum group metals. Ore will be mined from the pits and processed (crushed, ground, concentrated) at an on-site processing facility. Final concentrates containing copper and platinum group metals will be transported off-site via existing roadways and/or rail to a smelter and refinery for subsequent metal extraction and separation. Iron sulfide magnetite and vanadium concentrates may also be produced, depending upon the results of further metallurgical testing and market conditions at that time.

The construction workforce will average approximately 450 – 550 people, with a peak workforce of an estimated 900 people, and will be required for between 18 and 24 months. During operations, the workforce will comprise an estimated 350 workers. The mine workforce will reside in local and surrounding communities, as well as in an accommodations complex that will be constructed off-site.

Most of the mine rock produced through mining activities is non-acid generating (non-PAG) and will be permanently stored in a purposefully built Mine Rock Storage Area (MRSA). The non-PAG rock (also referred to as Type 1 mine rock) will also be used in the construction of access roads, dams and other site infrastructure, as needed. During operations, drainage from the MRSA will be collected and pumped back to the Water Management Pond (WMP) and managed with the other contact water sources on the site. The remaining small portion of mine rock is considered to be potentially acid generating (PAG) (also referred to as Type 2 mine rock) and will be stored in the open pits or the Process Solids Management Facility (PSMF). This will ensure that drainage from the Type 2 mine rock will be contained during operations. Following closure, the Type 2 mine rock will be permanently stored below water by flooding the open pits and maintaining saturated conditions in the PSMF to prevent acid generation in the future.

Most of the process solids produced at the site will be non-PAG (Type 1 process solids) with the minority being PAG (Type 2 process solids). Both the Type 1 and Type 2 process solids will be stored in the PSMF and potentially within the open pits. In both cases, the Type 2 process solids will be managed to prevent acid generation during both the operation and closure phases of the project. Water collected within the PSMF as well as water collected around the mine site (other than the MRSA), such as water pumped from the pits or run-off collected from the plant site, will be managed within the PSMF. Excess water not needed for processing ore will be discharged, following treatment as necessary, to Hare Lake.

Access to the Project site is currently provided by the Camp 19 Road, opposite Peninsula Road at Highway 17. The existing road will be upgraded and utilized from its junction with Highway 17 to a new road running north that will be constructed to access the Project site. The Project will also require the construction of a new 115 kV transmission line that will connect to the Terrace Bay-Manitouwadge transmission line (M2W Line). The width of the transmission corridor will be approximately 30 m.

Disturbed areas of the Project footprint will be reclaimed in a progressive manner during all Project phases. Natural drainage patterns will be restored as much as possible. The ultimate goal of mine decommissioning will be to reclaim land within the Project footprint to permit future use by resident biota and as determined through consultation with the public, Indigenous people and government. A certified Closure Plan for the Project will be prepared as required by Ontario Regulation (O.Reg.) 240/00 as amended by O.Reg.194/06 "Mine Development and Closure under Part VII of the Mining Act" and "Mine Rehabilitation Code of Ontario".

1.2 Changes to the Project and Updated Project-Related Information

GenPGM has implemented a series of refinements to the Project, including mine design, project activities, and external locations/processes in order to improve the efficiency, relative to the original EIS submission, of mining operations, address changes to mining practices, and to reduce potential effects to the environment. Many of these refinements were also informed through the comments received during consultation and engagement activities for the Project. Key physical changes to the mine design, as well as process-related changes, that are relevant to the assessment of water quality effects are summarized in Table 1-1.

Table 1-1: Project-related Physical and Process Changes

Topic	2013 Project	2020 Project[1]	Rationale
General Items			
Mineral Resource Estimate (measured, indicated, inferred)	121.0 M tonnes	179.9 M tonnes	Higher commodity prices, Project optimization and improved project efficiencies.
Mine Life	11.5 years	12.7 years	Updated mine schedule based on Project optimization.
Construction Timeline	2 years	2 years	Site preparation and construction phase combined for 2020 Project, however overall timeline has not changed.
Mine Schedule	Mining sequence does not factor in need to store mine rock in the open pits.	The mining schedule has been revised to allow for the North Pit to remain operational for the life of the mine and for mining of the South Pit to be completed within the first six years of operation, followed by mining of the Central Pit.	Sequential mining of the South and Central Pits allows for the storage of Type 2 materials and Type 1 mine rock within the pits as part of routine operations (eliminates rehandling of material), thus improving Project economics and facilitating mine closure.
Pits			
Configuration	Primary pit and five satellite pit	Three open pits	This change enhances Project economics and improves the overall operational efficiency of the mine. The general location and overall footprint of the pits remain relatively consistent to the prior designs (as outlined in the original EIS (2012)), remaining along

Topic	2013 Project	2020 Project[1]	Rationale
			the eastern portion of the Coldwell Complex.
Ore Processing			
Crushed Ore Stockpile	110,000 tonnes	75,000 tonnes	Smaller crushed ore stockpile based on Project optimization.
Process Plant Throughput (Average)	22,000 tonnes per day	25,200 tonnes/day (average)	Increased Process Plant throughput based on Project optimization.
Mine Rock and MRSA			
Total mine rock	288 M tonnes	326 M tonnes	Revised mining plan based on Project optimization.
Percentage of Type 1 Mine Rock	85-90%	85-90%	No change
Volume Type 2 Mine Rock	20 M tonnes	37 M tonnes	Updated estimate based on additional mine rock sampling and a lower (more conservative) total percent sulphur cut-off for PAG mine rock (Type 2)
Drainage Areas Affected by MRSA	Subwatersheds 102, 103, and 108	Subwatersheds 102 and 103 (removed from Subwatershed 108)	Addresses concerns expressed by Indigenous communities and the public that the Project needs to be developed in a manner that is protective of the Pic River watershed.
Type 2 Mine Rock Storage	Temporarily stockpiled on the surface, then placed in open pits and covered with water or Type 1 mine rock	Placed in the PSMF or the South or Central Pits during operations. Mine rock in the PSMF will be covered by Type 1 process solids (saturated). Mine rock in the pits will be covered by water.	Improved efficiency of mining operations (reduced handling of material). Facilitates mine closure.
Process Solids and PSMF			
PSMF Storage Capacity	61 M m^3	78 M m^3	PSMF design updated to accommodate increased mine production and segregation and storage of Type 2 process solids and Type 2 mine rock
Percent of Type 1 Process Solids	85-90%	85-90%	No change
Percent of Type 2 Process Solids	10-15%	10-15%	No change
Type 2 Process Solid Storage	Stored in PSMF or Satellite pits and	Stored in PSMF and Central Pit and covered by Type 1 process solids	Revised mine plan

Topic	2013 Project	2020 Project[1]	Rationale
	covered with water or Type 1 process solids	(saturated) or covered by water, respectively.	
PSMF Configuration	Cell 1 = 5 M m^3 Cell 2 = 45 M m^3	Cell 1 = 14 M m^3 Cell 2A + 2B = 64 M m^3	PSMF design updated to accommodate increased mine production and segregation and storage of Type 2 process solids and Type 2 mine rock
Water Management Pond (WMP)	Contact water managed in the PSMF (cell 2) and reclaimed	Manage process water from the PSMF and site contact water	PMSF design revised to minimize contact water stored / managed in Cells 1 and 2.
Stormwater Management (SWM) Pond	Stormwater runoff routed to PSMF, treated as necessary and discharged to Hare Lake	SWM Pond included to manage stormwater runoff water from Process Plant area and the Aggregate Plant area. Pumped to the WMP or treated as necessary, and discharged to Hare Lake.	Manage stormwater runoff from the Process Plant area, Truckshop / Warehouse area, Laydown area and the Aggregate Plant area. Provide tertiary containment for the Process Plant area and associated pipelines (i.e., process solids and reclaim water pipelines) and Fuel Farm, ensuring that Subwatershed 101 and the Pic River will be protected in the case of an unplanned event.
Dam Height	330 to 375 masl	343 to 380 masl	Increase in PSMF storage capacity required to accommodate increase in mine production (process solids and Type 2 mine rock)
Water Management			
Process Water (water required for commissioning and operation of the Process Plant)	1.3 M m^3	1.4 M m^3	Slight increase as a result of the optimization of the WMP within the PSMF.
Process Plant Reclamation water usage	23,000 – 26,400 m^3/day	Up to 25,000 m^3/day	Thickening of Type 1 process solids prior to discharge results in a lower reclaim water requirement.
[1] Values presented for the 2020 Project are indicative of the pending 2021 Feasibility study technical report and/or as outlined in the 2020 PEA technical report. *Note: All values are considered approximate and are based on conceptual design completed for the purposes of the environmental assessment. Some values may be revised at the detailed design stage of the Project.			

1.3 Objective and Scope of the Assessment

The main objective of this investigation is to provide an updated evaluation of the potential surface water quality affects that may be associated with the implementation of all phases of the Project.

The analysis of potential effects on surface water quality that may be associated with Project activities are assessed by both qualitative and quantitative techniques, depending on the nature of the Project-environment interaction. For some interactions, such as those related to Project-pathways that are well understood in terms of mode of effect and mitigation strategies, the assessment can be conducted in a qualitative manner and still provide and high level of certainty of outcome. For other interactions, such as those related to Project-pathways that can be numerically characterized, a quantitative assessment approach is employed.

The quantitative approach to the assessment of potential surface water quality effects uses numerical modeling to predict water quality (that is, the concentrations of individual water quality constituents) in water courses and water bodies that receive Project related discharges. The water quality model integrates, and was developed in consideration various factors including:

- Background water quality information as derived from the baseline water quality update (Ecometrix, 2020) **(CIAR #722)**. This information provides the basis upon which predicted incremental changes in constituent concentrations are based.
- Background hydrological information as derived from the baseline hydrological update (Stantec, 2020) **(CIAR #722)**. This information ensures that natural flow regimes and changes therein that may be associated with the project are accurately represented in the water quality predictions.
- The site water balance that describes the manner by which water is managed (used, collected, diverted) on the site and in the mining and milling processes (KP, 2021). This information is overlain on the natural hydrological system in the study area and ultimately provides estimates of the quantities of water that will be released from the site to the environment.
- Geochemical testing and modelling results that characterize the geochemical source terms and loadings profiles that are associated with mine components, such as the MRSA and PSMF (Ecometrix, 2012, 2021a, 2021b, 2021c). This information is used as an input to the water quality model and represents the incremental change in water quality beyond background upon which final water quality predictions are based.

Generally, information presented herein that pertains to the above-referenced documents is presented at a summary level to support the water quality assessment. The reader is directed to consult those reports in the case more detailed information pertaining to those topics as necessary. The original EIS documentation, as referenced in Section 1.0, also provides relevant information.

1.4 Report Format

Following this introductory section the remainder of this report is organized as follows:

- Section 2.0 – Geochemistry of Site Aspects – describes the methods by which the geochemical characterization of mine components was conducted and the results of this testing and defines constituent loadings rates for these components.
- Section 3.0 – Project Water Balance – describes the how water is managed on-site and in the mining and milling processes during all mine life phases.
- Section 4.0 – Hydrologic Conditions in the Study Area – describes the natural hydrologic regime of water courses and water bodies associated with the Project site and effects associated with the Project.
- Section 5.0 – Modelling Approach – describes the approach to the numerical modeling of water quality on which Project-related water quality predictions are based.
- Section 6.0 – Water Quality Predictions – presents the Project-related water quality predictions by which potential Project-related effects are assessed.

References consulted in the preparation of this report are listed in Section 7.0.

2.0 GEOCHEMISTRY OF SITE ASPECTS

A summary of the geochemical characterization, as completed for mine components included in the Project is presented below. The development of source terms, or relative loadings associated with each of these components is also presented below in relation to the presentation of the modelling approach and water quality predictions provided in subsequent sections of the report.

2.1 Mine Components

The primary mine components that were evaluated as part of the geochemical investigation included:

- Mine rock;
- Process solids;
- Water from the Process Plant; and
- Rock/rubble associated with the open pits.

2.1.1 Mine Rock

A single mine rock stockpile is proposed, to be located immediately east of the primary open pit. The material permanently stored in the Mine Rock Storage Area (MRSA) will encompass an area of approximately 200 ha in footprint. The MRSA has the capacity to store all of the mine rock generated during the 12.7 year mine life. The MRSA is intended to store rock that is characterized as being Non-Potentially Acid Generating (Non-PAG) and that does not adversely affect water quality in the receiving environment. This material is referred to as Type 1 rock.

Some of the mine rock that is generated will have elevated sulphur content and has the potential to generate acidity and leach constituents if stored on land over the long term without mitigation and is referred to as Type 2 rock. The mine plan includes provisions for identifying and segregating Type 2 rock for appropriate management. The amount of Type 2 rock for the life of mine was re-evaluated with updated and more conservative criteria and is currently estimated to be about 10% of the total mine rock inventory or approximately 37 Mt. There is capacity to store 52 Mt of Type 2 mine rock so that it will remain permanently under water, below the water table in the PSMF or below water in the South pit.

The chemical source terms for Types 1 and 2 rock were evaluated to assess water quality effects from each material, as presented in Section 2.5 below.

2.1.2 Process Solids

The process solids generated during the life of the mine will be separated according to their sulphur contents. The low sulphur materials, referred to as Type 1 process solids will have an average sulphur content of less than 0.1%S. The high sulphur materials, referred to as Type 2 process solids will have an average sulphur content in the range of 3%S and will be deposited in a manner that will ensure permanent storage below the water table in the PSMF. The process solids will be managed as Type 1 and 2 streams after the milling process, and delivered to their respective storage locations and/or facilities. The majority of the process solids will be permanently stored within the PSMF. A portion of the Type 2 process solids will be stored in the satellite pits and will be submerged underwater following filling of the pits, in order to prevent oxidation and acidity generation.

The PSMF option includes two engineered storage areas in Cell 2 for the Type 1 and 2 process solids that are produced at the mill site. The primary storage area will be designed to hold the majority of the Type 1 material, while a second storage area will be created to the south of the main area and will receive Type 2 material early in the operation. This second storage area will maintain Type 2 material under a water cover during operation and below the water table after operation to prevent oxidation.

2.1.3 Water from the Process Plant

The milling of ore requires water to transfer the crushed ore and to extract the economic minerals. The water in the mill is referred to as process water. Although a high degree of recycling of process water will occur in the mill, there will be excess process water that will be discharged to the environment during the operation in some years, as described in Section 3.0 and Section 6.0. The interactions between solids and process water can affect the water chemistry and these effects were considered in this assessment. The characteristics of the process water were estimated from the decant analysis of the water produced in metallurgical tests, as discussed in greater detail in Section 2.5.

2.1.4 Rock/Rubble in the Open Pits

The mining of the open pits will result in the production of the majority of mine rock. During mine operation and open pit development, water will be pumped from the pits to maintain dry working conditions. As the open pits are developed, water sheds will contribute surface water and some groundwater to the open pits, which will have contact with the pit walls and rock on benches and on the working floor of the pits. The effects of exposure of the open pit rock to water was considered for the operation and post-operation time periods, with source terms presented in Section 2.5.

Once mining operations have ceased, and the pits begin to fill with water, the amount of exposed rock that has the potential to undergo oxidation, will also decrease and reduce the amount of reactive area. It is estimated that the main pit will reach a final water level decades after mining operations have ceased. Some of the pit walls will remain exposed to the atmosphere above the natural final water level in the pit after filling with water. The pit water will continue to be monitored post decommissioning, and treated in-situ if necessary, in order to meet water quality criteria before allowing natural discharge to the surrounding environment.

2.2 Mine Components Testing Program

2.2.1 Mine Rock

There have been several phases of investigation that included sampling and static characterization of mine rock that is expected to be excavated and stored on site during the operation. These have been summarized in a memorandum that provided a comparison of updated mine rock characterization work in 2020-21 to the results of the previous investigation phases (Ecometrix 2021a). The mine rock sampling and characterization phases included samples from a 2007 campaign by Golder (2008), by Ecometrix, (2012) and by Stillwater (2013) to represent the 2012 pit shell.

A supplemental sampling campaign in 2020 was designed to fill some potential spatial gaps and to ensure that the 2020 pit shell was represented by mine rock samples. And the results were presented and compared to those from the previous sampling campaigns in Ecometrix (2021a). The main conclusion of the 2020 update was that the mine rock data set represents the proposed 2020 pit shell and that there were no changes in the characteristics of the rock and the samples and results previous to the 2020 supplemental samples remain valid for the proposed operation. The results confirm that the previous source terms for Type 1 and Type2 mine rock remain valid and those were used in the water quality modelling update.

2.2.2 Process Solids and Process Water

The mill process flow sheet was refined in 2020 to improve recovery of the economically valuable metals from the ore compared to previously proposed processing. It was expected that the flow sheet refinements could result in small changes in process solids characteristics. There were several metallurgical test programs in the past that produced process solids that were tested. A pilot plant test was completed in 2020 with the refinements and the pilot test generated process water and process solids that were sampled and characterized. The results from the program are presented and were compared to the previous results that had been used to generate source terms for water quality in Ecometrix (2021b).

It was concluded that the 2020 Type 1 and Type 2 process solids were similar to those from the previous metallurgical tests and that the source terms derived from the solids remained valid without need for modification. The source terms previously developed for the Type 1 and Type 2 process solids were therefore used in the current assessment and water quality modelling update.

The process waters for the Type 1 and Type 2 process solids were similar to but not identical to those from previous tests and it was considered appropriate to update the process water chemistry with the 2020 test results for the purposes of the source terms and water quality modelling update (Ecometrix 2021b).

2.2.3 Rock/Rubble Associated with the Open Pits

The pit wall rock and rubble in the pits were represented by the Type 1 mine rock for source terms in previous assessments. Because there was no change on mine rock characteristics, the same source terms were applied in the current assessment and water quality modelling update.

2.3 Results of Characterization of Mine Components

2.3.1 Mine Rock

A summary of the acid base accounting characteristics comparing the 2020 samples with those from previous campaigns is provided in **Table 2-1** (Ecometrix 2021a; Appendix A). On average, there was less sulphur, slightly lower carbonate neutralization potential (Carb-NP) and larger carbonate neutralization potential ratios (Carb-NPR) in the 2020 samples compared to those from the previous campaigns. Although conservative, it was assumed that these small changes did not alter the characteristics or potential behaviour of the mine rock from those presented previously (Ecometrix 2012). The plot of all data for sulphur content in relation to Carb-NPR is shown in **Figure 2-1**. The plot clearly shows that the 2020 sample results fall within the range of the previous samples.

Table 2-1: ABA comparison with former sample programs

Parameter	Units	Golder (2007), Ecometrix (2010), and Stillwater (2013) Combined					Ecometrix (2020)				
		Count	Minimum	Maxiumum	Median	Geomean	Count	Minimum	Maxiumum	Median	Geomean
Total Sulphur	wt. %	455	<0.005	0.960	0.030	0.037	38	<0.005	0.409	0.013	0.019
Carb-NP	kg-$CaCO_3$/t	398	0.7	63.7	9.1	8.6	38	1.0	79.9	7.3	6.7
Carb-NP/AP	--	398	0.2	154.5	11.9	9.6	38	0.2	212.8	16.3	13.3
		Criteria			Count	%	Criteria			Count	%
		Carb-NP/AP greater than 2 (Type 1)			360	90.5%	Carb-NP/AP greater than 2 (Type 1)			34	89.5%
		Carb-NP/AP between 1-2 (Type 2)			23	5.8%	Carb-NP/AP between 1-2 (Type 2)			0	0.0%
		Carb-NP/AP less than 1 (Type 2)			15	3.7%	Carb-NP/AP less than 1 (Type 2)			4	10.5%

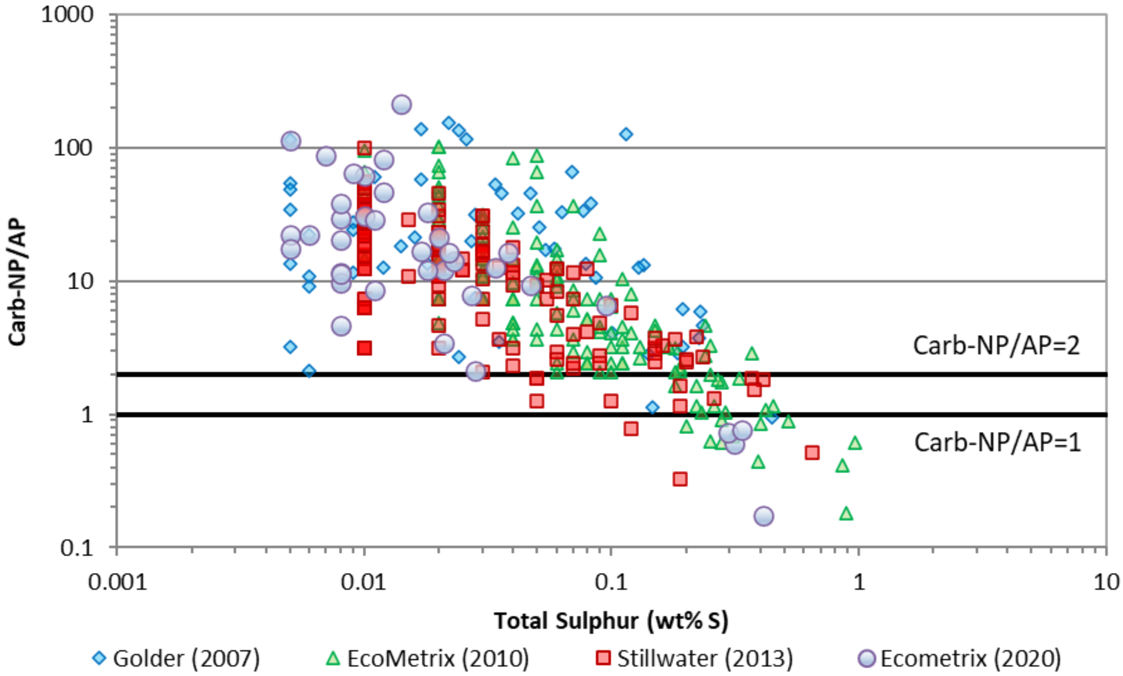

Figure 2-1: Carb-NP/AP ratio versus Total Sulphur

The 2020 sample program provides adequate representation to fill gaps within the 2020 pit shells. The additional data from the 2020 sampling program (Ecometrix 2021a; see Appendix A) support the conclusion that the previous samples included in the Golder (2008), Ecometrix (2012) and Stillwater (2013) data sets are representative of the mine rock from the 2020 pit shell. Moreover, it was concluded that no additional kinetic geochemistry testing for mine rock is necessary to support the source terms and model calculations. The previous kinetic test results remain valid for the mine rock from the Marathon Palladium Project and can therefore continue to be used to assess water quality in the updated water balance and water quality model.

2.3.2 Process Solids and Process Water

The ABA results for the Type 1 and Type 2 process solids are presented and compared to the 2012 test results in **Table 2-2** and **Table 2-3**, respectively (Ecometrix 2021b; see Appendix A)). Three test runs were completed on composite samples named 2012 Composite, 2020 W Horizon (central and south pit area) and 2020 Main Zone (north pit area). The 2012 Composite was composed of core samples selected from drill core collected in 2012.

The 2020 results for the Type 1 process solids show that the sulphur contents are slightly lower, the average Carb-NP value is similar and the Carb-NP/AP ratios are much greater than those reported in Ecometrix (2012). The 2020 results for the Type 2 process solids exhibit lower much sulphur contents, slightly lower Carb-NP values and much higher Carb-NP/AP ratios than those from the 2012 test.

Table 2-2: ABA Summary of Thickened Flotation (Type 1) Process Solids

Parameter	Unit	Thickened Flotation Tailings (Non-PAG) - Type 1			
		Former Low Sulphur Tailings (EcoMetrix, 2012)	2012 Composite FT-1 Tailings	2020 W-Horizon FT-1 Tailings	2020 Main Zone FT-1 Tailings
Paste pH	--	8.74	9.26	9.29	9.31
Sobek NP	kg-$CaCO_3$/t	20.83	28.4	32.4	21.2
AP (from Sulphide-S)	kg-$CaCO_3$/t	2.50	1.25	1.25	1.25
AP (from Total S)	kg-$CaCO_3$/t	4.45	2.94	0.44	0.28
Net NP	kg-$CaCO_3$/t	18.33	27.2	31.2	20.0
Sobek NP/AP	--	8.91	22.7	25.9	17.0
Total Sulphur	%S	0.14	0.094	0.014	0.009
Acid Leachable SO4-S	%S	0.06	0.05	< 0.04	< 0.04
Sulphide-S	%S	0.08	0.04	< 0.04	< 0.04
Total Carbon	%S	0.12	0.143	0.159	0.082
AP (from Total S)	kg-$CaCO_3$/t	4.45	2.94	0.44	0.28
Carb-NP	kg-$CaCO_3$/t	10.02	12.01	13.36	6.89
Carb-NP/AP	--	2.25	4.09	30.53	24.49

Table 2-3: ABA Summary of Scavenger (Type 2) Process Solids

Parameter	Unit	Scavenger Tailings (PAG) - Type 2			
		Former High Sulphur Tailings (EcoMetrix, 2012)	2012 Composite ST-3 Tailings	2020 W-Horizon ST-3 Tailings	2020 Main Zone ST-3 Tailings
Paste pH	--	7.64	--	--	--
Sobek NP	kg-$CaCO_3$/t	45.40	--	--	--
AP (from Sulphide-S)	kg-$CaCO_3$/t	191.00	--	--	--
AP (from Total S)	kg-$CaCO_3$/t	208.75	103.44	2.91	9.97
Net NP	kg-$CaCO_3$/t	-145.43	--	--	--
Sobek NP/AP	--	0.24	--	--	--
Total Sulphur	%S	6.68	3.31	0.09	0.32
Acid Leachable SO4-S	%S	0.57	--	--	--
Sulphide-S	%S	6.11	--	--	--
Total Carbon	%S	0.39	0.30	0.39	0.17
AP (from Total S)	kg-$CaCO_3$/t	4.45	--	--	--
Carb-NP	kg-$CaCO_3$/t	32.43	24.78	32.93	14.03
Carb-NP/AP	--	0.16	0.24	11.33	1.41

The QEMSCAN results showed that the pyrite is the dominant sulphide and calcite is the dominant carbonate mineral, representing the AP and NP of the process solids, respectively (**Table 2-4**).

Table 2-4: **QEMSCAN Summary of Modal Abundance Mineralogy**

Sample		2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
Fraction		-300/+3um	-300/+3um	-300/+3um	-300/+3um	-300/+3um	-300/+3um
Mass Size Distribution (%)		100.0	100.0	100.0	100.0	100.0	100.0
Calculated ESD Particle Size		15	12	15	12	16	11
Mineral Mass (%)	Pyrite	0.24	8.60	0.01	0.24	0.01	0.81
	Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
	Chalcopyrite	0.00	0.37	0.01	0.10	0.00	0.01
	Other Sulphides	0.00	0.05	0.01	0.03	0.00	0.01
	Quartz	1.52	1.96	0.57	0.44	0.16	0.15
	Plagioclase	45.51	30.86	44.81	33.51	37.82	36.06
	Epidote	0.18	0.41	0.11	0.07	0.44	0.33
	Muscovite/Illite	0.93	1.05	1.16	0.70	2.12	1.81
	Chlorite	3.29	4.54	3.65	5.22	4.21	6.08
	Biotite	0.53	0.96	0.39	0.66	0.59	1.13
	Clays	0.66	1.48	0.57	0.60	0.67	0.71
	K-Feldspar	0.80	0.62	0.21	0.16	0.30	0.39
	Talc	0.05	0.27	0.06	1.97	0.03	0.23
	Amphibole/Pyroxene	37.60	42.62	44.00	52.53	41.44	43.60
	Other Silicates	0.18	0.29	0.21	0.33	0.19	0.24
	Ti-(Fe)-Oxides	3.02	1.66	1.32	0.37	6.42	4.56
	Fe-Oxides	2.86	2.05	1.23	1.12	4.52	2.81
	Calcite	0.82	0.96	1.18	1.37	0.55	0.53
	Ankerite/Dolomite	0.07	0.04	0.00	0.00	0.00	0.01
	Apatite	1.70	1.03	0.48	0.57	0.46	0.49
	Other	0.02	0.16	0.01	0.01	0.06	0.06
	Total	100.0	100.0	100.0	100.0	100.0	100.0

Results from the geochemical characterization of process solids from the metallurgical pilot plant test program confirmed that the thickened flotation process solids are to be classified as Type 1 (non-PAG) and the scavenger (1st cleaner) process solids are to be classified as Type 2 (PAG) when managed in the PSMF. Comparative analysis also confirmed that the results from the 2020 pilot plant testing are consistent with those from the previous metallurgical test program, with respect to ABA analyses and ICP-MS bulk metals analysis. Therefore, it is concluded that no additional kinetic geochemistry testing for process solids material is necessary to support the process solids source terms and model calculations. The previously determined kinetic test results remain valid for the process solids from the Marathon Palladium Project and can therefore continue to be used to assess water quality in the updated water balance and water quality model.

Process water from the 2020 pilot plant was also sampled and analysed. The results for the Type 1and Type 2 process water are presented in **Table 2-5 and Table 2-6**, respectively.

Table 2-5: Summary of Thickened Flotation (Type 1) Process Water

Parameter	Unit	IPWQO/PWQO	2012 Composite FT-1 (Aged)	2020 Main Zone FT-1 (Aged)	2020 W-Horizon FT-1 (Aged)
pH	--	6.5 to 8.5	8.06	8.35	8.14
Alkalinity	mg/L as CaCO3	No Value[a]	111	101	118
Conductivity	uS/cm	No Value	328	293	315
Fluoride Dissolved	mg/L	No Value	0.44	0.78	0.96
Chloride	mg/L	No Value	18	19	19
Sulphate	mg/L	No Value	30	20	17
Bromide (dissolved)	mg/L	No Value	< 0.3	< 0.3	< 0.3
Nitrite (as N)	as N mg/L	No Value	< 0.03	< 0.03	< 0.03
Nitrate (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Nitrate + Nitrite (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Dissolved Organic Carbon	mg/L	No Value	6	8	5
Ammonia+Ammonium (N)	as N mg/L	0.02	< 0.1	< 0.1	< 0.1
Mercury (dissolved)	mg/L	0.0002	< 0.00001	< 0.00001	< 0.00001
Silver (dissolved)	mg/L	0.0001[b]	< 0.00005	< 0.00005	< 0.00005
Aluminum (dissolved)	mg/L	0.075[c]	0.069	0.087	0.023
Arsenic (dissolved)	mg/L	0.1	0.0005	0.0004	0.0006
Barium (dissolved)	mg/L	No Value	0.00754	0.00432	0.00467
Boron (dissolved)	mg/L	0.2	0.046	0.025	0.017
Calcium (dissolved)	mg/L	No Value	19.6	18.9	24.8
Cadmium (dissolved)	mg/L	0.0001/0.0005[b]	0.000009	0.000033	0.000031
Cobalt (dissolved)	mg/L	0.0009	0.000047	0.000060	0.000037
Chromium (dissolved)	mg/L	0.0089[b]	0.00008	0.00012	< 0.00008
Copper (dissolved)	mg/L	0.005[b]	0.0005	< 0.0002	0.0002
Iron (dissolved)	mg/L	0.3	0.029	0.076	< 0.007
Potassium (dissolved)	mg/L	No Value	14.9	13.8	8.04
Magnesium (dissolved)	mg/L	No Value	6.64	8.48	8.54
Manganese (dissolved)	mg/L	No Value	0.00989	0.00406	0.00931
Molybdenum (dissolved)	mg/L	0.04	0.0192	0.0201	0.0284
Sodium (dissolved)	mg/L	No Value	32.7	20.2	18.0
Nickel (dissolved)	mg/L	0.025[b]	0.0030	0.0011	0.0013
Phosphorus (dissolved)	mg/L	0.02	0.127	0.535	0.430
Lead (dissolved)	mg/L	0.001 / 0.005	0.00002	< 0.00001	< 0.00001
Sulfur (dissolved)	mg/L	No Value	9	11	7
Selenium (dissolved)	mg/L	0.1	0.00022	0.00057	0.00031
Strontium (dissolved)	mg/L	No Value	0.163	0.129	0.135
Thallium (dissolved)	mg/L	0.0003	< 0.000005	< 0.000005	< 0.000005
Uranium (dissolved)	mg/L	0.005	0.000120	0.000043	0.000154
Vanadium (dissolved)	mg/L	0.006	0.00081	0.00110	0.00036
Tungsten (dissolved)	mg/L	0.03	0.00080	0.00126	0.00090
Zinc (dissolved)	mg/L	0.02[b]	< 0.002	< 0.002	< 0.002

[a]Alkalinity should not be decreased by more than 25% of the natural concentration

[b]Hardness dependant

[c]pH dependant

Table 2-6: Summary of Scavenger (Type 2) Process Water

Parameter	Unit	IPWQO/PWQO	2012 Composite ST-3 (Aged)	2020 W-Horizon ST-3 (Aged)	2020 Main Zone ST-3 (Aged)
pH	--	6.5 to 8.5	8.29	8.73	8.20
Alkalinity	mg/L as CaCO3	No Value[a]	37	56	53
Conductivity	uS/cm	No Value	278	197	245
Fluoride Dissolved	mg/L	No Value	0.33	0.27	0.60
Chloride	mg/L	No Value	73	25	44
Sulphate	mg/L	No Value	21	10	21
Bromide (dissolved)	mg/L	No Value	< 0.3	< 0.3	< 0.3
Nitrite (as N)	as N mg/L	No Value	< 0.03	< 0.03	< 0.03
Nitrate (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Nitrate + Nitrite (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Dissolved Organic Carbon	mg/L	No Value	108	117	159
Ammonia+Ammonium (N)	as N mg/L	0.02	0.1	< 0.1	< 0.1
Mercury (dissolved)	mg/L	0.0002	< 0.00001	< 0.00001	< 0.00001
Silver (dissolved)	mg/L	0.0001[b]	< 0.00005	< 0.00005	< 0.00005
Aluminum (dissolved)	mg/L	0.075[c]	0.858	0.845	0.199
Arsenic (dissolved)	mg/L	0.1	0.0009	0.0067	0.0059
Barium (dissolved)	mg/L	No Value	0.00140	0.00192	0.00107
Boron (dissolved)	mg/L	0.2	0.039	0.023	0.041
Calcium (dissolved)	mg/L	No Value	16.6	12.8	12.0
Cadmium (dissolved)	mg/L	0.0001/0.0005[b]	< 0.000003	0.000007	0.000012
Cobalt (dissolved)	mg/L	0.0009	0.000064	0.000069	0.000068
Chromium (dissolved)	mg/L	0.0089[b]	0.00177	0.00191	0.00122
Copper (dissolved)	mg/L	0.005[b]	< 0.0002	0.0028	0.0002
Iron (dissolved)	mg/L	0.3	0.008	0.013	0.034
Potassium (dissolved)	mg/L	No Value	10.1	6.1	11.30
Magnesium (dissolved)	mg/L	No Value	0.04	0.05	0.13
Manganese (dissolved)	mg/L	No Value	0.00015	< 0.00001	0.00069
Molybdenum (dissolved)	mg/L	0.04	0.0126	0.0080	0.0158
Sodium (dissolved)	mg/L	No Value	24.9	22.8	26.6
Nickel (dissolved)	mg/L	0.025[b]	0.0011	0.0012	0.0016
Phosphorus (dissolved)	mg/L	0.02	0.875	0.582	1.390
Lead (dissolved)	mg/L	0.001 / 0.005	< 0.00001	< 0.00001	< 0.00001
Sulfur (dissolved)	mg/L	No Value	54	7	24
Selenium (dissolved)	mg/L	0.1	0.00205	0.00124	0.00132
Strontium (dissolved)	mg/L	No Value	0.121	0.092	0.070
Thallium (dissolved)	mg/L	0.0003	< 0.000005	< 0.000005	< 0.000005
Uranium (dissolved)	mg/L	0.005	0.000008	0.000026	0.000019
Vanadium (dissolved)	mg/L	0.006	0.04750	0.02340	0.07870
Tungsten (dissolved)	mg/L	0.03	0.00142	0.00067	0.00350
Zinc (dissolved)	mg/L	0.02[b]	< 0.002	< 0.002	< 0.002

[a]Alkalinity should not be decreased by more than 25% of the natural concentration

[b]Hardness dependant

[c]pH dependant

Despite only minor differences in the analysis of process waters, it was concluded that the water quality model source terms for process waters should be updated to include the values as determined by the recent 2020 metallurgical pilot plant test program for the water quality model used to predict discharge requirements and water treatment design since the 2020 testing reflects an updated metallurgical process. The maximum or most conservative value for the parameter was selected from the three tests, 2012 Composite, 2020 W Horizon and 2020 Main Zone.

2.4 Sulfur Cut-off – Differentiating between Type 1 and Type 2 Material

Ecometrix (2012; see Appendix A) defined a sulfur (S) cut-off levels of 0.3% S based on testing done at that time. Mine rock with a sulphur content less than 0.3% S would correspond to material with a neutralization potential (NP) to acid potential (AP) ration (ie,NP/AP) greater than 2 and could be classified as non-potentially acid generating (non-PAG). From a management perspective, such non-PAG material can be safely stored in on-land stockpiles without a need for mitigation. Conversely, it was recommended that mine rock with a sulphur content greater than 0.3% S be considered potentially acid generating (PAG), with segregation and management of this material to mitigate the potential for acidity generation.

Ecometrix (2021) revisited the sulfur cut-off level by consideration of a more conservative estimate of NP. This more conservative differentiation of non-PAG (Type 1) from PAG (Type 2) mine rock is calculated by considering the NP that is strictly attributed to carbonate minerals (Carb-NP), using a Carbonate Neutralization Potential Ratio (Carb-NPR) in place of the previously used Sobek-NPR. Based on the use of the Carb-NPR, a revised sulfur cut-off value of 0.18% S has been recommended for the segregation and management of mine rock.

2.5 Loading Rates for Mine Components

As presented above, the kinetic test cell results for mine rock and process solids and the submerged column tests for the high sulphur materials formed the basis of these loading rates. The loading rates associated with each mine component are described below, in relation to the development of a water quality model presented in Section 5.0 and the resultant predictions in Section 6.0.

2.5.1 Loading Rates for Mine Rock

The results from the humidity cells containing mine rock were utilized in the development of loading rates for mine rock that will be placed in mine rock stockpiles, exposed on pit walls and as rubble remaining on the pit benches.

Mine rock will be managed separately according to sulphur content, namely Type 1 (low-sulphur) and Type 2 (high-sulphur). Thus, the two types of mine rock material were also assessed independently to determine if loading rate correlations agreed with weighted average loading rates according to rock type.

The average values were selected to represent the loading rates for most constituents for the individual mine rock types as summarized in Appendix A. Only the loading rates for sulphate and copper were estimated from the sulphide content correlations for Type 1 mine rock because the correlations were strong for the small number for data points. Loading rates remain unchanged from those presented in the original EIS documentation, with the exception of the temperature scaling factor. The original laboratory rates applied a temperature correction factor of 0.17 to represent field conditions, whereas the rates presented herein applied a more conservative scaling factor for temperature of 0.3 as per MEND (2006).

2.5.2 Loading Rates for Low Sulphur Process Solids

Loading rates for constituents from the Type 1 process solids were estimated from the steady state unit rates observed for the humidity cell tests. The steady state loading rates were generally represented by the average humidity cell loading rates from week 44 to the end of the test (week 52). The results for most of the constituents are represented by concentrations in the leachate that are below analytical detection limits and therefore the estimated loading rates will represent conservative maximum values and will require careful interpretation when the effects of seepage on the local watershed drainage are considered. The loading rates are summarized Appendix A.

2.5.3 Loading Rates for Submerged Process Solids

2.5.3.1.1 Type 2 High Sulphur Process Solids Submerged

The loading rates and fluxes of constituents from the submerged high sulphur process solids were estimated from the results of the column tests presented in the original EIS documentation, as summarized in Appendix A. The results for many constituents in that test were reported as at or below analytical detection limits and therefore the estimated loading rates will conservatively represent maximum values.

The loading rates were estimated from mass balance calculation for the overlying water including mass associated with samples collected for chemical analysis. The mass release from the Type 2 process solids was calculated weekly to provide estimates of loading rates in mg/wk and then divided by the surface area of the solids to provide flux values in units of $mg/m^2/wk$. The results are summarized in Appendix A. Some of these loadings rates were subject to adjustments including those for aluminum and iron that will be controlled by solubility constraints at the pH value of the overlying water.

2.5.3.1.2 Bulk Process Solids Submerged

The loading rates and fluxes of constituents are based on the steady-state conditions in the test columns that represented weeks 43 to 68, as estimated in the original EIS documentation summarized in Appendix A. The concentrations of many constituents in the water were reported as below analytical detection limits so that the estimated loading rates and fluxes will represent conservative maximum values. The loading rates (mg/wk) were estimated from mass balance calculations that included mass associated with samples collected for analysis to quantify weekly release rates. The loading rates were then converted to flux values ($mg/m^2/wk$) by dividing by the surface are of the submerged process solids. The results are summarized in Appendix A. The loading rates for some constituents will be adjusted as a result of geochemical controls such as solubility.

2.5.4 Loading Rates for Pit Walls and Benches

The pit walls and rubble on the pit benches will contribute loadings of constituents to the pit water during operations. These loadings were estimated to allow an assessment of pit water quality.

The loadings from the pit walls and from the rubble on the benches were estimated with the following assumptions;

- the pit development schedule was a function of excavated rock to calculate pit wall heights and bench areas,
- the loadings from walls were based on the exposed wall areas by year and were surface area controlled,
- the benches were assumed to be an average of 25 m wide and were a function of the open pit area, in plain view,
- the loadings from the benches assumed that rubble was 0.1 m thick and uniformly distributed, and,
- the loading rate from rubble was estimated from humidity cell results on Type 1 mine rock.

The loading rates of constituents estimated from humidity cell results are expressed in terms of mass of rock tested with units of mg/kg/wk. These rates were expressed in terms of surface area of the rock to estimate loadings from pit walls, as described in Appendix A and remain unchanged from the original EIS predictions with the exception of the temperature scaling factor noted above.

The loading rates for rubble on the pit benches was estimated from humidity cell results with no correction for surface area. This means that the loading rates for rubble were assumed to be much greater than those for rock in the Type 1 stockpile. The loading rates are summarized in Appendix A and are similar to the original EIS predictions with the exception of the updated temperature scaling factor noted above.

2.5.5 Quality of Seepage from the PSMF

The quality of seepage water will be a function of the existing pore water in the process solids in the short to intermediate period, and a function of leaching of the surficial process solids and infiltration rates in the longer term. The pore water in the process solids at the end of the operation will slowly migrate downward to the natural ground and will migrate laterally to appear as seepage near the toes of the PSMF dams. The seepage that appears at the dam toes is expected to have similar quality as the resident pore water, as summarized in **Tables 2-5** and **2-6** above and in Appendix A.

3.0 PROJECT WATER BALANCE

Knight Piésold (2021) has developed at updated site water balance for the Project. The water balance was prepared using the GoldSim software package (GoldSim Technology Group LLC, 2019) and includes all Project phases. A stochastic analysis was completed to consider normal, wet and dry conditions. The water balance report describes the water management strategy, analysis assumptions, methodology, and results of the water balance analysis in detail. Within the context of the development of the water quality model and associated water quality predictions, the site water balance is overlain on the natural hydrological system in the study area and ultimately provides estimates of the quantities of water that will be released from the site to the environment.

Key aspects of the site water balance that pertain to the development of the water quality model and associated water quality predictions for routine mine operations are listed below. Schematic representations of site ware management during operations and closure are shown in Figure 3-1 and Figure 3-2.

1. Water management (collection and diversion) infrastructure will be developed early in the construction phase so as to ensure care and control of site-aspect influenced runoff and seepage (i.e., contact water) and also to ensure that sufficient water is available to commission the Process Plant once ore production has begun.

2. The Water Management Pond (WMP) of the PSMF will be operated as the primary contact water management pond and reclaim water source for the Process Plant.

3. During construction:

    - No discharge is expected from the site. Consistent with bullets 1 and 2, contact water that is collected around the site as it is developed will be conveyed back to the WMP for storage and eventually used in commissioning the Process Plant

4. During operations:

    - Contact water that is collected around the site, as well as process water from PSMF cells 1, 2A and 2B, will be conveyed to the WMP for care and control purposes.

    - Water will be reclaimed from the WMP for use as make-up water in the Process Plant.

    - Excess water, beyond that which is needed in the Process Plant, or could be stored safely within the associated water management infrastructure, will be released to the environment.

    - Excess water from the WMP will be conveyed to an effluent treatment plan (ETP) and subsequently to Hare Lake. Routine discharge of this sort during operations will be directed to Hare Lake only; there will be no routine releases to other receivers (e.g., Pic River) during operations.

- Discharge of treated effluent from the ETP to Hare Lake will occur annually between April and November, though the rate of discharge both within and between years will vary. Over the operational period of the mine, discharge will vary annually from a total of ~ 600,000 * 10^6 m^3 to ~ 2 * 10^6 m^3. On an hourly basis, the discharge will vary from 0 to 350 m^3, within any given month.

5. During the initial active care stage of closure, which for planning purposes is expected to last five years following the cessation of operations:

    - Contact water that is collected around the site, as well as remaining process water from PSMF cells 1, 2A and 2B, will be conveyed to the WMP for care and control purposes.
    - Water from the WMP will be conveyed to the Central Pit for storage. Once the Central Pit is filled, water will overflow to the North Pit.
    - There will be no discharge from the site during this period.
    - Site aspects will be actively reclaimed in preparation to configure the site from a surface water drainage perspective for long term closure.

6. During the longer term passive care phase of closure following site aspect reclamation:

    - Natural pre-mining surface water drainages will be restored once water quality has been deemed acceptable to do so. As indicated above, for planning purposes it has been assumed that this would occur five years after the cessation of operations and once site reclamation has been advanced sufficiently. In the event that water quality is not acceptable to pursue this strategy, water will continue to be diverted to the open pits so as to maintain care and control and to protect local off-site water quality.
    - Surface water runoff from the PSMF revegetated surface will be directed to Cell 1 and conveyed to subwatershed 106) via a closure swale. Annual runoff from the PSMF area to subwatershed 106 is estimated to be approximately 1.5 M m^3.
    - Runoff from the area of the WMP and stormwater management (SWM) Pond will be directed to subwatershed 101. Following closure, these ponds will be rehabilitated (e.g., dredged of deposited solids) such that the chemistry of any surface runoff from this area will reflect uninfluenced non-contact water. Annual runoff from the WMP/SWM Pond area to subwatershed 101 is estimated to be approximately 200,000 m^3.

- Runoff from the MRSA will be allowed to drain towards the Pic River via subwatersheds 102 and 103). Annual runoff from the MRSA to subwatersheds 102 and 103 is estimated to be approximately 800,000 m^3 and 300,000 m^3, respectively.

- The North Pit will fill to the pit rim elevation within subwatershed 103. Once filled water will be allowed to discharge passively from the North Pit into subwatershed 103 drainage, through the base of the MRSA to the Pic River. It has been estimated that it will take 30 years for the North pit to fill per the water management strategy described for site closure. Once filled the outflow from the North Pit will contribute ~ 2.35 M m^3 annually to subwatershed 103.

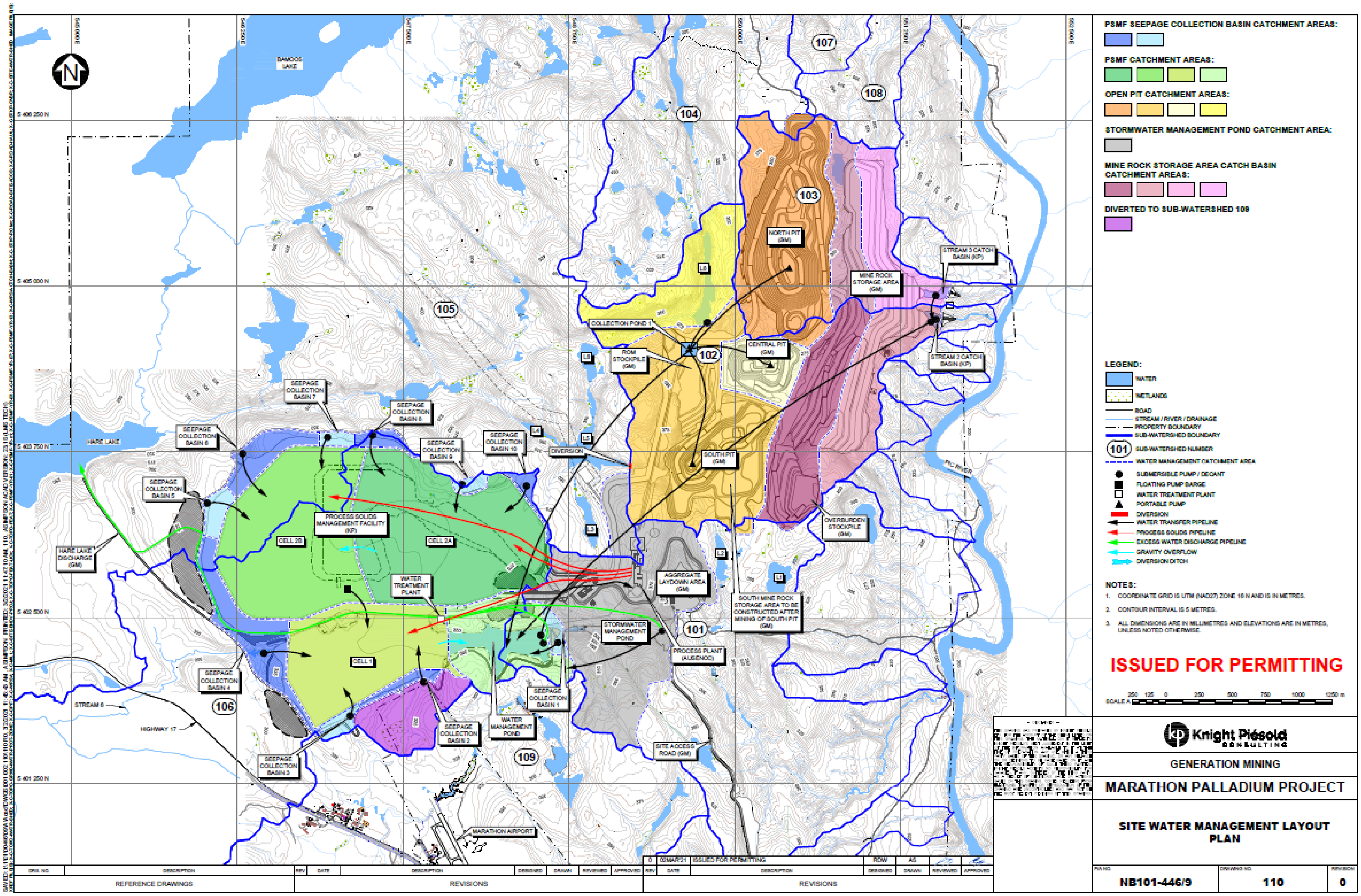

Figure 3-1: Site Water Management Plan Layout – Operations (Source: KP, 2021)

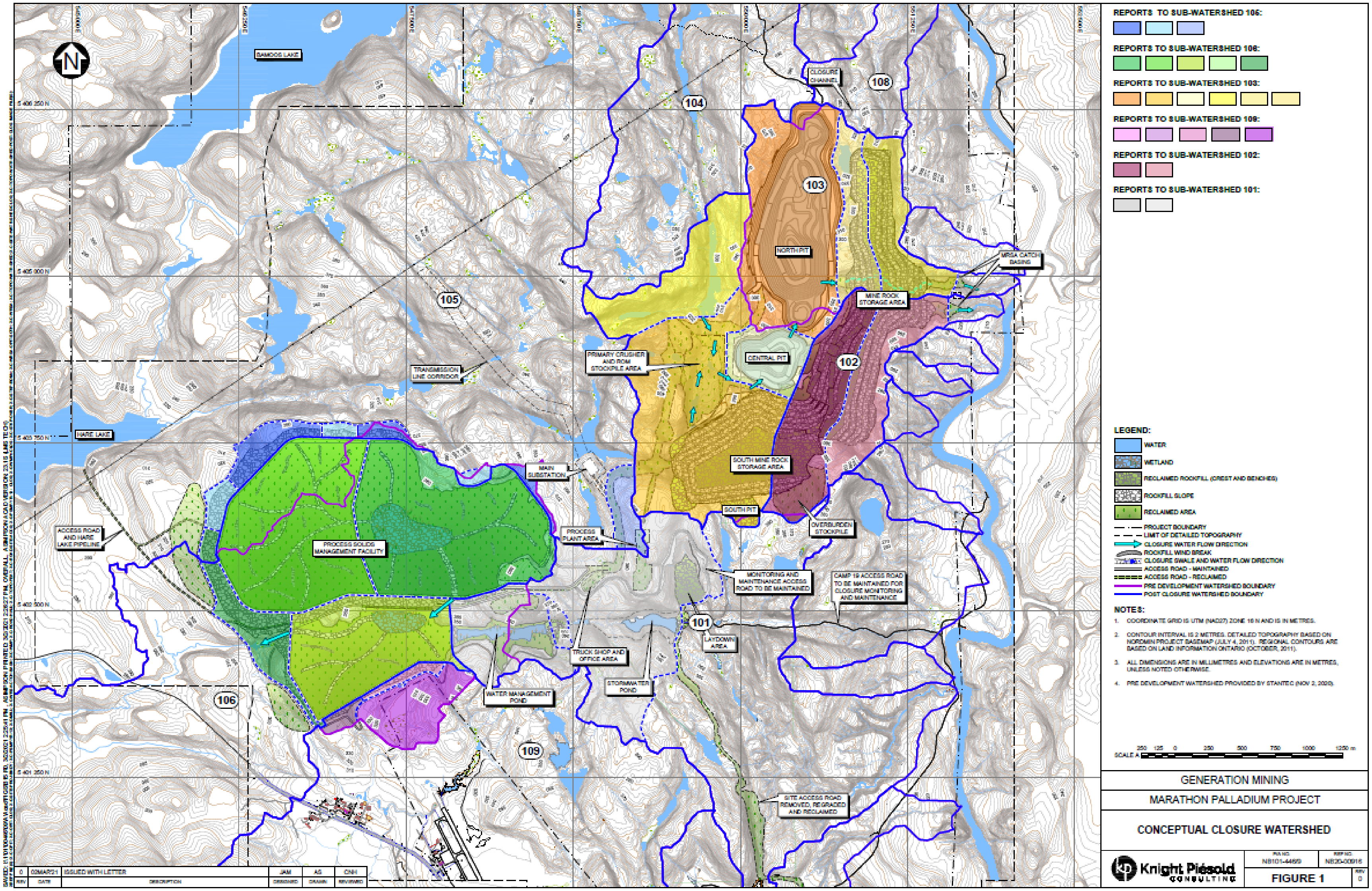

Figure 3-2: Conceptual Closure Watersheds Configuration (Source: KP, 2021)

4.0 HYDROLOGICAL CONDITIONS IN THE STUDY AREA

Existing, or baseline, hydrology and the hydrology of the study as influenced by the Project during all mine phases are described below.

4.1 Baseline Hydrology

Stantec (2020) provided an update assessment of hydrological baseline conditions by summarizing and documenting changes to the existing environmental conditions in the Project study area. Information considered to update the baseline condition included a review of historical information, supplemental field studies conducted by True Grit Engineering Ltd. (now Stantec) (2008-2018) and Stantec (2019-2020), and the updated design plans for the Project provided by GenPGM. A brief overview is provided below for reference.

The Project study area comprises a number of small subwatersheds that either flow west to Lake Superior or east to the Pic River, itself a tributary of Lake Superior. The divide that delineates west- from east-flowing subwatersheds bisects the Project site also a north-south axis just west of the location of the proposed open pit complex. Figure 4-1 shows the orientation of the subwatesheds. Table 4-1 provides a summary of the characteristics of the subwatersheds. Table 4-2 and Table 4-3 provide mean annual and mean monthly flow statistics for these subwatersheds.

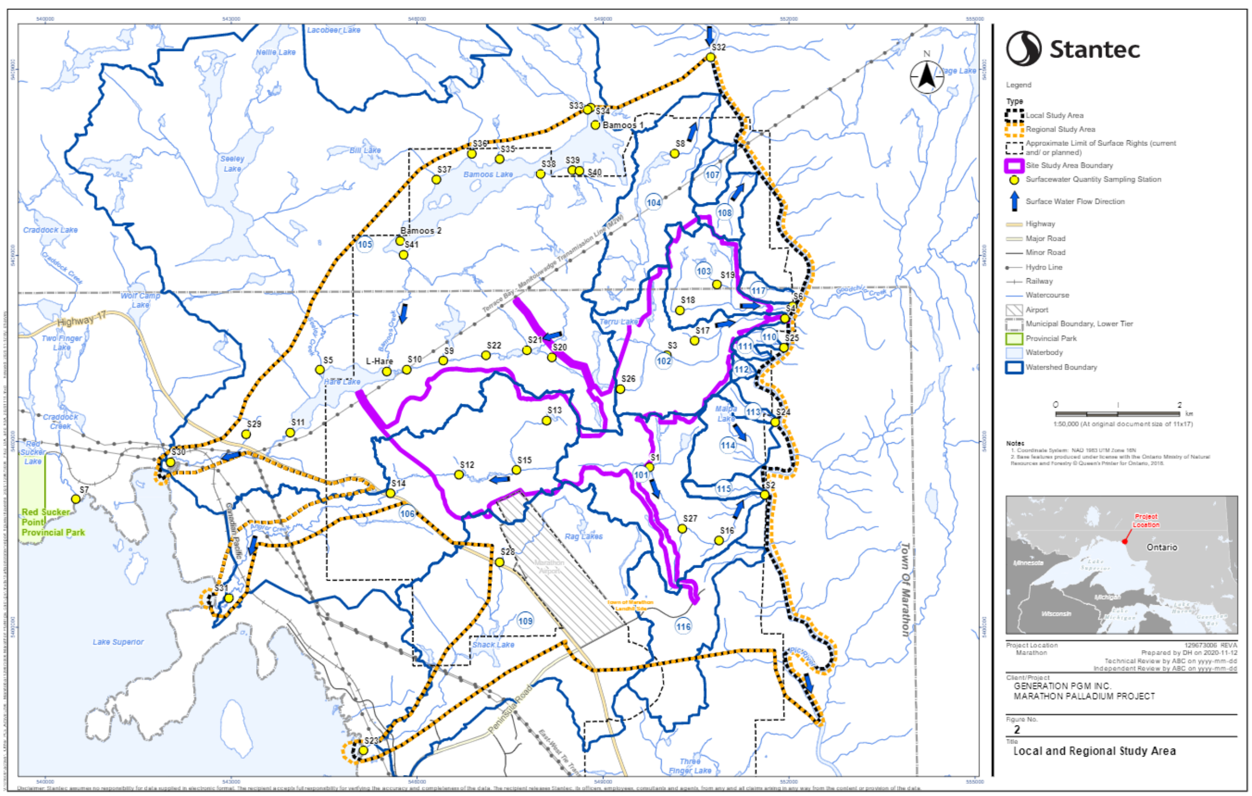

Figure 4-1: Delineation of Subwatersheds in the Project Study Area (Source, Stantec 2020)

Table 4-1: Characteristics of Local Subwatersheds (Source, Stantec 2020)

Watershed ID	Area (km2)	Mean Slope (%)	Area of Waterbodies (%)	Land Cover
101	4.538	17.307	3%	Deciduous Trees (38.1%)
102	3.495	20.918	4%	Mixed Trees (35.4%)
103	1.867	13.27	4%	Deciduous Trees (45.0%)
104	3.457	18.733	4%	Deciduous Trees (52.1%)
105	47.826	17.846	11%	Mixed Trees (45.1%)
106	10.523	11.025	3%	Mixed Trees (39.8%)
107	0.501	18.811	0%	Deciduous Trees (45.3%)
108	0.567	22.153	0%	Deciduous Trees (34.8%)
109	12.037	6.795	9%	Coniferous Trees (30.8%)
110	0.133	12.242	0%	Deciduous Trees (60.7%)
111	0.121	19.041	0%	Deciduous Trees (76.5%)
112	0.109	23.742	0%	Deciduous Trees (83.5%)
113	0.240	17.75	0%	Deciduous Trees (82.3%)
114	1.344	20.16	2%	Deciduous Trees (43.1%)
115	0.311	15.515	0%	Deciduous Trees (54.8%)
116	2.935	12.431	0%	Deciduous Trees (50.3%)
117	0.261	13.575	0%	Deciduous Trees (72.5%)

Table 4-2: Summary of Mean Annual Flows for Local Subwatersheds (Source, Stantec 2020)

Sub Watershed ID	Catchment Area (km2)	Mean Annual Flow (m^3/s)
101	4.54	0.074
102	3.50	0.058
103	1.87	0.032
104	3.46	0.057
105	47.83	0.691
106	10.52	0.164
107	0.50	0.009
108	0.57	0.010
109	12.04	0.187
110	0.13	0.003
111	0.12	0.002
112	0.11	0.002
113	0.24	0.005
114	1.34	0.023
115	0.31	0.006
116	2.94	0.049
117	0.26	0.005

Table 4-3: Summary of Mean Monthly Flows for Local Subwatersheds (Source, Stantec 2020)

Month		Area (km²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Flows (m3/s)	101	4.54	0.014	0.011	0.030	0.168	0.237	0.065	0.037	0.022	0.055	0.124	0.090	0.034
	102	3.50	0.011	0.008	0.024	0.133	0.186	0.050	0.028	0.017	0.043	0.098	0.071	0.026
	103	1.87	0.005	0.004	0.014	0.076	0.103	0.026	0.015	0.009	0.024	0.056	0.039	0.014
	104	3.46	0.010	0.008	0.024	0.131	0.184	0.049	0.028	0.017	0.042	0.097	0.070	0.026
	105	47.8	0.168	0.125	0.254	1.377	2.169	0.731	0.425	0.251	0.480	1.008	0.802	0.363
	106	10.5	0.034	0.026	0.065	0.355	0.523	0.155	0.088	0.053	0.119	0.262	0.197	0.079
	107	0.50	0.001	0.001	0.004	0.023	0.030	0.007	0.004	0.002	0.007	0.017	0.012	0.004
	108	0.57	0.002	0.001	0.005	0.026	0.034	0.008	0.004	0.003	0.008	0.019	0.013	0.004
	109	12.04	0.039	0.030	0.073	0.401	0.593	0.177	0.102	0.061	0.134	0.295	0.223	0.090
	110	0.13	0.0003	0.0003	0.001	0.007	0.009	0.002	0.001	0.001	0.002	0.005	0.003	0.001
	111	0.12	0.0003	0.0002	0.001	0.007	0.008	0.002	0.001	0.001	0.002	0.005	0.003	0.001
	112	0.11	0.0003	0.0002	0.001	0.006	0.007	0.001	0.001	0.0005	0.002	0.004	0.003	0.001
	113	0.24	0.001	0.0005	0.002	0.012	0.015	0.003	0.002	0.001	0.004	0.009	0.006	0.002
	114	1.34	0.004	0.003	0.010	0.056	0.076	0.019	0.010	0.006	0.018	0.042	0.029	0.010
	115	0.31	0.001	0.0007	0.003	0.015	0.019	0.004	0.002	0.001	0.005	0.011	0.007	0.002
	116	2.94	0.009	0.007	0.021	0.113	0.158	0.042	0.024	0.014	0.036	0.084	0.060	0.022
	117	0.26	0.001	0.001	0.002	0.013	0.016	0.003	0.002	0.001	0.004	0.010	0.006	0.002

The Pic River has a baseline watershed area of 4,207.6 km^2 which is predominantly north of the Project site. An existing Water Survey of Canada (WSC) station is located on Pic River downstream of the site (Station ID 02BB003) that collects real-time and historical flow data and was included as one of the stations used in the hydrology baseline update for the regional assessment. Mean monthly flows in the Pic River are shown for reference in Table 4-4.

Table 4-4: Mean Monthly Flows for the Pic River (Source, Stantec 2021)

	Mean Monthly Flows (m³/s)
Jan	19.26
Feb	13.35
Mar	14.38
Apr	75.54
May	145.52
Jun	72.43
Jul	44.04
Aug	25.09
Sep	30.00
Oct	54.09
Nov	51.20
Dec	32.82

4.2 Effects of the Project on Local Hydrology

Effects of the Project on local hydrology have been assessed by Stantec (2021). Effects on local hydrology will be caused by the development of the site footprint and Project operations that necessarily involves overprinting local subwatershed features and re-directing flow consistent with the project water balance and water management strategy. Changes in local hydrological conditions will occur in all mine phases, including at mine closure when natural flows will be restored as is possible. Such changes have been integrates into the water quality assessment as appropriate. Key highlights of the effects assessment are highlighted below.

- Net changes to subwatershed areas are expected to be greater than 10% in five of the 17 subwatersheds during construction and operation (subwatersheds 101, 102, 103, 105, 106), three during the initial active phase of closure (subwatersheds 102, 103, and 106), and two during the long-term passive phase of closure (sub watersheds 102 and 103).

- Reductions in the mean annual flow (MAF) of greater than 10% are predicted for subwatersheds 101, 102, 103, and 106.

    - In subwatershed 101, six months of the year during construction and two months of the year during operations do not maintain environmental flows but flows recover to less than the 10% threshold for MAF during closure and post-closure.
    - Subwatershed 102 is expected to undergo permanent changes commencing in construction and extending to the passive phase of closure. When the pit overflows and watershed 102 discharges to the Pic River, the permanent reductions in catchment area result in permanent reductions in flow.
    - Subwatershed 103 is predicted to have mean monthly flows (MMFs) that do maintain environmental flows during the construction, operation, and closure periods until the pit is filled and overflow commences. When the pit overflows in the passive phase of closure, net flow through subwatershed 103 will increase.
    - In subwatershed 106, during winter and sometimes during summer, lower flow periods extending from construction to the time in post-closure where the PSMF commences discharge to watershed 106, MMFs do not maintain environmental flows. However, when the PSMF commences discharge to watershed 106, flows will recover and be less than the 10% MAF screening threshold.

- Increases to the MAF greater than the 10% threshold were predicted for watersheds 103, 105, and 112.

- Minor changes (<5%) to Hare Lake water levels are expected to occur during construction and operations, and will return to baseline conditions during closure

- Effectively no changes are anticipated to Pic River flows (<1%) throughout during construction, operation, closure, or post-closure phases of mine life.

Changes to the hydrology through the Project phases are summarised in Table 4-5.

Table 4-5: Changes in Hydrology Through Project Mine Phases (Source, Stantec 2021)

Watershed ID	Watershed Location	Catchment Area (km^2)					Mean Annual Flow (m^3/s)				
		Baseline	Construction	Operation	Closure	Post-Closure	Baseline	Construction	Operation	Closure	Post-Closure
101	S1 Watershed	4.54	2.99	2.99	4.78	4.78	0.074	**0.050**	0.057	0.080	0.080
102	Terru Lake Watershed	3.50	0.07	0.07	1.18	1.18	0.058	**0.001**	0.002	0.020/0.002	0.020
103	S4 Watershed	1.87	0.07	0.07	4.20	4.20	0.032	**0.001**	0.002	0.009/0.002	0.056
104	Claw Lake Watershed	3.46	3.41	3.41	3.41	3.41	0.057	0.056	0.059	**0.060**	**0.060**
105	Hare Lake Watershed	47.83	58.39	58.39	47.18	47.18	0.691	0.676	**0.774**	0.683	0.683
106	Angler Creek Watershed	10.52	6.54	6.54	10.15	10.15	0.164	**0.105**	0.110	0.157/0.110	0.157
107	Watershed East of Claw Lake	0.50	0.50	0.50	0.50	0.50	0.009	**0.009**	**0.009**	**0.009**	**0.009**
108	Watershed South of Claw Lake	0.57	0.54	0.54	0.56	0.56	0.010	0.010	0.010	**0.009**	**0.009**
109	Shack Lake Watershed	12.04	12.27	12.27	12.35	12.35	0.187	0.190	0.195	**0.196**	**0.196**
110	S25 Watershed	0.13	0.13	0.13	0.13	0.13	0.003	0.003	0.003	**0.003**	**0.003**
111	Watershed east of Terru Lake	0.12	0.12	0.12	0.12	0.12	0.002	0.002	0.002	**0.003**	**0.003**
112	Watershed east of Terru Lake	0.11	0.11	0.11	0.11	0.11	0.002	0.002	0.003	**0.003**	**0.003**
113	S24 Watershed	0.24	0.24	0.24	0.24	0.24	0.005	0.005	0.005	**0.005**	**0.005**
114	Malpa Lake Watershed	1.34	1.34	1.34	1.34	1.34	0.023	0.023	0.024	**0.024**	**0.024**
115	Watershed South of Malpa Lake	0.31	0.31	0.31	0.31	0.31	0.006	0.006	**0.006**	**0.006**	**0.006**
116	Watershed South of S1	2.94	2.94	2.94	2.94	2.94	0.049	0.049	**0.049**	**0.049**	**0.049**
117	Watershed North of S6	0.26	0.26	0.26	0.26	0.26	0.005	0.005	0.005	**0.005**	**0.005**

NOTES:
1. Bolded numbers indicate the Project phase with the largest change in mean annual flows compared to baseline conditions.
2. Underlined number indicates flow is for long-term passive closure

5.0 MODELLING APPROACH

EcoMetrix developed geochemical modeling software called MineMod™ that was used to create a site-wide loadings model for the Project site. As shown in Figure 5-1, MineMod™ uses a windows interface to visually represent mine related objects including a base map or a satellite image. It presents objects in various layers that include the water bodies, catchment areas of interest and tailings and waste rock sources, etc.

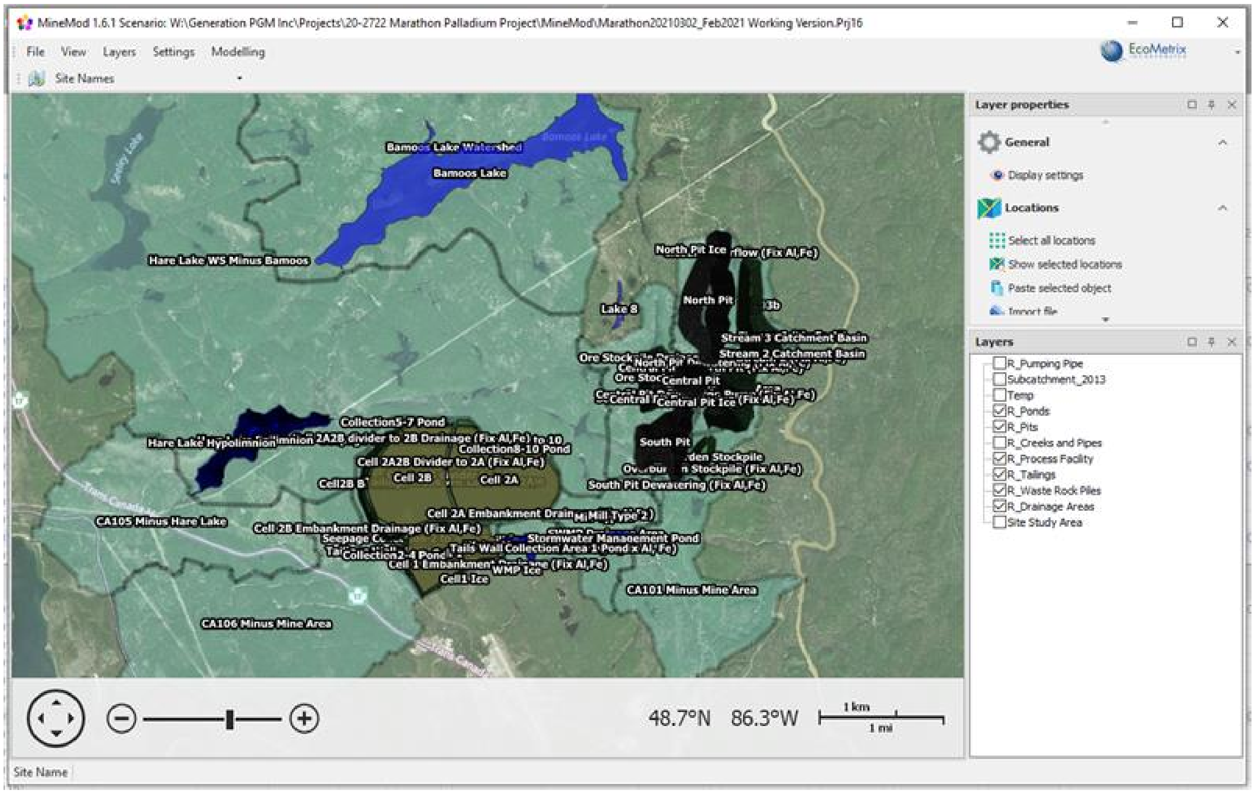

Figure 5-1: MineMod™ Interface for the Marathon Project

The loadings model was used to predict constituent concentrations in the downstream environment over the expected life of mine that includes both operations and closure. The model integrates loadings from potential source areas (see Section 2.0), the Site water balance (see Section 3.0) and hydrological conditions as influenced by the Project (see Section 4.0). The model represents a full mass and flow balance that includes chemical sources, surface water runoff and groundwater flow inputs, releases from sources to the surface water receiving environment as seepage flows within sub watersheds. Each of the mine-related constituent sources at the Site is unique and considered individually for the purposes of the loadings assessment, as below. Table 5-1 provides information related to the development of the conceptual site model on which the numerical water quality is based for reference.

Table 5-1: Conceptual site model for the MineMod™ water quality model

Component or Element	Name	Description	Associated Operations Source Terms	Associated Closure Source Term
Process Solids Management Facility	Cell 1, Cell 2A, Cell 2B	The PSMF includes two cells (Cell 1 and Cell 2), which will be separated by a lined embankment. Cell 2 is divided by an internal rockfill dyke, into Cells 2A and 2B, to optimize process solids management and storage. During the initial years of operation, Type 1 process solids will be deposited into Cell 1 and Type 2 process solids will be deposited into Cell 2A. Later during the mine life, Type 1 process solids will be deposited into Cell 2A and Cell 2B, with Type 2 process solids being deposited into Cell 2A. The process solids management strategy envisages Type 1 process solids being used as cover material for Type 2 process solids to prevent the onset of acid generation during both operations and following closure. Type 2 material will not be included in Cell 1 or Cell 2B.	Surface flush of the upper 1m of tailings with constituent loadings calculated from kinetic test results. Seepage represented by mill process water. Saturated (below water table) tailings represented by Type 1 low-sulphur humidity cell tests (Appendix A).	Surface flush not present following closure and post-vegetative cover. Long term constituent loadings associated with seepage from the TSF were estimated by allowing a 1m oxidation zone over the entirety of the facility, as calculated from kinetic test results.
	Mine Rock Berms and Embankments	The PSMF is located west of the Process Plant and will be created through the downstream construction of rockfill dams using Type 1 mine rock. The dams will be raised in stages to provide sufficient storage capacity for process solids and site water management. Seepage collection basins will be constructed along the toe of the dams to intercept seepage and pump it back to the facility.	Constituent loadings based on Type 1 mine rock humidity cell results (Appendix A)	
Open Pits	Central Pit, North Pit, South Pit	The conceptual plan for pit development is to mine the North Pit throughout the life of the project with mining of the Central and South Pits to occur at various times to supplement ore production from the North Pit. By the end of Year 6, the South Pit will be mined out and will be available for storage of mine rock and Type 2 material.	Loads are associated with the mine water quality. Loads are associated with the presence of rubble on the benches and exposed wall surface areas.	Loads are associated with the presence of rubble on the benches and exposed wall surface areas will diminish as the open pits fill.

Component or Element	Name	Description	Associated Operations Source Terms	Associated Closure Source Term
	Pit Dewatering	The open pits will be dewatered to maintain a dry mining environment. Water from the open pits will be conveyed to the WMP during operations.	Loads are associated with the presence of rubble on the benches and exposed wall surface areas, as well as baseline background groundwater quality.	Not present after closure.
Mine Rock	Mine Rock Stockpile Areas	Type 1 mine rock will be directed to the MRSA for permanent storage, though some will be crushed and used for dam construction and as aggregate for site infrastructure and operational needs. Type 2 mine rock will be placed in the PSMF and South Pit (once mined), as well as in the Central Pit closer to the end of the mining operations	Constituent loadings based on results from the Type 1 low-sulphur humidity cell tests and Type 2 high-sulphur humidity cell tests (Appendix A).	
	Overburden	The overburden stockpile, located to the south of the MRSA, will receive materials removed during grubbing and stripping to be used for reclamation purposes.	Constituent loadings associated with the overburden stockpile based on Type 1 low-sulphur humidity cell tests (Appendix A).	
	Run of Mine Ore	Run of mine ore will be hauled from the open pits directly to the Crusher or placed on the Run of Mill (ROM) Stockpile pad.	Constituent loadings for the Stockpile pad based on ore-grade humidity cell tests (Appendix A).	
Mill	Process Plant	Minerals will be recovered from the ore and processed into concentrate in the Process Plant that is located between the South Pit and the PSMF. The average daily feed rate will be approximately 25,200 tonnes. Ore will be processed into concentrate following a conventional two-step process grinding and flotation process.	Loadings are based on process water quality. Source terms were developed for Type 1 and Type 2 materials (Appendix A).	Not present after Closure
Water storage	Water Management Pond (WMP)	The WMP receives runoff from the PSMF, receives dewatering water from the pits, is the source of water for the mill, and is the point of discharge from the site.	No direct incremental loadings. Water quality calculated.	No direct incremental loadings. Water quality calculated.

Component or Element	Name	Description	Associated Operations Source Terms	Associated Closure Source Term
	Stormwater Management Pond	The stormwater management pond will store excess water from around the site in the event of a large precipitation event. Additionally, the pond will be use as a source of water to maintain a minimum volume in water management pond.	No direct incremental loadings. Water quality calculated.	No direct incremental loadings. Water quality calculated.
	Catch Basins	Catch basins will be established on the perimeter of the PSMF and MRSA to collect run off and shallow seepage from these facilities.	Water and associated constituent that are collected in catch basins during operations will be diverted to the WMP as part of the water management system.	Catch basis will be operated per operations for the first five years post-closure. Once water quality is deemed acceptable, PSMF catch basins will be decommissioned and water from MRSA catch basins will be allowed to drain to the environment as described below.
Key Local Subwatersheds Note – During operations contact water associated with the site will be collected from all of the small subwatershed that are directly associated with the developed part of the Project site and managed through the site ware management system. following closure. pre-mining draimge patterns will be	Hare Lake	Hare Lake is northwest of the site and discharges to Hare Creek at the western end, which outlets to Lake Superior approximately 3 km downstream at Port Munroe. The surface area of the lake is ~57 ha, total lake volume is approximately 8.5 M m^3 and maximum and average depths are 30 m and 15 m. Lake retention time, based on annual average flows, is in the order of 6 to 7 months.	Receives treated effluent during operations, between ~1 and 2 * 10^6 m^3 per year.	Over the long term Hare Lake will receive runoff from the north side (Cell 2A, 2B) of the PSMF embankment and a portion of the seepage from the north side (Cell 2A, 2B) of the PSMF that falls within the Hare Lake subwatersed.
	Pic River	The Pic River is directly east of the Project site. The Pic River has a baseline watershed area of 4,207.6 km^2 which is predominantly north (upstream) of the Project site. Mean monthly flows range from ~13 to 145 m^3/s over the year.	There will be no routine discharge to the Pic River during operations. Run-off and shallow seepage associated with the MRSA will be collected in catch basins and pumped back to the site water management system.	Following restoration of natural drainage patterns on the site (5 years post-closure) run-off and shallow seepage that will be collected by ditching and catch basins until that time, will be allowed to flow to the Pic River, rather than diverting it to the water management system. The pit complex is expected to fill with water approximately 30

Component or Element	Name	Description	Associated Operations Source Terms	Associated Closure Source Term
restored as possible. The key local subwatersheds into which water associated with site components will drain are highlighted in this table.				years following mine closure. At this time water from the pits will drain into subwatershed 103, through the MRSA and subsequently into the Pic River. This scenario represents the long-term configuration of the mine site from surface water drainage perspective.
	Subwatershed 106	Subwatershed 106 is ~10.5 km^2 in size and drains west from the Project site to Lake Superior. Mean annual flow is 0.164 m^3/s. The PSMF will be developed in the upper portion of this subwatershed.	There will be no water discharged to this subwatershed during operations. Contact water in this subwatershed will be collected and pumped back to the site water management system.	Following restoration of natural drainage patterns on the site (5 years post-closure) run-off and shallow seepage associated with the portion of the PSMF that is in subwatershed 106, that until that time will be collected by ditching and catch basins, will allowed to drain to subwatershed 6. This represents the long-term configuration of the mine site from surface water drainage perspective.
	Subwatershed 102	Subwatershed 102 is ~3.5 km^2 in size and drains east from the Project site to the Pic River. Mean annual flow is 0.058 m^3/s. The MRSA will be developed in this subwatershed.	The MRSA will be developed in Subwatershed 102. Contact water in this subwatershed will be collected and pumped back to the site water management system during operations.	Following restoration of natural drainage patterns on the site (5 years post-closure) run-off and shallow seepage that will be collected by ditching and catch basins until that time, will be allowed to flow to the Pic River from subwatershed 102, rather than diverting it to the water management system.

Component or Element	Name	Description	Associated Operations Source Terms	Associated Closure Source Term
				This scenario represents the long-term configuration of the mine site from surface water drainage perspective.
	Subwatershed 103	Subwatershed 103 is ~3.5 km^2 in size and drains east from the Project site to the Pic River. Mean annual flow is 0.058 m^3/s. The MRSA will be developed in this subwatershed.	The MRSA will be developed in Subwatershed 103. Contact water in this subwatershed will be collected and pumped back to the site water management system during operations.	Following restoration of natural drainage patterns on the site (5 years post-closure) run-off and shallow seepage that will be collected by ditching and catch basins until that time, will be allowed to flow to the Pic River from subwatershed 103, rather than diverting it to the water management system. The pit complex is expected to fill with water approximately 30 years following mine closure. At this time water from the pits will drain into subwatershed 103, through the MRSA and subsequently into the Pic River. This scenario represents the long-term configuration of the mine site from surface water drainage perspective.

The geochemical characteristics of the Site aspects form the basis for the derivation of chemical source terms used in the prediction of key constituent concentrations in contact waters associated with these aspects. The source terms serve as inputs to the overall site-wide water quality model used to assess the effects of these mine aspects into the receiving environment. Source terms were derived from conceptual geochemistry models based on the current understanding of the geochemical characteristics of each site aspect and supported by empirical data from the field and laboratory.

Development of geochemical source terms depend on the site-specific conditions for each aspect in consideration. Aspect specific geochemical characteristics were used to determine the mass loadings, the geochemical source term used to estimate the site aspect constituent contribution, typically in mg/s, to the receiving catchment. Together with the site water balance, mass loadings were used as inputs to the site-wide water quality model to predict concentrations of constituents to the receiving environment.

Summaries of key site aspects and associated loading rates included within the water quality model, along with the geochemical assessments and the source terms from which they were developed are provided in Appendix A. Sensitivity analyses based on alternative loadings model scenarios are provided for reference in Appendix E.

6.0 WATER QUALITY PREDICTIONS

Project activities may interact with surface water quality in all Project phases. In general, the interactions can be characterized as being primarily associated with controlled, routine discharges from the site and these are considered in more detail below on a Project phase basis.

6.1 Construction

During site preparation and construction, the primary effect pathway relates to the mobilization of suspended material into natural surface water features as the result of land disturbance and clearing.

6.1.1 Local Subwatersheds

Per the site water balance, contact waters associated with site aspects will be managed through site water management infrastructure during construction. There will be no direct discharge to local subwatersheds associated with the Project site during construction, and therefore no formal predictions of water quality are provided since changes to water quality are expected.

6.1.2 Hare Lake

Per the site water balance, contact waters associated with site aspects will be managed through site water management infrastructure during construction. There will be no direct discharge to Hare Lake associated with the Project site during construction, and therefore no formal predictions of water quality are provided since changes to water quality are expected.

6.1.3 Pic River

Per the site water balance, contact waters associated with site aspects will be managed through site water management infrastructure during construction. There will be no direct discharge to Pic River associated with the Project site during construction, and therefore no formal predictions of water quality are provided since changes to water quality are expected.

6.2 Operations

During operations, excess water from the PSMF and MRSA beyond that which was needed as process water at the Process Plant, or could be stored safely within the associated water management infrastructure, will be released to the environment. Routine discharge of this sort will be directed to Hare Lake only; this is a departure from the original EIS submission as water associated with the MRSA was to be released to the Pic River. In the updated Project design, drainage associated with the MRSA will be pumped to, and managed within the WMP of the PSMF. Water quality is discussed below in local study area watersheds, Hare Lake and in the Pic River during operations.

6.2.1 Local Subwatersheds

Per the site water balance, contact waters associated with site aspects will be managed through site water management infrastructure during operations. There will be no direct discharge to local subwatersheds associated with the Project site during operations, and therefore no formal predictions of water quality are provided since changes to water quality are expected.

As described above, the site-wide water management strategy involves care and control of all site aspect influenced water and no discharge is proposed beyond that to Hare Lake. In practice, it may be necessary at times to manage runoff from disturbed areas that are either outside the water management system, or are yet to be integrated into the water management system. In these cases, the areas would be isolated and specific water and sediment control management practices would be implemented to ensure that any water released to natural surface water drainages would be suitable for release and that water quality in these natural surface water drainages would be protected.

6.2.2 Hare Lake

During operations the primary potential water quality effect from the project is the discharge of excess water from the site water management system to Hare Lake. Discharge to Hare Lake has the potential to change the concentrations of water quality constituents from background.

For planning purposes, the water balance has assumed discharge will occur between April and November. Rates of discharge vary within and among years according to the development of the site and Process Plant needs. In general, it is expected that between ~1 and 2 * 10^6 m^3 of treated mine water will be discharged from the site to Hare Lake per year of the operations phase of the mine.

No other routine mine-related discharges to other receiving environments are proposed during operations. Water management infrastructure will collect and divert all site aspect influenced water (often referred to as contact water), as well as water associated with the PSMF, through the water management pond. Water quantities that exceed the needs of the process plant, and that cannot be stored within the operational limits of water management system will be released to Hare Lake. The excess treated water that will be discharged from the site, or effluent, will be comprised of three primary streams that are all managed through the WMP. The effluent stream will comprise a mix of process water from the PSMF, drainage (run-off and shallow seepage) associated with the MRSA that will be collected by ditching, catch basins and pumps to the WMP and contact water from the developed portion of the site (including for example, mine dewatering water, runoff from temporary stockpiles, process plant site) that will be collected by ditching and basins and pumped or gravity fed to the water management pond. Effluent will be conveyed to Hare Lake in the same manner as proposed in the original EIS – that is, effluent will be conveyed from the water management pond via a surface pipeline to a multi-port diffuser in the south side of the lake.

As describe above the predictive assessment of water quality relies on and incorporates information associated with a variety of factors including, background water quality and hydrology the site water balance and geochemical testing results. The following provides some specific context to the water quality predictions derived for the operations phase for Hare Lake.

Based on the mine waste testing programs completed to date phosphorus, as well as total suspended solids (TSS), have been identified as potential management needs. The geochemical source terms derived from mine waste testing indicate that low levels of metals/metalloids will be generated and that overall were not expected to represent a potential risk to water quality receiving environment. Moreover, there is an effective management strategy for Type 2 (PAG) materials that will mitigate the likelihood of ARD associated water quality issues. Nitrogen species, as blasting residues, will be actively managed and also were not identified as likely water quality risk.

With respect to phosphorus, it is noted that a phosphorus (phosphate) based reagent is planned to be used in the floatation circuit. Taking a very conservative view, it can be assumed that this phosphorus will remain in the dissolved form within the process water stream. In this case, the dissolved phosphorus would be at levels at end of pipe that could result in phosphorus concentrations that are greater than background and exceeding relevant receiver water quality objectives, without appropriate management. Therefore there is potential for nutrient enrichment (increased primary productivity) in Hare Lake if not mitigated. Local Indigenous communities have expressed direct concern for possible nutrient enrichment related effects. In consideration of the potential risk and local Indigenous community concern, phosphorus levels in the final discharge to Hare Lake will be managed via treatment as needed. Treatment technologies are readily available to reduce phosphorus levels at end of pipe (MEND, 2014) to ensure that phosphorus concentrations in Hare Lake remain at or below PWQO, which are protective of aquatic ecosystems to mitigate the potential risk of nutrient enrichment. GenPGM is committed to implementing such a management/system and the water quality predictions presented herein for Hare Lake reflect this commitment.

With respect to TSS, it has been recognized as a general management priority. Management of TSS levels in the final discharge will ensure expected discharge quality can be maintained consistently. To this end, GenPGM will employ active means (e.g., filtering), if required to achieve low TSS levels in discharge, in addition to passive means such as settling and clarification in the water management pond to manage TSS in the effluent stream to low levels.

6.2.2.1 Water Quality

6.2.2.1.1 Discharge Effluent Quality

Predictions of the quality of treated effluent that will be discharged to Hare Lake under the expected discharge scenario are shown in Table 6-1. The concentrations shown represent the average and maximum predicted concentrations in treated effluent over the operations phase of the project. Metal and Diamond Mine Effluent Regulations (MDMER) effluent limits that will apply to the discharge are provided for reference.

Table 6-1: Average and maximum predicted constituent concentrations in treated effluent that will be discharged to Hare Lake during the operations phase

Chemical Constituent	Average Concentration (mg/L)	Max Concentration (mg/L)	MDMER Effluent Quality Limits[1]
Aluminum	0.037	0.49	-
Antimony	0.000053	0.00094	-
Arsenic	0.00042	0.0063	0.2
Boron	0.0040	0.054	-
Cadmium	0.0000035	0.000049	-
Chromium	0.00015	0.0023	--
Cobalt	0.000053	0.00098	-
Copper	0.00039	0.0063	0.2
Iron	0.0069	0.099	-
Lead	0.000014	0.00022	0.16
Manganese	0.0024	0.042	-
Mercury	0.00000077	0.0000091	-
Molybdenum	0.0016	0.020	-
Nickel	0.00034	0.0049	0.5
Selenium	0.00018	0.0027	-
Silver	0.0000055	0.000073	-
Thallium	0.000013	0.00022	-
Uranium	0.000049	0.00080	-
Vanadium	0.0023	0.028	-
Zinc	0.00065	0.010	0.8
Hardness	0.064	1.4	-
Sulphate	3.3	46	-
Nitrate	0.57	8.1	-
Total Ammonia[2]	0.072	1.0	-
Phosphorus	0.011	0.10	-

1. Maximum Authorized Concentration in a Grab Sample
2. Limits for un-ionized ammonia (as N) are prescribed.

6.2.2.1.2 Predictions of Water Quality in Hare Lake

Predictions of water quality in Hare Lake under the expected discharge scenario are shown in Table 6-2. Time series graphs showing the constituent concentrations over the operations phase of the project are provided in Appendix B. The concentrations shown represent the maximum predicted concentrations in Hare Lake over the operations phase of the project. The predictions reflect whole-lake constituent concentrations following mixing, the physical process whereby the effluent mixes with the lake water. Hydrodynamic mixing in Hare Lake is discussed below in Section 6.2.2.2.

As shown in Table 6-2, maximum predicted concentrations are not expected to exceed relevant water quality benchmarks in Hare Lake during operations. Overall, the results of the updated water quality analysis for Hare Lake are very similar with those presented in the original EIS. In many cases constituent concentrations are not predicted to change from background levels. In some cases (e.g., molybdenum, nitrate) constituents in Hare Lake show small incremental increases in predicted concentrations relative to background during periods of discharge but, as indicated the concentrations remain below water quality benchmark values. For a small number of constituents (e.g., iron, aluminum), it is noted that background concentrations exceed the water quality benchmark values upon which the water quality assessment is based. In this case, the predicted concentrations of these constituents are compared to their respective background concentrations – that is the background concentration becomes the de facto water quality benchmark to confirm that no further changes in water quality are predicted. For each of these constituents no change, or a reduction from background levels is predicted.

Table 6-2: Average and maximum predicted constituent concentrations in Hare Lake during the operations phase

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Ops)	Max. Conc. Prediction (Ops)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.17	0.17	0.17
Antimony	0.02	-	0.005	0.005	0.005
Arsenic	0.005	0.005	0.001	0.001	0.001
Boron	0.2	1.5	0.05	0.05	0.05
Cadmium	0.0001	0.00005	0.00009	0.00009	0.00009
Chromium	0.0089	0.0089	0.0005	0.0005	0.0006
Cobalt	0.0009	-	0.0005	0.0004	0.0005
Copper	0.005	0.002	0.001	0.001	0.001
Iron	0.3	0.3	0.9	0.9	0.9
Lead	0.001	0.001	0.001	0.0009	0.001
Manganese	-	0.32	0.08	0.08	0.09
Mercury (filtered)	0.0002	0.000026	0.000005	0.000005	0.000006
Molybdenum	0.04	0.073	0.001	0.001	0.002
Nickel	0.025	0.025	0.002	0.002	0.002
Selenium	0.1	0.001	0.001	0.001	0.001
Silver	0.0001	0.00025	0.0001	0.0009	0.001
Thallium	0.0003	0.0008	0.0003	0.0002	0.0003
Uranium	0.005	0.005	0.005	0.004	0.005
Vanadium	0.006	-	0.001	0.002	0.002
Zinc	0.02	0.008	0.006	0.006	0.007
Hardness	-	-	20	20	20
Sulphate	-	-	3.5	4.5	5.9
Nitrate (N)	-	3.0	0.11	0.3	0.6
Total Ammonia (N)	-	1.04	0.06	0.08	0.11
Phosphorous	0.02	0.01 to 0.02	0.01	0.02	0.02

Notes:

Total concentrations unless denoted.

PWQO is Provincial Water Quality Objectives. Where interim PWQOs are available the interim value is used.
CCME is Canadian Council of Ministers of the Environment; values shown are federal water quality benchmarks.

6.2.2.2 Hydrodynamic Mixing and Effluent Bouyancy

Treated mine water will be discharged to Hare Lake via a multi-port diffuser. The configuration of the diffuser in described in response to SIR #5 (CIAR #582) as part of the original EIS submission. Briefly, the discharge structure in Hare Lake will be located along the south side of the lake in 3 to 5 m of water depth. This water depth corresponds to the upper water layer (epilimnion) when the lake is thermally stratified. The 3 to 5 m depth interval situated about 10 to 15 m from the shoreline. Riparian zone vegetation includes spruce, with sedge and grasses intermixed with boulders at the water's edge. Near-shore substrates in the proposed location comprise rock and boulder. There is little to no submergent or emergent aquatic vegetation in the embayment.

The conceptual minimum design configuration for the proposed diffuser is summarized in Table 6-1. This conceptual design provides for a 30:1 mixing (ratio of lake water to discharge water) within 50 m of the discharge – the so-called mixing zone.

Table 6-3: Conceptual minimum design configuration for the Hare Lake discharge diffuser

Design Aspect	Features	Comment
Discharge location	Offshore	An offshore discharge is preferred over a shore based discharge since it provides greater protection of nearshore habitats.
Pipe alignment	Parallel to shore	A parallel alignment was selected as it is the only practical orientation given the steep relief of the shoreline area.
Port orientation	Horizontal, perpendicular to shore	The horizontal orientation of the discharge ports directs the effluent further offshore away from nearshore habitats.
Depth	3 to 5 m	A surfaced layer discharge is preferred to a deep water discharge as here the discharge is in an area of relatively higher currents and associated mixing.
Number of ports	10	A multi-port discharge is preferred to a single port discharge as it induces greater mixing through distribution of the discharge water along the full length of the diffuser.
Port diameter	0.051 m (2 inch)	The diameter of ports was set to achieve an exit velocity in the range of 3 m/s to 7 m/s to promote mixing while minimizing potential effects to fish.
Diffuser length	10 m	A 10 m long diffuser provides for sufficient mixing while occupying as little of the lake bottom as is practical.

Hydrodynamic mixing can be affected by the relative difference in density of the of two water sources that are mixed. In this case, the treated mine effluent has a higher level of total dissolved solids (TDS), and is therefore more dense, than the water in Hare Lake and consideration of the potential implications of this difference warrants attention. The relationship of water density, total dissolved solids (TDS) and temperature is shown in Figure 6-1.

Highlighted are the densities of surface and bottom waters for temperatures that are typical in Hare Lake during the summer when the lake is thermally stratified, based on data collected during the baseline program. In addition, the density of the treated mine water discharge water is shown, assuming an end of pipe TDS of 250 mg/L TDS. As can be seen on the graph the density of the treated mine water discharge and the ambient water in the surface layer of Hare Lake are virtually indistinguishable from one another, particularly following 10:1 mixing. The PSMF discharge will neither sink nor float since it is discharged into water of similar density. In practical terms, this means that the treated mine water discharge in the lake will not affect the normal dimictic thermal regime of the lake.

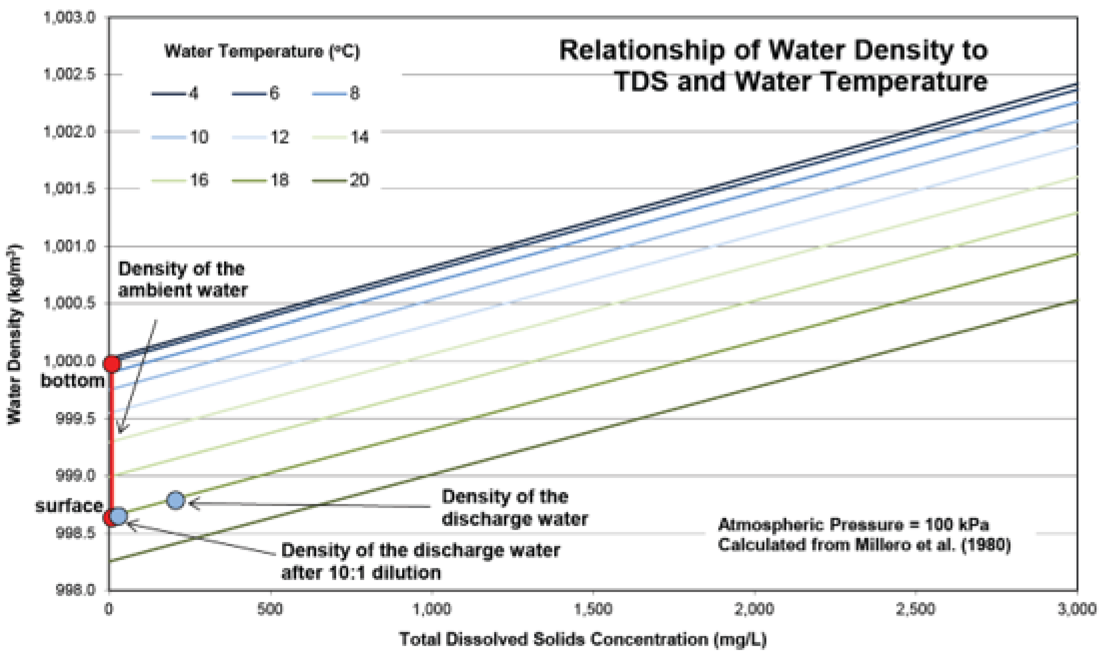

Figure 6-1: The relationship between water density, temperature and total dissolved solids in Hare Lake during summer stratification

6.2.2.3 Temperature Regime of Hare Lake

The temperature of the discharge will not be affected by anthropogenic activities associated with ore extraction, milling process or any other activity relating to the Project. The temperature of water in the discharge will be subject to the same natural warming and cooling processes to which natural water bodies. As such the water in the PSMF during the proposed discharge period is expected to be similar to the surface layer of water, the epilimnion, in Hare Lake. Some small differences may be seen as there will be minor coldwater inputs to Hare Hake in the form of small cold-water tributaries. In any event, any difference in temperature between the discharge and the ambient temperature in Hare Lake will be rapidly dissipated based on the mixing provided by the diffuser. As indicated in Section 6.2.2.2, the discharge is expected to be afforded 30:1 mixing within 50 m of release from the diffuser; accordingly it is expected that the discharge will be indistinguishable from background, with respect to temperature, within the mixing zone.

6.2.2.4 Sediment Quality

The IMPACT™ model was used to derive sediment quality predictions. IMPACT™ ("Integrated Model for the Probabilistic Assessment of Contaminant Transport") is an environmental pathways model used to evaluate the transport and effects of cons on environmental media and biological receptors, including humans. The IMPACT™ model simulates the transport of constituents from sources through various environmental media such as air, water, soil and sediment to receptors. The model estimates the concentration of constituents in environmental media, potential uptake by aquatic and terrestrial vegetation and animals, and potential intake by and dose to animals and humans. Further information regarding IMPACT™ was provided in the original EIS submission in response to IR 12.8 – this information is reproduced in Appendix F for reference.

The equation that is the basis for sediment concentration predictions is a partial differential equation that is solved within IMPACT™. The equation is characterized by a series of parameters that describe the physical and biochemical environment of the lake. The equation is solved iteratively, with the model estimating the change in sediment concentrations over time as follows:

$$\frac{dC_s}{dt} = \frac{g_w \cdot f_w \cdot C_{wc}}{z_s} + \frac{k_s}{z_s}\left[\left(1 - f_w\right) \cdot C_{wc} - C_{pw}\right] - C_s \cdot \left[\frac{g_b}{z_s}\right]$$

Where:

- dC_s is change in concentration over time
- dt is change in time
- g_w is settling rate of particles in water column
- f_w is fraction of a constituent that is particulate in the water column
- C_{wc} is concentration of constituent in water column
- Z_s is thickness of sediment layer
- k_s is sediment-water transport coefficient
- C_{pw} is concentration in the surficial sediment pore water
- C_s is concentration of constituent in surficial sediments
- g_b is burial rate of sediments

In the equation above, f_w is a function of the water-to-sediment partitioning coefficient (K_d), or the manner by which a constituent in the water partitions to sediments, which is determined by the equation:

$$f_w = \frac{K_d \cdot \frac{\rho_s}{\varepsilon_s}}{1 + K_d \cdot \frac{\rho_s}{\varepsilon_s}}$$

Where:

K_d is the water-to-sediment partitioning coefficient
ρ_s is bulk density of surficial sediment
ε_s porosity of surficial sediment

Predictions of sediment quality in Hare Lake during operations are shown in Table 6-4. These predictions represent the maximum concentrations predicted during operations. Time series graphs showing the constituent concentrations over the operations phase of the project are provided in Appendix C. Its is noted that the predictions are compared to assessment benchmarks to understand the significance of any predicted changes. These assessment benchmarks represent published sediment quality thresholds provided by the provincial and federal governments. The provincial guidelines are presented as the Lowest Effect Level (LEL) and Severe Effect Level (SEL). The Lowest Effect Level and Severe Effect Level are based on the long-term effects which the contaminants may have on the sediment-dwelling organisms. The federal guidelines consist of threshold effect levels (TELs) and probable effect levels (PELs). The TELs and PELs are used to identify the following three ranges of chemical concentrations with regard to biological effects: below the TEL - the minimal effect range within which adverse effects rarely occur; between the TEL and PEL - the possible effect range within which adverse effects occasionally occur; and, above the PEL - the probable effect range within which adverse effects frequently occur.

The incremental increases seen in sediment constituent concentrations in Hare Lake are generally within the background variability seen for individual constituents in Hare Lake based on baseline data and therefore are essentially indistinguishable from existing constituent levels. The exceptions to this pattern are molybdenum and vanadium, for which greater relative increases in concentrations are predicted than for other constituents. There are no sediment quality objectives provided for molybdenum or vanadium by the provincial and federal governments. Thompson et al. (2005) has derived equivalent LEL and SEL concentrations for a number of metals, including molybdenum or vanadium, and radionuclides associated with uranium mining and milling. For molybdenum, the LEL and SEL are 13.8 mg/kg and 1,239 mg/kg, respectively. For vanadium, the LEL and SEL are 35.2 mg/kg and 160 mg/kg, respectively. The maximum predicted molybdenum level in Hare Lake is about is about half the LEL, and therefore no effects on aquatic biota would be expected. For vanadium, the average and maximum predicted concentrations are 39.6 mg/kg and 49.6 mg/kg, respectively. The maximum predicted vanadium concentration is greater than the LEL but well below the SEL. The range of background vanadium levels in lake sediments also exceeds the LEL. In this context, no Project effects on aquatic biota would be expected as the result of vanadium. Overall, the results of the updated sediment quality analysis for Hare Lake are very similar with those presented in the original EIS.

Table 6-4: Average and maximum predicted constituent concentrations in Hare Lake sediments during operations

Constituent	PSQG		FSQO		Background (mg/kg)		Avg Predicted Conc. (mg/kg)	Max Predicted Conc. (mg/kg)
	LEL (mg/kg)	SEL (mg/kg)	TEL (mg/kg)	PEL (mg/kg)	Min	Max		
Aluminum	-	-	-	-	10,400	26,000	18,127	18,410
Arsenic	6	33	5.9	17	2.5	18	9.3	10.2
Cadmium	0.6	10	0.6	3.5	0.7	4.9	2.4	2.4
Copper	16	110	35.7	197	10.1	38.6	27.1	28.6
Iron	20,000	40,000	-	-	13,100	65,500	33,019	40,000
Lead	31	250	35	91.3	12.5	84.9	40.9	41.7
Molybdenum	-	-	-	-	<1.0	2.2	2.1	2.6
Nickel	16	75			12.7	20.3	16.3	16.7
Selenium					<1.0	3.0	1.9	2.0
Uranium					<1.0	<1.0	1.0	1.0
Vanadium					20.7	40.4	39.6	49.6
Zinc	120	820	123	315	164	422	271.4	273.5

Notes:
PSQG, Provincial Sediment Quality Guidelines
FSQO, Federal Sediment Quality Guidelines

6.2.2.5 Risks to Ecological Receptors

The potential effects of bioaccumulation of constituents on biota in Hare Lake during operations was assessed. The assessment considered the potential effects of the discharge of treated water during operations on representative species, including northern pike, muskrat, mink and moose. These VECs reside within, or be associated with Hare Lake and Hare Creek. IMPACT™ was used to provide a screening evaluation of the potential risk to these animals. For conservatism, the assessment considered upper bound water quality effects in Hare Lake and includes exposure pathways through ingestion of water and foods that have been exposed to Hare Lake water and sediment. The risk assessment follows methods described in Ecometrix (2009), Suter (2000) and Sample et al. (1996).

Table 6-5 presents the results of the screening level risk assessment. The table presents the calculated exposure ratios for various constituents and the species referenced above. The exposure ratios represent the ratio of constituent exposure level to a reference dose for that constituent that is considered to be non-toxic. A value less than 1.0 indicates no potential risk to the animal while a value greater than 1 suggests that the toxic exposure risk should be evaluated in more detail. As shown in Table 6-5, all exposure ratios are less than 1.0 indicating no risks.

Table 6-5: Predicted Exposure Ratios for Selected Ecological Receptors

Constituent	Predicted Exposure Ratio (unitless)			
	Northern Pike	Muskrat	Mink	Moose
Arsenic	<0.01	0.06	<0.01	<0.01
Cobalt	<0.01	0.02	<0.01	<0.01
Copper	0.49	0.19	<0.01	0.01
Lead	<0.01	0.97	0.05	0.06
Molybdenum	<0.01	0.06	<0.01	<0.01
Nickel	0.07	<0.01	<0.01	<0.01
Selenium	0.60	0.37	0.54	<0.01
Vanadium	0.05	0.10	0.05	<0.01
Zinc	0.05	0.40	0.09	0.02

6.2.3 Pic River

Per the site water balance, contact waters associated with site aspects, including the MRSA, will be managed through site water management infrastructure during operations. There will be no direct routine discharge to the Pic River local subwatersheds associated with the Project during operations, and therefore no formal predictions of water quality are provided since no changes to water quality are expected.

6.3 Closure

Following the cessation of mining operations, the discharge to Hare Lake will cease. The site wide water management system will continue to operate such that GenPGM will remain in control of site aspect affected water via the water management pond. At that time, water (runoff and shallow seepage) from the PSMF, drainage (run-off and shallow seepage) associated with the MRSA and contact water from the developed portion of the site (including for example, mine dewatering water, runoff from temporary stockpiles, process plant site) will continue to be collected and diverted to the water management pond. From the water management pond, the water will be directed to the open pit complex, where there are decades worth of water storage capacity. For planning purposes, it is assumed that these diversions will continue for a period of five years following the cessation of mining operations. This strategy ensures control of water quality on and off site while site decommissioning and rehabilitation activities are implemented, allowing the water quality associated with these site aspects to stabilize.

Following this five-year period, it is expected that natural surface water drainages will be restored.

6.3.1 Local Subwatersheds

For the PSMF, that means surface runoff and seepage will be re-directed into the subwatershed 106. Predictions of water quality in subwatershed 106 are shown in Table 6-6. The predictions provided in Table 6-6 are average long-term concentrations that are expected during, and following, mine closure and the restoration of pre-development drainage patterns. As indicated the predictions, consider both expected seepage and runoff sources that will report into subwatershed 106. Small incremental increases in the concentrations of a number of constituents are predicted, relative to background, but no constituents are predicted to exceed their respective water quality benchmarks. For example, arsenic concentrations are predicted to increase from 0.001 mg/L (75th percentile of background data) to on average 0.002 mg/L, but will remain less than the water quality benchmark of 0.005 mg/L. Similarly, nitrate concentrations are predicted to increase from on 0.11 mg/L (75th percentile of background data) to on average 0.3 mg/L, but will remain less than the water quality benchmark of 3.0 mg/L. No incremental change in concentration is predicted for many constituents.

Table 6-6: Long-term predicted constituent concentrations (average) in the Stream 106 subwatershed post-closure following restoration of pre-development surface water drainage patterns

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Post-Closure)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.17	0.17
Antimony	0.02	-	0.005	0.003
Arsenic	0.005	0.005	0.001	0.002
Boron	0.2	1.5	0.05	0.05
Cadmium	0.0001	0.00005	0.00009	0.00009
Chromium	0.0089	0.0089	0.0005	0.0007
Cobalt	0.0009	-	0.0005	0.0004
Copper	0.005	0.002	0.001	0.001
Iron	0.3	0.3	0.9	0.7
Lead	0.001	0.001	0.001	0.001
Manganese	-	0.32	0.08	0.07
Mercury (filtered)	0.0002	0.000026	0.000005	0.000005
Molybdenum	0.04	0.073	0.001	0.003
Nickel	0.025	0.025	0.002	0.002
Selenium	0.1	0.001	0.001	0.001
Silver	0.0001	0.00025	0.0001	0.0001
Thallium	0.0003	0.0008	0.0003	0.0002
Uranium	0.005	0.005	0.005	0.004
Vanadium	0.006	-	0.001	0.002
Zinc	0.02	0.008	0.006	0.006
Hardness	-	-	20	20
Sulphate	-	-	3.5	7.2
Nitrate (N)	-	3.0	0.11	0.30
Total Ammonia (N)	-	1.04	0.06	0.28
Phosphorous	0.03	0.01 to 0.02	0.01	0.03

Notes:

Total concentrations unless denoted.

PWQO is Provincial Water Quality Objectives. Where interim PWQOs are available the interim value is used.

CCME is Canadian Council of Ministers of the Environment; values shown are federal water quality benchmarks.

Runoff from the area of the water management ponds associated with the PSMF will be directed to the Stream 101 subwatershed. Following closure, these ponds will be rehabilitated (e.g., dredged of deposited solids) such that the chemistry of any surface runoff from this area will reflect uninfluenced con-contact water. It is expected therefore that water quality will be similar to existing baseline conditions once the natural flow regime in subwatershed 101 has been restored.

6.3.2 Hare Lake

There will be no direct discharge to Hare Lake during the mine closure phase. A small portion of the PSMF is located in the Hare Lake drainage and therefore some run-off and seepage associated loadings will report to Hare Lake.

Predictions of long term water quality in Hare Lake during closure are shown in Table 6-7. The concentrations shown represent the average long-term predicted concentrations in Hare Lake during closure.

As shown in Table 6-7, predicted concentrations are not expected to exceed relevant water quality benchmarks in Hare Lake during closure, and constituent concentrations are generally expected to be on the order of pre-discharge background levels. In some cases (e.g., molybdenum, nitrate) constituents in Hare Lake show small incremental increases in predicted concentrations relative to background during periods of discharge but, as indicated the concentrations remain below water quality benchmark values. For a small number of constituents (e.g., iron, aluminum), it is noted that background concentrations exceed the water quality benchmark values upon which the water quality assessment is based. In this case, the predicted concentrations of these constituents are compared to their respective background concentrations – that is the background concentration becomes the de facto water quality benchmark to confirm that no further changes in water quality are predicted.

Table 6-7: Predicted constituent concentrations in the Hare Lake during closure

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Closure)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.17	0.17
Antimony	0.02	-	0.005	0.005
Arsenic	0.005	0.005	0.001	0.001
Boron	0.2	1.5	0.05	0.05
Cadmium	0.0001	0.00005	0.00009	0.00009
Chromium	0.0089	0.0089	0.0005	0.0005
Cobalt	0.0009	-	0.0005	0.0005
Copper	0.005	0.002	0.001	0.001
Iron	0.3	0.3	0.9	0.9
Lead	0.001	0.001	0.001	0.001
Manganese	-	0.32	0.08	0.08
Mercury (filtered)	0.0002	0.000026	0.000005	0.000005
Molybdenum	0.04	0.073	0.001	0.001

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Closure)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)
Nickel	0.025	0.025	0.002	0.002
Selenium	0.1	0.001	0.001	0.001
Silver	0.0001	0.00025	0.0001	0.0001
Thallium	0.0003	0.0008	0.0003	0.0003
Uranium	0.005	0.005	0.005	0.005
Vanadium	0.006	-	0.001	0.001
Zinc	0.02	0.008	0.006	0.006
Hardness	-	-	20	20
Sulphate	-	-	3.5	3.7
Nitrate (N)	-	3.0	0.11	0.11
Total Ammonia (N)	-	1.04	0.06	0.06
Phosphorous	0.02	0.01 to 0.02	0.01	0.01

6.3.3 Pic River

For the MRSA, drainage (run-off and shallow seepage) that will be collected by ditching and catch basins will be allowed to flow to the Pic River, rather than diverting it to the water management system.

Predictions of water quality in the Pic River during this phase of site closure are shown in Table 6-8. The predictions provided in Table 6-8 are maximum concentration predictions during this period. Time series graphs showing the constituent concentrations during this period (and for entire life of mine) are provided in Appendix D. Generally, no incremental change in concentration relative to background is noted for the majority of constituents. No exceedances of water quality benchmarks in the Pic River as the result of drainage from the MRSA during this period are predicted. In the few instances where background water quality exceeds water quality benchmark levels (e.g., aluminum, iron) no incremental increase in concentration relative to background is noted.

Table 6-8: Predicted constituent concentrations in the Pic River during the initial phase of post-closure following initial restoration of drainage from MRSA (post-five years after operations have ceased)

Constituent	Pic River		Background WQ	Max. Conc. Prediction (Post-Closure)
	PWQO (mg/L)	CCME(mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.5	0.5
Antimony	0.02	-	<0.005	0.005
Arsenic	0.005	0.005	<0.001	0.001
Boron	0.2	1.5	<0.05	0.05
Cadmium	0.0001	0.0002	<0.00009	0.00009
Chromium	0.0089	0.0089	0.004	0.005
Cobalt	0.0009	-	0.001	0.001
Copper	0.005	0.003	0.004	0.004
Iron	0.3	0.3	2.7	2.7
Lead	0.005	0.005	0.001	0.001
Manganese	-	0.26	0.08	0.09
Mercury (filtered)	0.0002	0.000026	<0.0001	0.0001
Molybdenum	0.04	0.073	<0.001	0.001
Nickel	0.025	0.12	0.004	0.004
Selenium	0.1	0.001	<0.001	0.001
Silver	0.0001	0.00025	<0.0001	0.0001
Thallium	0.0003	0.0008	<0.0003	0.0003
Uranium	0.005	0.005	<0.005	0.005
Vanadium	0.006	-	0.005	0.005
Zinc	0.02	0.041	0.009	0.009
Hardness	-	-	138	138
Sulphate	-	-	2.6	2.8
Nitrate (N)	-	3.0	0.08	0.2
Total Ammonia (N)	-	1.04	0.03	0.04
Phosphorous	0.03	0.01 to 0.02	0.08	0.08

Notes:

Total concentrations unless denoted.

PWQO is Provincial Water Quality Objectives. Where interim PWQOs are available the interim value is used.

CCME is Canadian Council of Ministers of the Environment; values shown are federal water quality benchmarks.

The pit complex is expected to fill with water approximately 30 years following mine closure. At this time water from the pits will drain into subwatershed 103, through the MRSA and subsequently into the Pic River. This scenario represents the long-term configuration of the mine site from surface water drainage perspective.

Long term post-closure predictions of water quality in the Pic River, inclusive of the contributions from the open pit are shown in Table 6-9. The predictions provided in Table 6-9 are maximum concentration predictions during this period. Time series graphs showing the constituent concentrations during this period are provided in Appendix D

Generally, no incremental change in concentration relative to background is noted for the majority of constituents. No exceedances of water quality benchmarks in the Pic River as the result of drainage from the MRSA during this period are predicted. In the few instances where background water quality exceeds water quality benchmark levels (e.g., aluminum, iron) no incremental increase in concentration relative to background is noted.

Table 6-9: Predicted constituent concentrations in the Pic River over the long term post-closure following controlled release of water from the open pit (post- thirty-five years after operations have ceased)

Constituent	Pic River		Background WQ	Max. Conc. Prediction (Post-Closure)
	PWQO (mg/L)	CCME(mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.5	0.5
Antimony	0.02	-	<0.005	0.005
Arsenic	0.005	0.005	<0.001	0.001
Boron	0.2	1.5	<0.05	0.05
Cadmium	0.0001	0.0002	<0.00009	0.00009
Chromium	0.0089	0.0089	0.004	0.005
Cobalt	0.0009	-	0.001	0.001
Copper	0.005	0.003	0.004	0.004
Iron	0.3	0.3	2.7	2.7
Lead	0.005	0.005	0.001	0.001
Manganese	-	0.26	0.08	0.09
Mercury (filtered)	0.0002	0.000026	<0.0001	0.0001
Molybdenum	0.04	0.073	<0.001	0.001
Nickel	0.025	0.12	0.004	0.004
Selenium	0.1	0.001	<0.001	0.001
Silver	0.0001	0.00025	<0.0001	0.0001
Thallium	0.0003	0.0008	<0.0003	0.0003
Uranium	0.005	0.005	<0.005	0.005
Vanadium	0.006	-	0.005	0.005
Zinc	0.02	0.041	0.009	0.010
Hardness	-	-	138	138
Sulphate	-	-	2.6	2.9
Nitrate (N)	-	3.0	0.08	0.3
Total Ammonia (N)	-	1.04	0.03	0.06
Phosphorous	0.03	0.01 to 0.02	0.08	0.08

Notes:
Total concentrations unless denoted.
PWQO is Provincial Water Quality Objectives. Where interim PWQOs are available the interim value is used.
CCME is Canadian Council of Ministers of the Environment; values shown are federal water quality benchmarks.

It is noted that, the predictions provided for the post-closure phase, though conservative in nature, are provided for planning purposes. GenPGM will not release water to the environment from its care and control until such time as monitoring data demonstrate it is safe to do so. In practice, this could entail continuing to divert all or some site aspect affected water to the water management pond and subsequently to the open pits for a period of longer than 5 years. The storage capacity in the open pits is such that the diversions could be in place for many more years providing sufficient time to develop alternative long term water quality management strategies. If all site aspect water was diverted to the open pits for storage indefinitely it would take approximately 17 years to fill to the elevation where controlled release would be required to mitigate uncontrolled overtopping.

6.4 Summary of Key Results

The key results of the updated water quality analysis are as follows:

- Construction
  - Per the site water balance, contact waters associated with site aspects will be managed through site water management infrastructure during construction. No routine direct discharges to local subwatersheds, Hare Lake or the Pic River are planned during construction. The focus of water management during construction, will be the mitigation of the potential for mobilization of suspended material into natural surface water features as the result of land disturbance and clearing.
- Operations
  - During operations the primary potential water quality effect from the Project is the discharge of excess water from the site water management system to Hare Lake. No other routine discharges from the site are planned during operations. For planning purposes, the water balance has assumed discharge will occur between April and November. Rates of discharge vary within and among years according to the development of the site and Process Plant needs. In general, it is expected that between ~1 and 2 * 10^6 m^3 of treated mine water will be discharged from the site to Hare Lake per year of the operations phase of the mine.
  - Maximum predicted concentrations are not expected to exceed relevant water quality benchmarks in Hare Lake during operations. In many cases constituent concentrations are not predicted to change from background levels. In some cases (e.g., molybdenum, nitrate) constituents in Hare Lake show small incremental increases in predicted concentrations relative to background during periods of discharge but, as indicated the concentrations remain below water quality benchmark values. For a small number of constituents (e.g., iron, aluminum), it is noted that background concentrations exceed the water quality benchmark values upon which the water quality assessment is based. For each of these constituents no change, or a reduction from background levels is predicted.

  - Based on the nature of the treated effluent to Hare Lake, no effects on the normal seasonal mixing, nor thermal regime of the lake are expected.

  - The incremental increases predicted in sediment constituent concentrations in Hare Lake are generally within the background variability seen for individual constituents in Hare Lake based on baseline data and therefore are essentially indistinguishable from existing constituent levels. The exceptions to this pattern are molybdenum and vanadium, for which greater relative increases in concentrations are predicted than for other constituents; however, no Project effects on aquatic biota would be expected.

  - No risks to ecological receptors in Hare Lake are predicted.

- Initial phase of closure

  - At the cessation of operations routine discharge of water from the site to the local environment are not planned. All contact water on the site will be managed within the water management pond and conveyed to the open pit for storage to ensure care and control while active rehabilitation of the site is underway. For planning purposes it is assumed this period will last 5 years.

- Long-term closure

  - Following the initial 5 year period, natural pre-mining drainage patterns will be restored to the extent possible. Water quality predictions extending over the long term indicate water quality in Hare Lake, the Pic River and local site-associated subwatersheds (e.g., subwatersheds, 101, 106) will meet relevant water quality benchmarks for the protection of aquatic life.

7.0 REFERENCES

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Appendix A Geochemical Investigations Supporting Information

Table A.1: Conceptual Pit, MRSA and Overburden Stockpile Development during Operations Phase

Year		*Date*	Mine Rock								Overburden
			kg of Material								
			Rubble - North Pit	*Rubble - South Pit*	*Rubble - Centre Pit*	*East Waste Dump (NPAG)*	*South Pit Inpit Dumping (NPAG + PAG)*	*South Pit Dump Extension (NPAG)*	*PSMF Cell 2 (PAG)*	*Center Pit Inpit Dumping (PAG)*	*Ovb Dump (OVB)*
0	*2022*	*01-Jan-22*	606,106	420,814	-	-	-	-	-	-	51,657,590
1	*2023*	*01-Jan-23*	1,653,475	6,941,688	967,498	10,817	-	-	-	-	675,368,707
2	*2024*	*01-Jan-24*	19,738,107	6,941,688	967,498	9,367,737,966	-	-	1,285,195,654	-	1,489,763,717
3	*2025*	*01-Jan-25*	42,363,920	11,749,569	967,498	26,200,917,917	-	-	7,648,355,975	-	1,747,822,808
4	*2026*	*01-Jan-26*	48,616,791	32,593,564	967,498	45,489,219,694	-	-	12,033,947,205	-	2,191,682,800
5	*2027*	*01-Jan-27*	50,549,657	60,551,257	967,498	65,643,319,939	-	-	18,325,850,209	-	2,371,902,442
6	*2028*	*01-Jan-28*	68,096,710	72,679,828	967,498	87,716,927,722	-	-	19,545,009,169	-	2,575,068,934
7	*2029*	*01-Jan-29*	99,234,708	72,679,828	967,498	113,890,737,582	3,600,536,857	-	19,545,009,169	-	2,663,209,990
8	*2030*	*01-Jan-30*	112,361,921	72,679,828	16,901,055	131,342,764,800	5,534,589,716	-	19,545,009,169	-	3,031,060,631
9	*2031*	*01-Jan-31*	144,581,602	72,679,828	16,901,055	131,342,764,800	34,757,880,275	-	19,545,009,169	-	3,701,109,744
10	*2032*	*01-Jan-32*	166,459,674	72,679,828	25,921,686	131,342,764,800	54,150,300,175	-	19,545,009,169	-	3,732,202,966
11	*2033*	*01-Jan-33*	195,501,405	72,679,828	27,240,969	131,342,764,800	73,342,584,000	11,168,729,693	19,545,009,169	-	3,732,202,966
12	*2034*	*01-Jan-34*	217,622,025	72,679,828	27,240,969	131,342,764,800	73,342,584,000	15,750,653,327	19,545,009,169	7,049,374,107	3,732,202,966
13	*2035*	*01-Jan-35*	228,045,877	72,679,828	27,240,969	131,342,764,800	73,342,584,000	16,027,276,256	19,545,009,169	13,790,063,193	3,732,202,966
14	*2036*	*01-Jan-36*	230,009,348	72,679,828	27,240,969	131,342,764,800	73,342,584,000	16,234,246,028	19,545,009,169	15,546,564,736	3,732,202,966
15	*2037*	*01-Jan-37*	230,255,866	72,679,828	27,240,969	131,342,764,800	73,342,584,000	16,236,052,200	19,545,009,169	15,791,276,132	3,732,202,966
16	*2038*	*01-Jan-38*	230,255,866	72,679,828	27,240,969	131,342,764,800	73,342,584,000	16,236,052,200	19,545,009,169	15,791,276,132	3,732,202,966
17	*2039*	*01-Jan-39*	230,255,866	72,679,828	27,240,969	131,342,764,800	73,342,584,000	16,236,052,200	19,545,009,169	15,791,276,132	3,732,202,966
18	*2040*	*01-Jan-40*	230,255,866	72,679,828	27,240,969	131,342,764,800	73,342,584,000	16,236,052,200	19,545,009,169	15,791,276,132	3,732,202,966

Table A.2: Conceptual PSMF and Run of Mine Stockpile Development during Operations Phase

Year		*Date*	Type 1 PSMF Construction Rock						Type 2 PSMF Construction Rock		Run of Mine Ore	
			kg of Material									
			Water Management Pond - West Embankment	**Water Management Pond** - East Embankment	**Cell 1** - West Embankment	**Cell 2A** - S, E, N Embankments	**Cell 2A-2B Divider Portion in 2033 is TYPE 1 ROCK**	**Cell 2B** - W Embankment	**Cell 2A** - S, E, N Embankments	**Cell 2A-2B Divider TYPE 2 ROCK**	**Ore at Stockpile**	**Mill Throughput**
0	***2022***	***01-Jan-22***	612,720,000	788,400,000	-	-	-	-	-	-	-	-
1	***2023***	***01-Jan-23***	612,720,000	788,400,000	1,247,280,000	3,700,800,000	-	-	240,960,000	-	1,616,396,569	201,558,936
2	***2024***	***01-Jan-24***	612,720,000	788,400,000	2,812,560,000	3,700,800,000	-	-	240,960,000	1,285,440,000	2,598,255,487	4,933,509,960
3	***2025***	***01-Jan-25***	612,720,000	788,400,000	6,713,280,000	8,800,800,000	-	-	240,960,000	7,568,880,000	6,056,227,360	9,108,333,000
4	***2026***	***01-Jan-26***	612,720,000	788,400,000	6,713,280,000	8,800,800,000	-	3,132,480,000	240,960,000	12,429,360,000	9,759,368,577	9,200,000,000
5	***2027***	***01-Jan-27***	612,720,000	788,400,000	6,713,280,000	9,349,200,000	-	5,886,000,000	240,960,000	19,034,400,000	10,668,804,189	9,200,000,000
6	***2028***	***01-Jan-28***	612,720,000	788,400,000	6,713,280,000	9,349,200,000	-	11,704,080,000	240,960,000	21,166,320,000	11,475,560,339	9,200,000,000
7	***2029***	***01-Jan-29***	612,720,000	788,400,000	6,713,280,000	10,813,680,000	-	11,704,080,000	240,960,000	21,644,640,000	11,695,671,848	9,200,000,000
8	***2030***	***01-Jan-30***	612,720,000	788,400,000	6,713,280,000	10,813,680,000	-	20,124,240,000	240,960,000	22,871,040,000	12,633,790,453	9,200,000,000
9	***2031***	***01-Jan-31***	612,720,000	788,400,000	6,713,280,000	13,439,760,000	-	20,124,240,000	240,960,000	25,946,640,000	11,213,956,800	9,200,000,000
10	***2032***	***01-Jan-32***	612,720,000	788,400,000	6,713,280,000	13,439,760,000	-	31,494,960,000	240,960,000	27,513,120,000	11,076,789,080	9,200,000,000
11	***2033***	***01-Jan-33***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	31,494,960,000	240,960,000	30,588,240,000	6,764,115,237	9,200,000,000
12	***2034***	***01-Jan-34***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	31,494,960,000	240,960,000	30,588,240,000	4,761,424,296	9,200,000,000
13	***2035***	***01-Jan-35***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	43,812,720,000	240,960,000	30,588,240,000	3,881,764,170	9,200,000,000
14	***2036***	***01-Jan-36***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	43,812,720,000	240,960,000	30,588,240,000	908,857,800	9,200,000,000
15	***2037***	***01-Jan-37***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	43,812,720,000	240,960,000	30,588,240,000	0	2,257,252,603
16	***2038***	***01-Jan-38***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	43,812,720,000	240,960,000	30,588,240,000	0	-
17	***2039***	***01-Jan-39***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	43,812,720,000	240,960,000	30,588,240,000	0	-
18	***2040***	***01-Jan-40***	612,720,000	788,400,000	6,713,280,000	16,640,400,000	1,903,200,000	43,812,720,000	240,960,000	30,588,240,000	0	-

Table A.3: Summary of Mine Rock Loading Rates

Chemical Constituent	Type 1 Mine Rock Field Rate[1] (mg/kg/wk)	Type 2 Mine Rock Field Rate[1] (mg/kg/wk)	Rubble Field Rate[2] (mg/kg/wk)	Pit Walls Field Rate[3] (mg/m2/wk)	Run of Mine Ore Field Rate[1] (mg/kg/wk)
Aluminum[3]	0.13	0.02	0.13	0.13	0.02
Antimony	7.22E-07	7.17E-07	7.22E-05	6.28E-06	6.39E-07
Arsenic	3.77E-06	8.54E-06	3.77E-04	3.28E-05	1.31E-06
Boron	1.07E-06	2.86E-06	1.07E-04	9.35E-06	2.01E-06
Cadmium	9.78E-09	3.02E-08	9.78E-07	8.51E-08	5.81E-08
Chromium	1.43E-06	1.35E-06	1.43E-04	1.24E-05	1.33E-06
Cobalt	2.58E-07	4.90E-06	2.58E-05	2.24E-06	3.37E-06
Copper	1.79E-06	1.36E-05	1.79E-04	1.56E-05	2.89E-05
Iron[3]	0.004	0.004	0.004	0.004	0.004
Lead	1.00E-07	1.00E-07	1.00E-05	8.71E-07	1.84E-07
Manganese	2.41E-05	7.21E-05	2.41E-03	2.10E-04	9.54E-05
Molybdenum	8.39E-07	4.17E-07	8.39E-05	7.29E-06	3.35E-07
Nickel	7.07E-07	1.75E-05	7.07E-05	6.15E-06	1.29E-05
Selenium	1.39E-06	1.40E-06	1.39E-04	1.21E-05	1.33E-06
Silver	1.48E-08	5.00E-08	1.48E-06	1.29E-07	7.97E-08
Thallium	2.20E-08	1.17E-07	2.20E-06	1.91E-07	2.44E-07
Uranium	4.12E-07	7.37E-07	4.12E-05	3.58E-06	4.31E-07
Vanadium	2.82E-06	6.56E-07	2.82E-04	2.45E-05	2.09E-07
Zinc	2.86E-06	4.23E-06	2.86E-04	2.49E-05	4.00E-06
Sulphate	4.19E-03	1.86E-02	4.19E-01	3.64E-02	6.29E-02

Notes:

1 - Adjusted for surface area (particle size) and temperature.

2 - Based on Type 1 unit rates, adjusted for temperature.

3 - Converted from Type 1 unit rates (mg/kg/wk) to surface area rates ($mg/m^2/wk$).

4 - Dependant on geochemical characteristics of solubility and pH control. Constant concentration in mg/L.

Table A.4: Summary of Nitrogen Loadings Associated with Mine Rock

Year	Ammonia N Released	Nitrate N Released
	mg/kg/wk	mg/kg/wk
2022	5.53E-04	4.37E-03
2023	1.01E-03	8.02E-03
2024	1.20E-03	9.52E-03
2025	1.01E-03	8.00E-03
2026	9.75E-04	7.71E-03
2027	9.96E-04	7.88E-03
2028	9.66E-04	7.64E-03
2029	9.43E-04	7.46E-03
2030	8.96E-04	7.08E-03
2031	8.36E-04	6.61E-03
2032	7.93E-04	6.27E-03
2033	7.43E-04	5.88E-03
2034	7.37E-04	5.83E-03
2035	6.93E-04	5.48E-03
2036	6.55E-04	5.18E-03
2037	6.00E-04	4.75E-03
2038	5.45E-04	4.31E-03
2039	4.95E-04	3.91E-03
2040	4.49E-04	3.55E-03
2041	4.08E-04	3.22E-03
2042	3.70E-04	2.93E-03
2043	3.36E-04	2.66E-03
2044	3.05E-04	2.41E-03
2045	2.77E-04	2.19E-03
2046	2.51E-04	1.99E-03
2047	2.28E-04	1.80E-03
2048	2.07E-04	1.64E-03
2049	1.88E-04	1.49E-03
2050	1.71E-04	1.35E-03
2051	1.55E-04	1.23E-03
2052	1.41E-04	1.11E-03
2053	1.28E-04	1.01E-03
2054	1.16E-04	9.17E-04
2055	1.05E-04	8.33E-04
2056	9.56E-05	7.56E-04
2057	8.67E-05	6.86E-04
2058	7.87E-05	6.23E-04
2059	7.15E-05	5.65E-04
2060	6.49E-05	5.13E-04
2061	5.89E-05	4.66E-04
2062	5.35E-05	4.23E-04
2063	4.86E-05	3.84E-04
2064	4.41E-05	3.49E-04
2065	4.00E-05	3.16E-04
2066	3.63E-05	2.87E-04
2067	3.30E-05	2.61E-04
2068	2.99E-05	2.37E-04
2069	2.72E-05	2.15E-04
2070	2.47E-05	1.95E-04
2071	2.24E-05	1.77E-04
2072	2.03E-05	1.61E-04
2073	1.85E-05	1.46E-04
2074	1.68E-05	1.33E-04
2075	1.52E-05	1.20E-04
2076	1.38E-05	1.09E-04
2077	1.25E-05	9.91E-05
2078	1.14E-05	9.00E-05
2079	1.03E-05	8.17E-05
2080	9.38E-06	7.42E-05
2081	8.51E-06	6.73E-05
2082	7.73E-06	6.11E-05
2083	7.02E-06	5.55E-05
2084	6.37E-06	5.04E-05
2085	5.78E-06	4.57E-05

Notes:

1 - Estimated basec on an expected 0.27 g N/g emulsion. The expected explosives use was based on the mine rock production schedule.

2 - Relative proportions of N-species are based on Ferguson & Leask, 1988. "The Export of Nutrients from Surface Coal Mines."

3 - Release rate estimated using Brenda L.Bailey, Lianna J.D.Smith, David W.Blowes, Carol J.Ptacek, Leslie Smith, David Segod (2013). The Diavik Waste Rock Project: Persistence of contaminants from blasting agents in waste rock effluent. Applied Geochemistry (36), pp 256-270.

Table A.5: Process Solids Loadings Rates

Parameter	Process Solids Beach Loading Rates		Submerged Process Solids Loading Rates
	Laboratory Rate (mg/kg/wk)	Field Rate[1] (mg/kg/wk)	Laboratory Rate & Field Rate[2] (mg/m2/wk)
Aluminum	0.12	0.020	0.14
Antimony	0.00010	0.000017	0.0010
Arsenic	0.00013	0.000021	0.0011
Boron	0.0099	0.0017	1.3
Cadmium	0.0000099	0.0000017	0.000080
Chromium	0.00014	0.000024	0.0035
Cobalt	0.00010	0.000018	0.00093
Copper	0.00053	0.000090	0.0055
Iron	0.030	0.0051	0.10
Lead	0.000051	0.0000086	0.00041
Manganese	0.0013	0.00023	0
Molybdenum	0.00024	0.000041	0.18
Nickel	0.00056	0.000094	0.0091
Selenium	0.00027	0.000045	0.0024
Silver	0.0000099	0.0000017	0.00010
Thallium	0.000099	0.000017	0.0010
Uranium	0.000099	0.000017	0.0026
Vanadium	0.0010	0.00018	0.010
Zinc	0.0033	0.00056	0.031
Sulphate	11	1.9	404
Phosphorus	0.050	0.0085	3.1

Notes:

1. Process Solids Beach field loading rates apply an adjustment factor for temperature of 0.17.
2. Submerged Process Solids loading rates do not apply adjustment factors for field conditions.

Table A.6: Loadings Rates Associated with the Process Plant

Parameter	Type 1 Process Solids Mill Water (mg/L)	Type 2 Process Solids Mill Water (mg/L)
Aluminum	0.087	0.858
Antimony	--	--
Arsenic	0.0006	0.0067
Boron	0.046	0.041
Cadmium	0.000033	0.000012
Chromium	0.00012	0.00191
Cobalt	0.00006	0.000069
Copper	0.0005	0.0028
Iron	0.076	0.034
Lead	0.00002	0.00001
Manganese	0.00989	0.00069
Molybdenum	0.0284	0.0158
Nickel	0.003	0.0016
Selenium	0.00057	0.00205
Silver	0.00005	0.00005
Thallium	0.000005	0.000005
Uranium	0.000154	0.000026
Vanadium	0.0011	0.0787
Zinc	0.002	0.002
Sulphate	30	21
Phosphorus	0.535	1.39

Note:
N-species concentrations vary per year. See Table A.7

Table A.7: Loadings Rates Associated with the Process Plant – N-species

Year	Constituent		
	Ammonia-N	**Nitrate-N**	**Nitrite-N**
2020	0.00	0.00	0.00
2021	0.00	0.00	0.00
2022	0.00	0.00	0.00
2023	0.41	3.28	0.08
2024	0.41	3.23	0.07
2025	0.41	3.23	0.07
2026	0.41	3.23	0.07
2027	0.41	3.23	0.07
2028	0.41	3.23	0.07
2029	0.41	3.23	0.07
2030	0.41	3.23	0.07
2031	0.41	3.23	0.07
2032	0.41	3.23	0.07
2033	0.41	3.23	0.07
2034	0.41	3.23	0.07
2035	0.41	3.23	0.07
2036	0.41	3.23	0.07
2037	0.67	5.32	0.12
2038	0.00	0.00	0.00
2039+	0.00	0.00	0.00

Notes:
Concentrations calculated assuming 4.55 g of N-residual per tonne of ore. Residual is approximately 11% as ammonia, 87% as nitrate, and 2% as nitrite.

MEMO

To:	Tabatha LeBlanc, Generation PGM Inc.	From:	Neal Sullivan Ron Nicholson
Ref:	**Marathon Palladium Project: Geochemical Characteristics of Mine Rock Samples for the 2020 Pit Shells**	Date:	17 February 2021

Generation PGM Inc. (GenPGM) is advancing the Marathon Palladium Project through a feasibility study (FS) to optimize mine planning and ore processing. It is anticipated that the 2020 pit shells and mine plan will result in the production of approximately 326 Mt of mine rock.

A mine rock sampling and geochemical characterization program was designed and executed in October 2020 by Ecometrix to complement existing samples and to fill gaps within the 2020 optimized pit shells. This characterization program included all the required static testing to compare results with the mine rock results from the 2013 pit shell for the rock types expected to report to the mine rock storage area (MRSA).

This memo provides more results on the geochemical characteristics of the 2020 samples selected to fill gaps in the 2020 pit shells and to assess if further kinetic testing is necessary to support model calculations. These results are compared to those from previous mine rock samples.

Sample Selection and Representation

The 2020 samples were selected in a manner consistent with those in previous sampling events, referred to as the Golder (2007), Ecometrix (2010) and Stillwater (2013) samples, to represent mine rock within the pit shell and outside of the ore zone. All samples were collected as composites containing multiple samples from diamond drill core over approximately 10m lengths, representing the planned bench heights in the pits. A summary of the sulphur or acid potential (AP) and neutralization potential (NP) characteristics were presented and discussed in the context of an operational sulphur cut-off value to identify Type 1 and Type 2 mine rock during mining in Ecometrix (2021).

The lithologies of the former 2013 pit shells are geologically similar to the newly optimized 2020 pit shells. The estimated proportions of lithologies in the MRSA were estimated from the mine plan (J. McBride, pers. Comm) and are summarized as follows:

Eastern Gabbro – 83.6%
Footwall/Volcanics – 10%
Syenite – 5%
Fine Grained Gabbro Breccia – 1.4%

The revised 2020 mine rock sampling program was tailored to the newly optimized 2020 pit shells and included 38 samples from 30 drill holes. The samples were selected to fill gaps within the pit shells and are consistent with the distribution of lithologies. The proportion of samples are follows:

Fine Grained Gabbro (13 samples – 34.2%) Wehrlite-troctolite Sill (4 samples – 10.5%) Oxide Melatroctolite (2 samples – 5.3%) Two Duck Lake Gabbro (13 samples – 34.2%)	Eastern Gabbro (32 samples – 84.2%)
Footwall/Volcanics (4 samples – 10.5%)	
Syenite (2 samples – 5.3%)	

The 2020 and former sample locations hosted within the pit shells are shown in **Appendix A**.

Acid Base Accounting

The Acid Base Accounting (ABA) characteristics used to determine the potential risk of acid generation in mine materials includes the AP that is calculated from the sulphide-sulphur content and the NP which may be estimated in several ways. Both AP and NP are presented in units of kg-$CaCO_3$/t that represent the kilograms of calcium carbonate equivalent per tonne of rock. The NP is commonly measured using some modification of the Sobek method, which includes addition of a strong acid to a sample, allowing time to react and then measuring the remaining acid to determine the amount of acid consumed. However, due to uncertainty in the estimation of the NP by the Sobek method, the most current guideline for prediction of acid generation presented by MEND (Price, 2009) also recommends the use of “effective” NP for ABA characterization. Calcium and magnesium carbonate minerals are considered to represent effective NP because they consume acid and maintain a neutral pH drainage or contact water. As a result, a more conservative approach is to consider the carbonate content in the solids as an estimate of effective-NP and thus the carbonate-NP (Carb-NP) is reviewed in detail throughout this memo.

The ratio of Carb-NP/AP was used to determine if the material has adequate NP to consume the acid produced if all the available sulphide-sulphur is oxidized. As a conservative measure, it is assumed that 2 units of NP will be required to neutralize the acid from 1 unit of AP in order to maintain neutral conditions in the mine material indefinitely and therefore the ratio of Carb-NP/AP should be greater than 2 to maintain neutral conditions. Type 1, that is non-potentially acid generating (Non-PAG) mine rock is defined by a Carb-NP/AP ratio greater than 2. Type 2, that is potentially acid generating (PAG) mine rock is defined by Carb-NP/AP ratio less than 1, according to the guidance by MEND (Price, 2009). Carb-NP/AP ratio between 1 and 2 is characterized as uncertain and is classified conservatively as Type 2 mine rock for the Marathon Palladium Project.

A summary of the 2020 sample program is presented in **Table 1**. A total of 15 of 38 samples were analyzed for full ABA which includes the Sobek method as well as carbon and sulphur species (C/S species) to calculate the Carb-NP/AP ratio. The remaining 23 samples were analyzed for only C/S species. As a result, the Carb-NP/AP ratio was determined for all 38 samples whereas 15 of the samples were also tested for ABA using the Sobek method. **Figure 1** shows the relationship between the Carb-NP/AP ratio versus total sulphur analyses from the recent 2020 static geochemistry program compared to former sample programs. There are 436 samples with Carb-NP/AP ratios in total. **Figure 1** shows a strong inverse relationship between the Carb-NP/AP ratio and total sulphur, as expected. It is evident that the 2020 samples fall within the ranges of previous samples for both sulphur and Carb-NP/AP ratios and are therefore consistent with the former samples. A comparison of the 2020 samples with previous samples using the Sobek method is presented in Ecometrix (2021).

Further comparison of ABA statistics between the 2020 sample program results and those from the former geochemistry programs is summarized in **Table 2** and is also illustrated using box plot comparisons in **Figure 2**. In general, it is apparent that the interquartile range (between the 25^{th} and 75^{th} percentile) for the 2020 analyses overlap with the former for total sulphur, Carb-NP and Carb-NP/AP ratio which highlight a good agreement between the data sets. More specifically, the 2020 samples are generally lower in total sulphur, and by extension, AP. Considering the 2020 Carb-NP values show a very strong agreement with the previous results, with geometric means of 6.7 and 8.6 kg-$CaCO_3$/t, respectively, the 2020 samples exhibit slightly higher Carb-NP/AP ratios than those from the former sampling programs. The proportion of Type 1 mine rock, as classified by Carb-NP/AP ratio greater than 2, is also strongly comparable between the 2020 samples and former samples. **Table 2** shows that the 2020 sample program classified 89.5% of samples (34 of 38 samples) as Type 1, and similarly, the former sampling programs combined determined 90.5% of samples (360 of 393 samples) as Type 1.

ICP-MS Bulk Metal Analysis

Samples submitted for metals contents underwent an aqua-regia digestion followed by a full metal scan by inductively coupled plasma mass spectrometry (ICP-MS) analyses, consistent with previous analyses. As recommended by MEND (2009), metal content values were compared to average crustal abundances for measured parameters (in mg/kg).

Elevated concentrations of metals in the solid phase do not necessarily increase the potential for metal leaching, but rather identify parameters for further consideration. Therefore, for screening purposes, mine rock solids contents were compared to 10 times (10X) the average crustal abundances, as outlined by Faure (1998), in order to identify elements that may require additional investigation.

A summary of statistics for the ICP-MS bulk metals analyses are shown in **Table 3**. Except for selenium, there are no samples which exceed 10 times (10X) the average crustal abundances for any of the parameters in the 2020 sample program. However, it should be noted that the statistics for selenium are heavily influenced by the detection limit of 0.7 mg/kg, which exceeds the 10X of the average crustal abundance for selenium. It should be noted that 13 of 15 samples were below the detection limit of 0.7 mg/kg. A similar result was observed for the former sample programs in which 38 of 57 samples were below the detection limit of 0.5 mg/kg. All parameters from the 2020 sample program have strongly comparable geomean values to those in the former sample programs which highlights excellent agreement of results between the current and former programs.

Reference: Marathon Palladium Project: Geochemical Characteristics of Mine Rock Samples for the 2020 Pit Shells

Table 1: Summary of the 2020 geochemistry sample program

Sample Information					Selected Analytical Methods			ABA Summary Results			
Sample ID	Core ID	Lithology	From (m)	To (m)	Full ABA	C/S Species	ICP-MS Metals	Total Sulphur	Total Carbon	Sobek-NP/AP	Carb-NP/AP
K004617	M-06-195	Fine Grained Gabbro	52	62		✓		0.006	0.043		19.13
K004620	M-06-217	Fine Grained Gabbro	50	60	✓		✓	0.021	0.081	102.25	10.29
K004621	M-06-217	Fine Grained Gabbro	122	132		✓		0.008	0.098		32.70
K004622	M-06-219	Fine Grained Gabbro	11	21		✓		0.022	0.115		13.95
K004625	M-08-445	Fine Grained Gabbro	101	111		✓		0.008	0.029		9.68
K004627	M-08-446	Fine Grained Gabbro	37	47		✓		0.008	0.012		4.00
K004628	M-08-452	Fine Grained Gabbro	34	44	✓		✓	0.008	0.03	58.40	10.01
K004632	M-06-213	Fine Grained Gabbro	30	40		✓		<0.005	0.182		97.15
K004634	M-06-214	Fine Grained Gabbro	8	18		✓		0.017	0.092		14.44
K004635	M-07-373	Fine Grained Gabbro	116	126	✓		✓	0.007	0.196	104.23	74.73
K004638	M-06-198	Fine Grained Gabbro	10	20		✓		0.027	0.068		6.72
K004642	M-05-106	Fine Grained Gabbro	10	20	✓		✓	0.008	0.076	97.60	25.36
K004646	G4	Fine Grained Gabbro	118	128		✓		0.409	0.024		0.16
K004630	BO-05-01	Footwall (Volcanics)	50	59.7		✓		0.005	0.028		14.95
K004631	BO-07-49	Footwall (Volcanics)	87	97	✓		✓	0.005	0.036	64.64	19.22
K004640	GD-06-04	Footwall (Volcanics)	75	85		✓		0.038	0.199		13.98
K004641	GD-06-04	Footwall (Volcanics)	91	101	✓		✓	0.095	0.174	6.67	4.89
K004645	M-05-134	Oxide Melatroctolite	26	36		✓		0.338	0.083		0.66
K004647	M-05-131	Oxide Melatroctolite	6	16	✓		✓	0.297	0.06	3.64	0.54
K004624	M-11-522	Syenite	93	101	✓		✓	0.012	0.316	51.20	70.29
K004639	G3	Syenite	30	40		✓		0.014	0.958		182.64
K004611	M-06-145	Two Duck Lake Gabbro	49	59	✓		✓	0.028	0.019	24.91	1.81
K004612	M-06-165	Two Duck Lake Gabbro	11	21		✓		0.023	0.104		12.07
K004613	M-07-256	Two Duck Lake Gabbro	10	20		✓		0.034	0.137		10.75
K004614	M-05-119	Two Duck Lake Gabbro	32	42		✓		0.01	0.197		52.58
K004615	M-05-121	Two Duck Lake Gabbro	30	40	✓		✓	0.008	0.025	89.60	8.34
K004616	M-06-181	Two Duck Lake Gabbro	59	69		✓		0.047	0.141		8.01
K004618	M-06-196	Two Duck Lake Gabbro	50	60		✓		0.011	0.103		24.99
K004626	M-08-444	Two Duck Lake Gabbro	50	60		✓		0.009	0.186		55.16
K004629	M-08-438	Two Duck Lake Gabbro	59	69	✓		✓	0.018	0.189	52.44	28.03
K004637	M-06-198	Two Duck Lake Gabbro	28	38	✓		✓	0.02	0.137	31.68	18.28
K004643	M-08-438	Two Duck Lake Gabbro	13	23		✓		0.021	0.023		2.92
K004644	M-06-180	Two Duck Lake Gabbro	20	30	✓		✓	0.314	0.061	3.21	0.52
K004648	M-06-232	Two Duck Lake Gabbro	74	84		✓		0.01	0.099		26.42
K004619	M-06-195	Wehrlite-troctolite Sill	142	152	✓		✓	0.011	0.03	61.09	7.28
K004623	M-06-219	Wehrlite-troctolite Sill	49	59		✓		0.012	0.18		40.04
K004633	M-06-213	Wehrlite-troctolite Sill	66	76	✓		✓	0.008	0.052	128.40	17.35
K004636	M-06-198	Wehrlite-troctolite Sill	64	74		✓		0.018	0.07		10.38

Reference: Marathon Palladium Project: Geochemical Characteristics of Mine Rock Samples for the 2020 Pit Shells

Table 2: ABA comparison with former sample programs

Parameter	Units	Golder (2007), Ecometrix (2010), and Stillwater (2013) Combined					Ecometrix (2020)				
		Count	Minimum	Maxiumum	Median	Geomean	Count	Minimum	Maxiumum	Median	Geomean
Total Sulphur	wt. %	455	<0.005	0.960	0.030	0.037	38	<0.005	0.409	0.013	0.019
Carb-NP	kg-$CaCO_3$/t	398	0.7	63.7	9.1	8.6	38	1.0	79.9	7.3	6.7
Carb-NP/AP	--	398	0.2	154.5	11.9	9.6	38	0.2	212.8	16.3	13.3
		Criteria			Count	%	Criteria			Count	%
		Carb-NP/AP greater than 2 (Type 1)			360	90.5%	Carb-NP/AP greater than 2 (Type 1)			34	89.5%
		Carb-NP/AP between 1-2 (Type 2)			23	5.8%	Carb-NP/AP between 1-2 (Type 2)			0	0.0%
		Carb-NP/AP less than 1 (Type 2)			15	3.7%	Carb-NP/AP less than 1 (Type 2)			4	10.5%

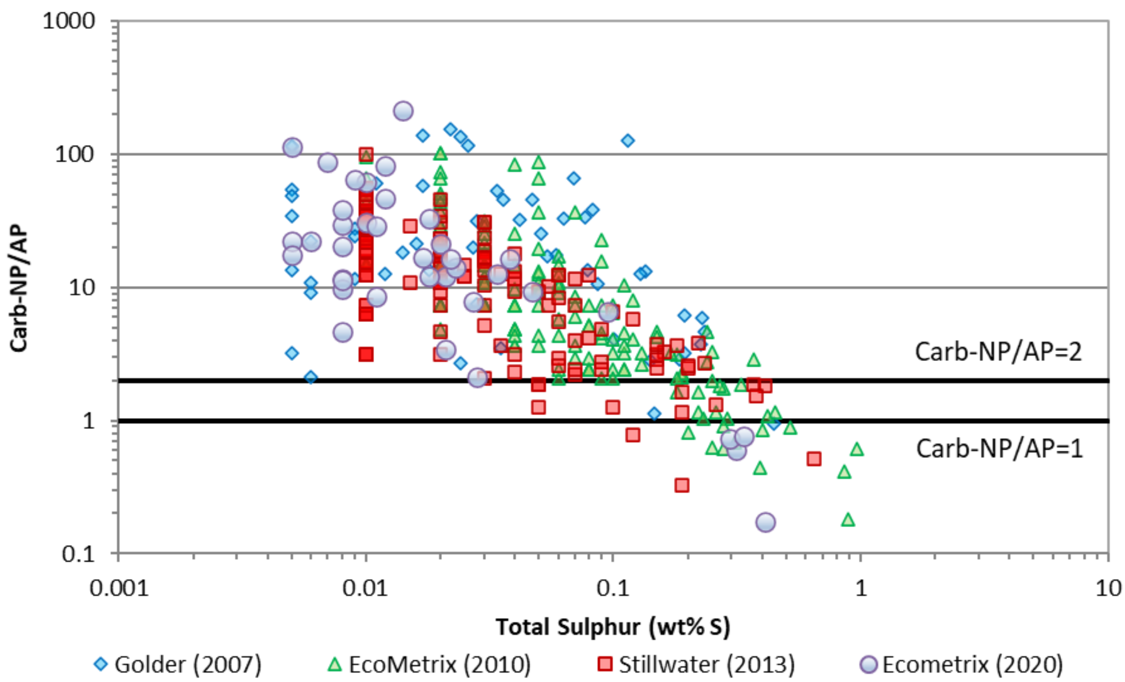


Figure 1: Carb-NP/AP ratio versus Total Sulphur

Reference: Marathon Palladium Project: Geochemical Characteristics of Mine Rock Samples for the 2020 Pit Shells

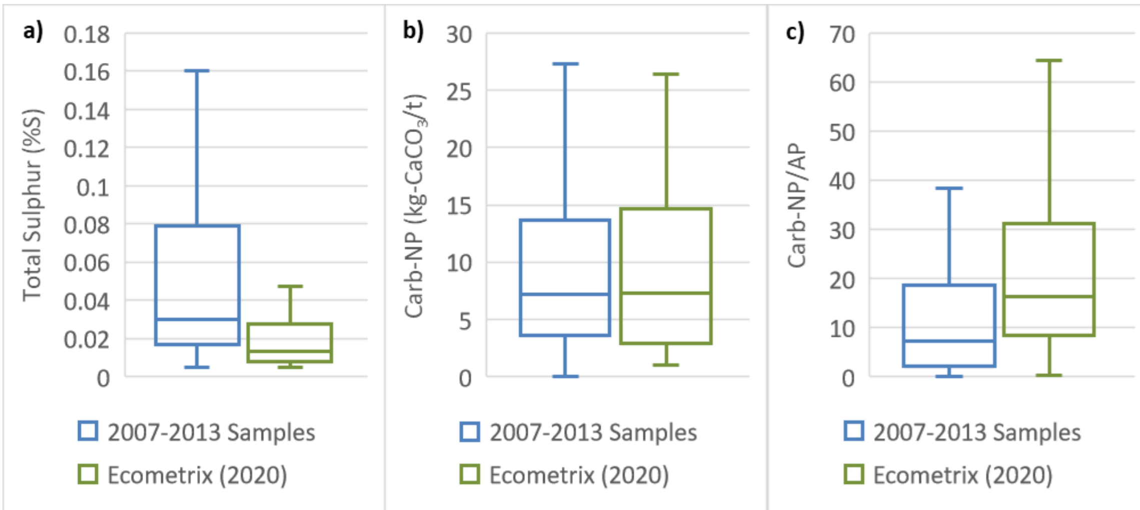


Figure 2: Box plot comparison of ABA statistics between 2020 and former sample programs

Table 3: ICP-MS bulk metals comparison with former sampling programs

Parameter	Units	10X Average Crustal Abundance[1]	Golder (2007) and Ecometrix (2010) Combined					Ecometrix (2020)				
			Count	Minimum	Maxiumum	Median	Geomean	Count	Minimum	Maxiumum	Median	Geomean
Arsenic	mg/kg	22	257	<1.0	11.0	2.0	2.3	15	<0.5	4.9	0.8	0.9
Aluminum	wt. %	82.8	257	0.3	11.0	1.5	1.8	15	0.3	1.6	0.7	0.6
Cadmium	mg/kg	2.1	257	0.07	0.65	0.14	0.17	15	<0.02	0.28	0.03	0.04
Cobalt	mg/kg	470	257	2	170	37	36	15	3	150	39	33
Copper	mg/kg	940	257	4	2200	118	130	15	21	760	92	111
Iron	wt. %	86	257	2	29	7	7	15	1.6	20.0	5.2	5.9
Molybdenum	mg/kg	15	257	0.3	31.0	1.0	1.3	15	0.2	5.0	1.2	1.1
Nickel	mg/kg	1450	257	1	867	90	77	15	1.2	750.0	70.0	57.5
Lead	mg/kg	70	257	1	66	3	4	15	0.3	12.0	0.8	1.0
Selenium	mg/kg	0.5	57[a]	<0.5	2.0	0.5	0.7	15[b]	<0.7	1.8	0.7	0.8
Uranium	mg/kg	7.5	257	0.08	15.00	0.57	0.72	15	<0.002	5.300	0.350	0.249
Vanadium	mg/kg	2250	257	1	1600	179	157	15	2	660	150	116
Zinc	mg/kg	1180	257	18	280	69	70	15	34	170	49	60

[1]Faure (1998)

[a]38 of 57 samples are less than detection limit of 0.5 mg/kg.

[b]13 of 15 samples are less than detection limit of 0.7 mg/kg.

Conclusions

The results from the 2020 static geochemistry sample program for the Marathon Palladium Project show that the results are consistent with former sample programs by comparative analysis of all parameters from the ABA analyses and ICP-MS bulk metals statistics. The 2020 sample program provides adequate representation to fill gaps within the 2020 pit shells. The additional data from the 2020 sampling program support the conclusion that the previous samples included in the Golder (2007), Ecometrix (2010) and Stillwater (2013) data sets are representative of the mine rock from the 2020 pit shell. Moreover, it is concluded that no additional kinetic geochemistry testing for mine rock is necessary to support the source terms and model calculations. The previous kinetic test results remain valid for the mine rock from the Marathon Palladium Project and can therefore continue to be used to assess water quality in the updated water balance and water quality model.

Closure

We trust this memorandum serves your needs at this time. Should you have any questions, please contact the authors at your convenience.

References

EcoMetrix. 2012. Supporting Information Document No.5 – Geochemical Assessment of Mine Components at the Marathon PGM-Cu Project.

Ecometrix. 2021. Revision of the Sulphur Cut-off Value to Determine Type 1 (Non-PAG) and Type 2 (PAG) Mine Rock for the Marathon Palladium Project, Memorandum to T. LeBlanc, 22 January 2021.

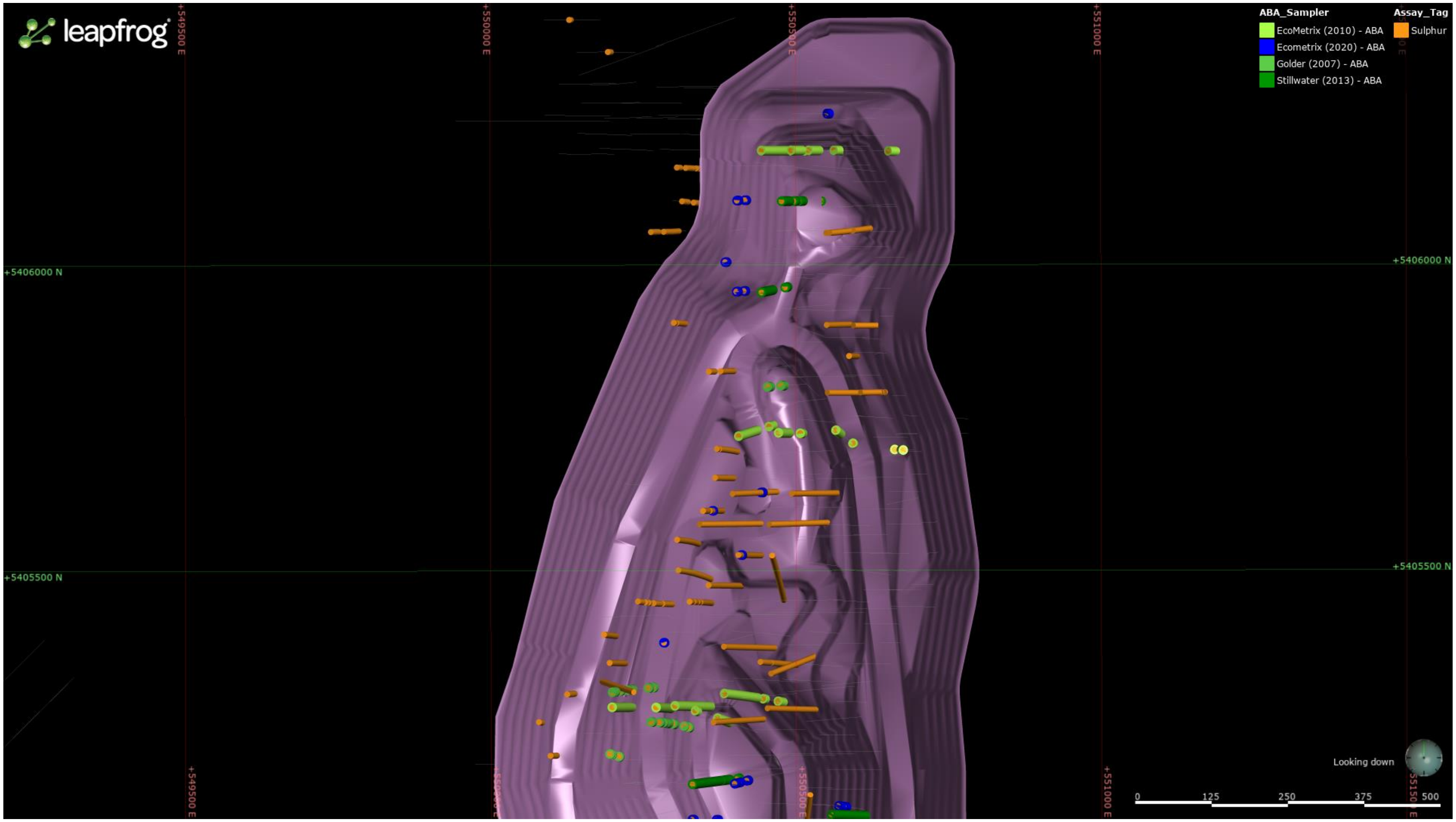
Faure, G. 1998. Principles and Applications of Geochemistry. Prentice Hall. New Jersey.

Golder Associates (Golder). 2008. Geochemical Characterization Program for Feasibility Study Marathon PGM-Cu Project, Marathon, Ontario. 07-1118-0012 (4000). Golder Associates Ltd.

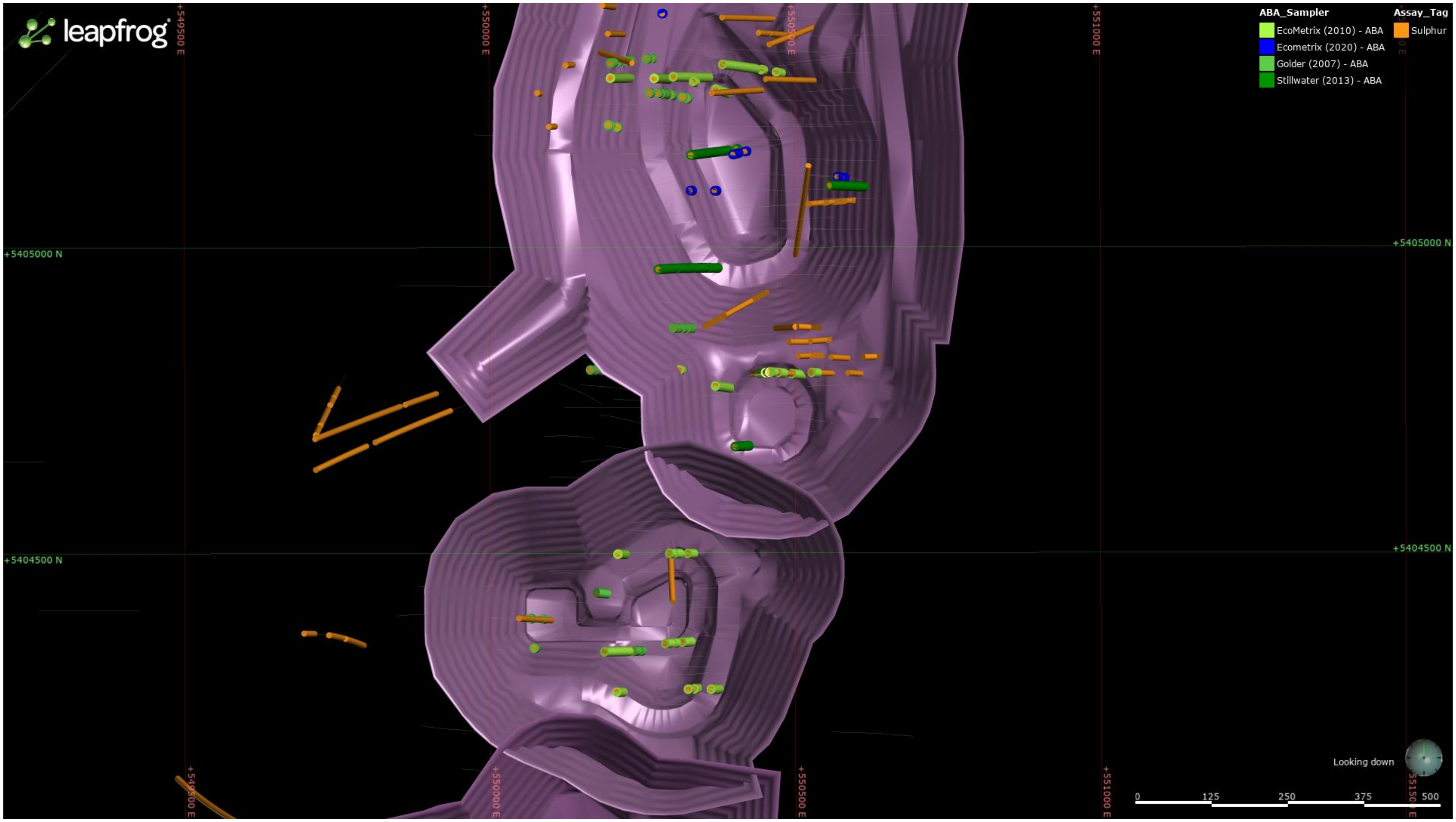
Price, W.A. 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. Canadian MEND Report 1.20.1, Natural Resources Canada, December, 2009.

Stillwater (EcoMetrix). 2013. IR 9.4.1 in response to: *EcoMetrix. 2012. Supporting Information Document No.5 – Geochemical Assessment of Mine Components at the Marathon PGM-Cu Project.*

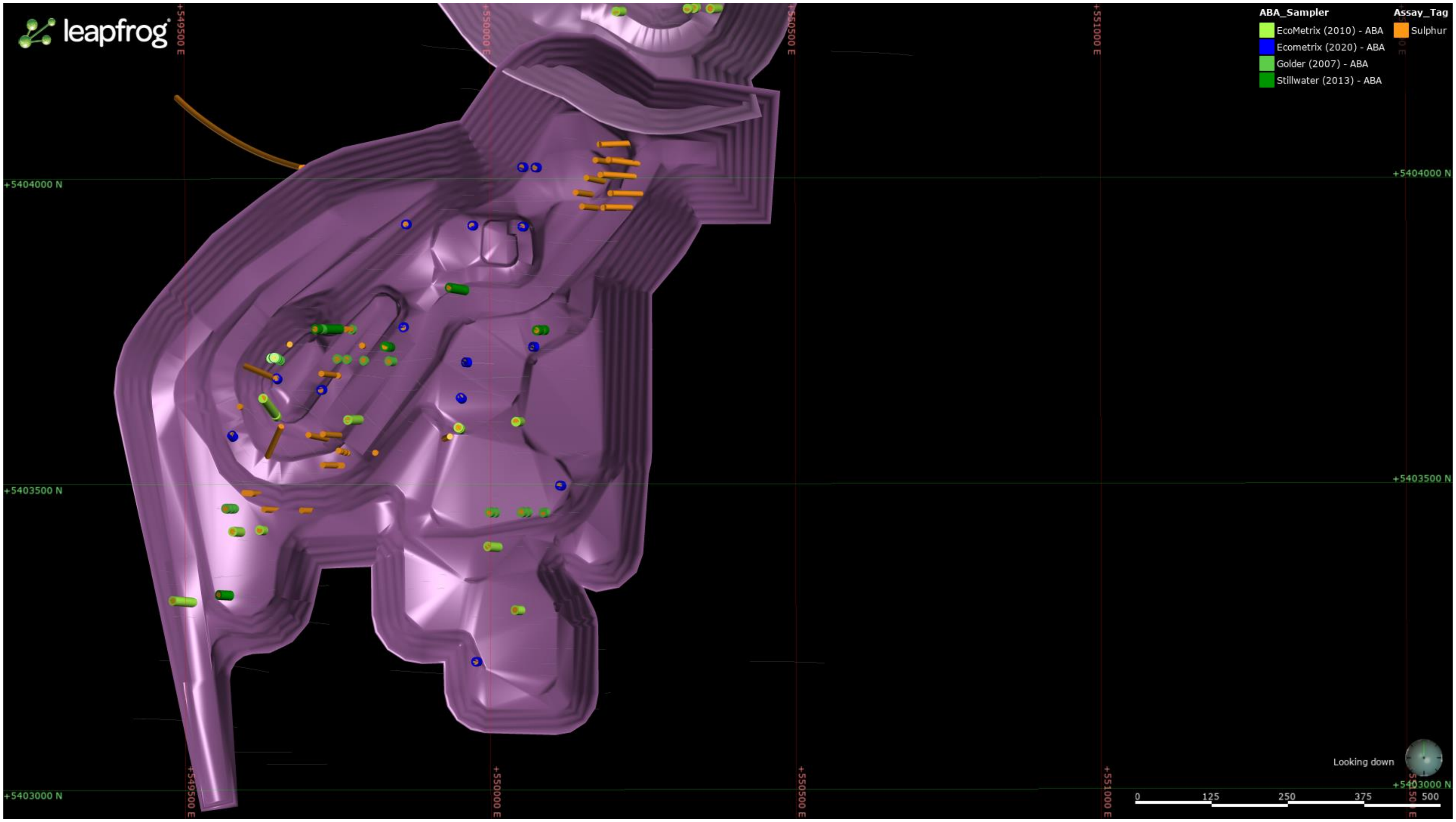
Appendix A: ABA Sample Locations for the 2020 Sample Program



Appendix A-1: Northern extent of the pit with approximate sampling locations. 2020 samples are represented by blue cylinders. Previous samples analyzed for ABA and/or sulphur are represented by green and orange cylinders, respectively.



Appendix A-2: Central region of the pit with approximate sampling locations. 2020 samples are represented by blue cylinders. Previous samples analyzed for ABA and/or sulphur are represented by green and orange cylinders, respectively.



Appendix A-3: Southern extent of the pit with approximate sampling locations. 2020 samples are represented by blue cylinders. Previous samples analyzed for ABA and/or sulphur are represented by green and orange cylinders, respectively.

Reference: Marathon Palladium Project: Geochemical Characteristics of Mine Rock Samples for the 2020 Pit Shells

---

Appendix B: Laboratory Certificate of Analysis

SGS Canada Inc.
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Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

ABA - Modified Sobek

Project : 20-2722

23-November-2020

Ecometrix
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Mississauga, ON
L5N 2L8, Canada

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Date Rec. : 16 October 2020
LR Report: **CA10171-OCT20**

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CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 004611	6: 004628	7: 004615	8: 004629	9: 004635	10: 004641	11: 004619	12: 004637	13: 004631	14: 004620
Sample Date & Time					05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20
Paste pH [no unit]	10-Nov-20	13:31	11-Nov-20	08:53	9.50	9.57	9.74	9.50	9.63	9.41	9.82	9.58	9.49	9.73
Fizz Rate [no unit]	09-Nov-20	09:18	11-Nov-20	08:53	1	1	2	3	2	2	1	1	1	1
Sample weight [g]	09-Nov-20	09:18	11-Nov-20	08:53	1.97	1.99	2.01	1.99	2.03	1.98	1.96	2.02	1.99	1.98
HCl_add [mL]	10-Nov-20	07:28	11-Nov-20	08:53	25.50	20.00	25.00	27.00	24.80	20.00	24.90	20.00	20.00	51.30
HCl [Normality]	09-Nov-20	09:18	11-Nov-20	08:53	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
NaOH [Normality]	09-Nov-20	09:18	11-Nov-20	08:53	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vol NaOH to pH=8.3 [mL]	10-Nov-20	07:28	11-Nov-20	08:53	16.90	14.19	16.01	15.25	15.52	12.15	16.66	11.98	16.00	24.72
Final pH [no unit]	10-Nov-20	07:28	11-Nov-20	08:53	1.61	1.53	1.63	1.79	1.61	1.61	1.62	1.85	1.38	1.61
NP [t CaCO3/1000 t]	10-Nov-20	07:28	11-Nov-20	08:53	21.8	14.6	22.4	29.5	22.8	19.8	21.0	19.8	10.1	67.1
AP [t CaCO3/1000 t]	23-Nov-20	12:35	23-Nov-20	12:36	1.25	1.25	1.25	1.25	1.25	2.19	1.25	1.25	1.25	1.25
Net NP [t CaCO3/1000 t]	23-Nov-20	12:35	23-Nov-20	12:36	20.6	13.4	21.2	28.2	21.6	17.6	19.8	18.6	8.85	65.8
NP/AP [ratio]	23-Nov-20	12:35	23-Nov-20	12:36	17.4	11.7	17.9	23.6	18.2	9.05	16.8	15.8	8.08	53.7
S [%]	04-Nov-20	14:56	06-Nov-20	08:56	0.028	0.008	0.008	0.018	0.007	0.095	0.011	0.020	0.005	0.021
Acid Leachable SO4-S [%]	05-Nov-20	17:48	06-Nov-20	08:56	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Sulphide [%]	05-Nov-20	17:45	06-Nov-20	08:56	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.07	< 0.04	< 0.04	< 0.04	< 0.04
C [%]	04-Nov-20	14:56	06-Nov-20	08:56	0.019	0.030	0.025	0.189	0.196	0.174	0.030	0.137	0.036	0.081
CO3 [%]	05-Nov-20	12:06	06-Nov-20	08:56	< 0.025	< 0.025	0.050	0.724	0.380	0.659	0.040	0.285	0.060	0.130
C(g) [%]	---	---	---	---	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

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Project : 20-2722

LR Report : **CA10171-OCT20**

Analysis	15: 004633	16: 004642	17: 004624	18: 004644	19: 004647	20: 004612	21: 004613	22: 004614	23: 004648	24: 004618	25: 004627	26: 004643	27: 004626	28: 004616
Sample Date & Time	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20
Paste pH [no unit]	9.26	9.63	8.77	9.44	9.45	---	---	---	---	---	---	---	---	---
Fizz Rate [no unit]	1	1	2	1	1	---	---	---	---	---	---	---	---	---
Sample weight [g]	1.99	1.98	1.98	2.02	2.02	---	---	---	---	---	---	---	---	---
HCl_add [mL]	27.70	24.70	20.00	37.90	29.70	---	---	---	---	---	---	---	---	---
HCl [Normality]	0.10	0.10	0.10	0.10	0.10	---	---	---	---	---	---	---	---	---
NaOH [Normality]	0.10	0.10	0.10	0.10	0.10	---	---	---	---	---	---	---	---	---
Vol NaOH to pH=8.3 [mL]	14.91	15.03	12.39	25.18	16.05	---	---	---	---	---	---	---	---	---
Final pH [no unit]	1.91	1.59	1.85	1.60	1.93	---	---	---	---	---	---	---	---	---
NP [t CaCO3/1000 t]	32.1	24.4	19.2	31.5	33.8	---	---	---	---	---	---	---	---	---
AP [t CaCO3/1000 t]	1.25	1.25	1.25	8.44	6.88	---	---	---	---	---	---	---	---	---
Net NP [t CaCO3/1000 t]	30.8	23.2	18.0	23.1	26.9	---	---	---	---	---	---	---	---	---
NP/AP [ratio]	25.7	19.5	15.4	3.73	4.92	---	---	---	---	---	---	---	---	---
S [%]	0.008	0.008	0.012	0.314	0.297	0.023	0.034	0.010	0.010	0.011	0.008	0.021	0.009	0.047
Acid Leachable SO4-S [%]	< 0.04	< 0.04	< 0.04	0.04	0.08	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Sulphide [%]	< 0.04	< 0.04	< 0.04	0.27	0.22	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
C [%]	0.052	0.076	0.316	0.061	0.060	0.104	0.137	0.197	0.099	0.103	0.012	0.023	0.186	0.141
CO3 [%]	0.030	0.105	0.575	0.135	0.065	0.170	0.280	0.585	0.250	0.370	< 0.025	< 0.025	0.799	0.570
C(g) [%]	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	---	---	---	---	---	---	---	---	---

Analysis	29: 004640	30: 004617	31: 004638	32: 004636	33: 004630	34: 004622	35: 004623	36: 004621	37: 004634	38: 004632	39: 004625	40: 004639	41: 004645	42: 004646
Sample Date & Time	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20
Paste pH [no unit]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Fizz Rate [no unit]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sample weight [g]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
HCl_add [mL]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
HCl [Normality]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NaOH [Normality]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Vol NaOH to pH=8.3 [mL]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Final pH [no unit]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
NP [t CaCO3/1000 t]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
AP [t CaCO3/1000 t]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Net NP [t CaCO3/1000 t]	---	---	---	---	---	---	---	---	---	---	---	---	---	---

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Analysis	29: 004640	30: 004617	31: 004638	32: 004636	33: 004630	34: 004622	35: 004623	36: 004621	37: 004634	38: 004632	39: 004625	40: 004639	41: 004645	42: 004646
NP/AP [ratio]	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S [%]	0.038	0.006	0.027	0.018	0.005	0.022	0.012	0.008	0.017	< 0.005	0.008	0.014	0.338	0.409
Acid Leachable SO4-S [%]	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.05	< 0.04
Sulphide [%]	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.29	0.37
C [%]	0.199	0.043	0.068	0.070	0.028	0.115	0.180	0.098	0.092	0.182	0.029	0.958	0.083	0.024
CO3 [%]	0.759	0.070	0.160	0.070	< 0.025	0.165	0.445	0.220	0.160	0.335	< 0.025	0.370	0.210	< 0.025
C(g) [%]	---	---	---	---	---	---	---	---	---	---	---	---	---	---

```
*NP (Neutralization Potential)
 = 50 x (N of HCL x Total HCL added - N NaOH x NaOH added)
   -------------------------------------------------------
                        Weight of Sample

*AP (Acid Potential) = % Sulphide Sulphur x 31.25
*Net NP (Net Neutralization Potential) = NP-AP
NP/AP Ratio = NP/AP
*Results expressed as tonnes CaCO3 equivalent/1000 tonnes of material
Samples with a % Sulphide value of <0.04 will be calculated using a 0.04 value.
```

Catharine Arnold, B.Sc., C.Chem
Project Specialist,
Environment, Health & Safety

OnLine LIMS

0002329689

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Project : 20-2722

17-November-2020

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Date Rec. : 16 October 2020
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CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 004611	6: 004628	7: 004615	8: 004629	9: 004635	10: 004641	11: 004619	12: 004637	13: 004631	14: 004620
Sample Date & Time					05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20
Ag [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
As [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	0.6	< 0.5	< 0.5	0.9	< 0.5	1.0	0.8	1.0	1.4	0.8
Al [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	16000	7300	15000	9400	8000	6600	9400	7700	6100	2900
Ba [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	81	23	60	47	44	21	130	63	24	15
Be [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	0.07	< 0.02	0.05	0.07	0.02	0.13	0.06	0.05	0.09	< 0.02
Bi [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	< 0.09	< 0.09	< 0.09	< 0.09	< 0.09	0.21	< 0.09	< 0.09	< 0.09	< 0.09
Ca [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	11000	4500	11000	11000	7000	8300	9100	9900	4800	3100
Cd [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	0.03	< 0.02	0.02	0.05	< 0.02	0.02	0.04	0.03	< 0.02	0.03
Co [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	39	28	41	30	31	11	41	33	9.7	110
Cr [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	25	250	20	27	100	39	5.4	24	74	240
Cu [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	210	73	78	170	84	64	130	140	21	200
Fe [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	54000	51000	48000	47000	46000	16000	64000	65000	19000	110000
K [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	1200	400	1000	1100	810	810	1900	1100	900	260
Li [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	3	5	5	3	3	11	4	3	8	4
Mg [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	17000	6100	24000	14000	14000	3500	19000	9100	4700	91000
Mn [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	590	310	710	630	460	280	1000	480	180	1400
Mo [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	0.9	0.2	0.8	1.0	0.6	3.0	1.1	1.2	1.4	0.5
Ni [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	69	79	100	48	58	21	70	70	20	750
Pb [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	0.83	1.8	0.39	1.0	0.27	1.5	0.56	0.72	1.2	0.42
Sb [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6

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0002323525

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Project : 20-2722

LR Report : CA10173-OCT20

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 004611	6: 004628	7: 004615	8: 004629	9: 004635	10: 004641	11: 004619	12: 004637	13: 004631	14: 004620
Se [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
Sn [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Sr [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	140	61	130	85	55	23	76	56	18	19
Ti [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	1900	3300	680	780	1400	340	2300	3300	740	500
Tl [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.02	0.03	< 0.02	< 0.02	< 0.02
U [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	0.29	< 0.002	0.19	0.43	0.048	0.77	0.44	0.35	0.94	0.072
V [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	270	230	63	150	220	48	130	470	63	42
Y [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	1.9	0.63	1.3	5.0	1.1	9.5	7.9	7.7	7.7	0.97
Zn [µg/g]	11-Nov-20	19:00	12-Nov-20	16:44	35	36	41	43	36	34	68	50	35	100

Analysis	15: 004633	16: 004642	17: 004624	18: 004644	19: 004647
Sample Date & Time	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20	05-Oct-20
Ag [µg/g]	< 1	< 1	< 1	< 1	< 1
As [µg/g]	< 0.5	< 0.5	2.1	4.9	2.6
Al [µg/g]	2900	5600	2700	6600	4400
Ba [µg/g]	22	17	28	97	230
Be [µg/g]	< 0.02	< 0.02	2.2	0.16	0.02
Bi [µg/g]	< 0.09	< 0.09	< 0.09	0.31	0.19
Ca [µg/g]	3600	4300	9900	41000	54000
Cd [µg/g]	0.04	< 0.02	0.12	0.18	0.28
Co [µg/g]	150	45	2.7	64	87
Cr [µg/g]	6.2	330	0.9	63	2.5
Cu [µg/g]	58	92	21	670	760
Fe [µg/g]	170000	52000	37000	140000	200000
K [µg/g]	390	320	1500	5100	1500
Li [µg/g]	6	2	3	6	4
Mg [µg/g]	88000	26000	860	19000	24000
Mn [µg/g]	2700	600	620	1500	2400
Mo [µg/g]	1.3	1.3	5.0	1.8	2.0
Ni [µg/g]	310	230	1.2	89	14
Pb [µg/g]	0.31	0.26	12	4.9	2.9
Sb [µg/g]	< 6	< 6	< 6	< 6	< 6
Se [µg/g]	< 0.7	< 0.7	< 0.7	1.7	1.8

OnLine LIMS

0002323525

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Project : 20-2722

LR Report : **CA10173-OCT20**

Analysis	15: 004633	16: 004642	17: 004624	18: 004644	19: 004647
Sn [µg/g]	< 0.5	< 0.5	1.6	2.2	< 0.5
Sr [µg/g]	25	36	37	68	160
Ti [µg/g]	1300	1500	800	3100	9200
Tl [µg/g]	< 0.02	< 0.02	0.03	0.12	< 0.02
U [µg/g]	0.15	0.034	5.3	1.8	1.0
V [µg/g]	110	150	2	440	660
Y [µg/g]	2.5	0.57	51	62	75
Zn [µg/g]	150	49	110	110	170

Catharine Arnold

CHARTERED CATHARINE ARNOLD CHEMIST — ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO

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Project : 20-2722

LR Report : CA10173-OCT20

Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Metals in Soil - Aqua-regia/ICP-MS - QCBatchID: EMS0053-NOV20													
Aluminum	3	µg/g	<3			0	20	104	70	130	93	70	130
Antimony	6	µg/g	<0.8			ND	20	101	70	130	NV	70	130
Arsenic	0.5	µg/g	<0.5			0	20	103	70	130	112	70	130
Barium	0.01	µg/g	<0.01			0	20	109	70	130	93	70	130
Beryllium	0.02	µg/g	<0.02			1	20	101	70	130	NV	70	130
Bismuth	0.09	µg/g	<0.09			ND	20	98	70	130	NV	70	130
Cadmium	0.02	µg/g	<0.02			0	20	103	70	130	NV	70	130
Calcium	3	µg/g	<3			0	20	105	70	130	NV	70	130
Chromium	0.5	µg/g	<0.5			0	20	108	70	130	82	70	130
Cobalt	0.01	µg/g	<0.01			0	20	105	70	130	101	70	130
Copper	0.1	µg/g	<0.1			0	20	106	70	130	99	70	130
Iron	3	µg/g	<3			0	20	103	70	130	95	70	130
Lead	0.05	µg/g	<0.05			0	20	106	70	130	112	70	130
Lithium	2	µg/g	<2			1	20	102	70	130	NV	70	130
Magnesium	3	µg/g	<3			1	20	108	70	130	NV	70	130
Manganese	0.1	µg/g	<0.1			0	20	103	70	130	104	70	130
Molybdenum	0.1	µg/g	<0.1			0	20	99	70	130	NV	70	130
Nickel	0.1	µg/g	<0.1			0	20	102	70	130	88	70	130
Potassium	3	µg/g	<3			0	20	107	70	130	NV	70	130
Selenium	0.7	µg/g	<0.7			ND	20	100	70	130	NV	70	130
Silver	1	µg/g	<0.01			0	20	98	70	130	113	70	130
Strontium	0.02	µg/g	<0.02			0	20	105	70	130	NV	70	130
Thallium	0.02	µg/g	<0.02			ND	20	110	70	130	NV	70	130
Tin	0.5	µg/g	<0.5			ND	20	100	70	130	NV	70	130
Titanium	0.1	µg/g	<0.1			1	20	91	70	130	NV	70	130
Uranium	0.002	µg/g	<0.002			0	20	95	70	130	NV	70	130
Vanadium	1	µg/g	<1			0	20	105	70	130	104	70	130
Yttrium	0.004	µg/g	<0.004			0	20	107	70	130	NV	70	130
Zinc	0.7	µg/g	<0.7			0	20	100	70	130	79	70	130

MEMO

To:	Tabatha LeBlanc, Generation PGM Inc.	From:	Neal Sullivan Ron Nicholson
Ref:	**Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program**	Date:	15 March 2021

Generation PGM Inc. (GenPGM) is in the process of completing a feasibility study that includes a metallurgical pilot plant test program to further refine the proposed milling and extraction process that had been developed and tested in 2008 and 2011 (EcoMetrix 2012). The process solids from the milling process are expected to produce a thickened flotation process solids (low sulphur) stream and a first cleaner scavenger process solids (high sulphur) stream in approximate proportions of 79% and 21% by mass, respectively. The thickened flotation process solids are expected to be classified as Type 1 which is non-potentially acid generating (non-PAG) and the scavenger (1st cleaner) process solids are expected to be classified as Type 2 (PAG). The Type 2 process solids will be managed separately from the Type 1 in the process solids storage facility (PSMF).

A geochemical characterization program was conducted for the process solids and process water that were produced during the November 2020 pilot plant metallurgical testing. The program was carried out in order to confirm the results obtained from process solids samples produced in former metallurgical pilot plant test programs. The flow sheet and geochemical sampling locations for the 2020 pilot plant is shown in **Figure 1**.

The metallurgical pilot plant program and subsequent geochemical testing of process solids and process water was completed at SGS (Lakefield, ON). Three (3) composite ore samples were selected for metallurgical testing: 1) 2012 Composite; 2) 2020 W-Horizon; and 3) 2020 Main Zone. The flotation feed (head feed) samples, thickened floatation process solids and scavenger process solids (1st cleaner) streams were sampled and characterized individually and are shown as sampling locations 0, 1 and 2, repectively, in **Figure 1**. This memo provides the details of the geochemical characterization program. The complementary test work provides required information on the process solids to confirm storage facility design and to confirm water quality related to process water to be

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discharged with process solids. Process water will also be characterized as input for the feasibility study water quality model used to predict discharge requirements and water treatment design.

Reference: **Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program**

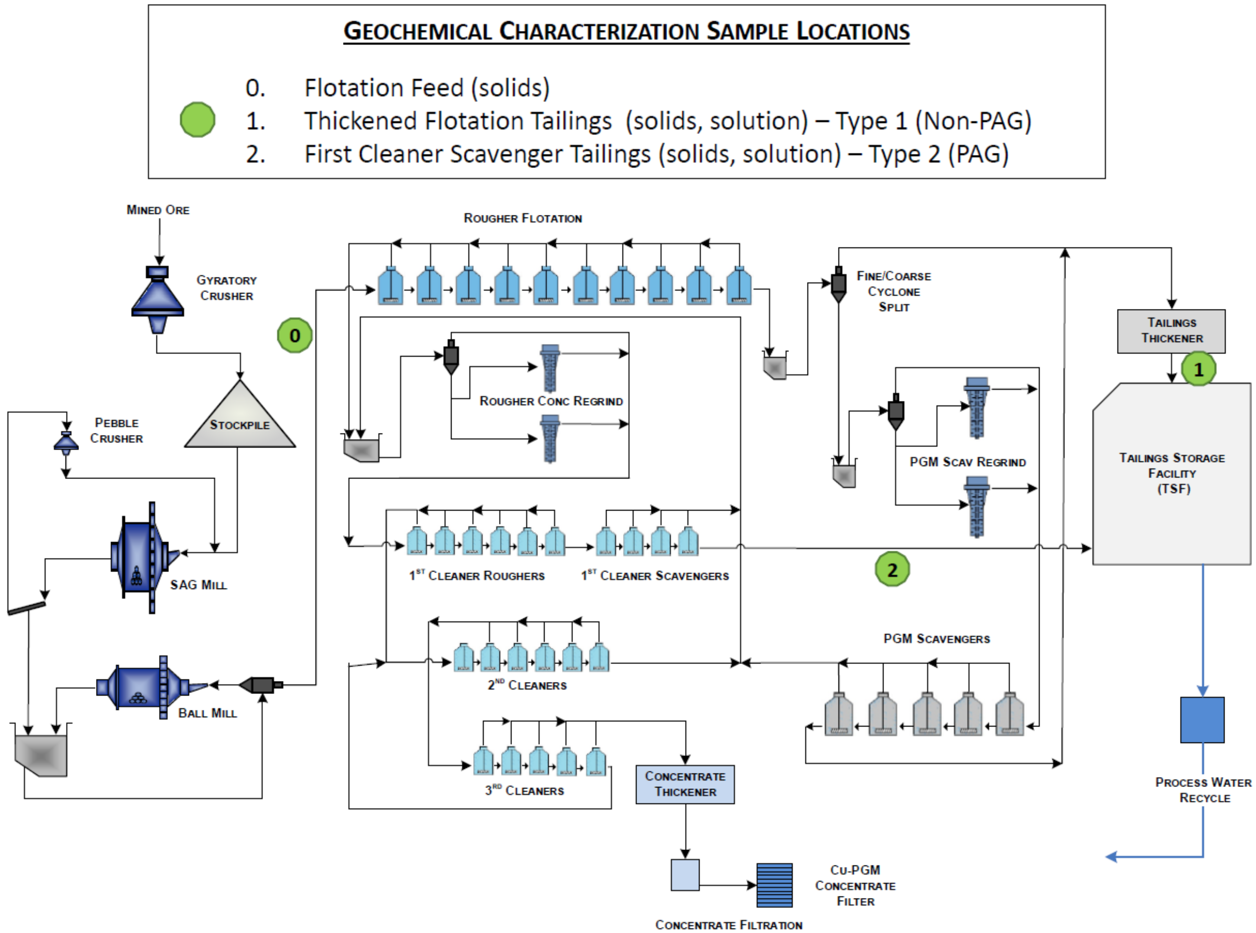

Figure 1: Flow sheet for the Marathon Palladium Project denoting geochemical sampling locations

Sampling Methods

Samples were collected for each ore composite tested, including the 2012 Composite, the 2020 W-Horizon Composite and the 2020 Main Zone Composite. Approximately 2 kg of head feed material were collected prior to sampling the process solids. Process solids samples were collected after the pilot plant reached steady state for each composite. Each sample was collected in a single, clean 20 L pail. The solids in the pail occupied approximately 25% of the volume or about 5 L (approx. 5 to 8 kg dry weight). The process water on top of the solids occupied the remaining volume of the pail (approx. 15 L).

Process Solids Characterization

Each sample of head feed, rougher and cleaner process solids were subjected to the analyses summarized in **Table 1** and included the following:

1. Acid Base Accounting (ABA, including modified Sobek, sulphur species, carbon species and graphite carbon)

1a. Carbon and sulphur species (totals sulphur, sulphate sulphur, sulphide sulphur; total carbon, carbonate carbon)

2. ICP-MS metals after aqua regia digest (including sulphur and trace level Hg)
3. QEMSCAN analysis with a focus on sulphide and carbonate minerals
4. Particle-size analysis with laser diffraction

At least 5 kg of each of the process solids from each composite, after metallurgical extraction and testing, was archived for additional testing, if required at a later date.

Process Water Characterization

Samples of the process water at the specified sampling locations in **Figure 1** were collected and analyzed. Two process water samples were collected from each specified location in the pilot plant. One sample was immediately analyzed (*Fresh* Process Water). The second sample was placed in a clean 20 L pail, stored in a clean room and allowed to age for 7 days with a lid fitted loosely over the pail to prevent dust entry but to allow exposure to air (*Aged* Process Water). All water samples were filtered at 0.45 micron.

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Sample Representation

The 2012 Composite was developed by Stillwater Canada Inc. to support previously completed test work which was reported by EcoMetrix (2012; SID #5). It is referenced as the "2012 Composite" throughout this memo as the reporting was issued by EcoMetrix in 2012. For the purpose of comparing updated processing concepts to past test work and performance, the 2012 Composite serves as the most accurate ore feed for such comparative analysis.

The make-up of the 2012 Composite is from across the entire wire frame of the ore deposit with an approximate weighting of 75% Main Zone, 10% Central Zone and 15% W-Horizon (S. Haggarty, pers. comm. 2021). The 2012 Composite included 890 sub-samples from the respective zones and is considered to represent an average type performance from a geochemical and metallurgical perspective (S. Haggarty, pers. comm. 2021). The recent 2020 composite samples (2020 Main Zone and 2020 W-Horizon) were specifically selected to evaluate material with varying Pd/Cu ratios, and at varying sulfide contents. Nonetheless, their results are also included in this memo.

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Table 1: Summary of Geochemical Analyses for Process Solids and Process Water

Composite Number	Composite Ore Samples	Geochemical Sample	Sample ID	Analysis						
				ABA[1]	C/S Species[1a]	ICP-MS Metals[2]	QEMSCAN[3]	Particle Size Distribution	Fresh Process Water Analysis	Aged Process Water Analysis
1	2012 Composite	Floatation Feed	2012 Composite-HF-0		✓					
		Thickened Floatation Tailings	2012 Composite FT-1	✓		✓	✓	✓	✓	✓
		Scavenger Tailings (1st Cleaner)	2012 Composite-ST-3		✓	✓	✓	✓	✓	✓
2	2020 W-Horizon	Floatation Feed	W-Horizon-HF-0		✓					
		Thickened Floatation Tailings	W-Horizon-FT-1	✓		✓	✓	✓	✓	✓
		Scavenger Tailings (1st Cleaner)	W-Horizon-ST-3		✓	✓	✓	✓	✓	✓
3	2020 Main Zone	Floatation Feed	Main Zone-HF-0		✓	✓				
		Thickened Floatation Tailings	Main Zone-FT-1	✓		✓	✓	✓	✓	✓
		Scavenger Tailings (1st Cleaner)	Main Zone-ST-3		✓	✓	✓	✓	✓	✓
Total Number of Analyses				**3**	**6**	**7**	**6**	**6**	**6**	**6**

Notes: 1 - ABA includes Modified Sobek, S/C species, graphite
1a - C/S species include: total sulphur, sulphate sulphur, sulphide sulphur; total carbon, carbonate carbon, organic carbon
2 - ICP-MS metals after aqua regia digest
3 - QEMSCAN with focus on carbonate and sulphide minerals

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Process Solids

Acid Base Accounting

The Acid Base Accounting (ABA) characteristics used to determine the potential risk of acid generation in mine materials includes the acid potential (AP) that is calculated from the sulphide-sulphur content and the neutralization potential (NP) which may be estimated in several ways. Both AP and NP are presented in units of kg-$CaCO_3$/t that represent the kilograms of calcium carbonate equivalent per tonne of rock. The NP is commonly measured using some modification of the Sobek method, which includes addition of a strong acid to a sample, allowing time to react and then measuring the remaining acid to determine the amount of acid consumed. However, due to uncertainty in the estimation of the NP by the Sobek method, the most current guideline for prediction of acid generation presented by MEND (Price, 2009) also recommends the use of “effective” NP for ABA characterization. Calcium and magnesium carbonate minerals are considered to represent effective NP because they consume acid and maintain a neutral pH in drainage or contact water. As a result, a more conservative approach is to consider the carbonate content in the solids as an estimate of effective-NP and thus the carbonate-NP (Carb-NP) is reviewed in detail throughout this memo.

The ratio of Carb-NP/AP was used to determine if the material has adequate NP to consume the acid produced if all the available sulphide-sulphur is oxidized. As a conservative measure, it is assumed that 2 units of NP will be required to neutralize the acid from 1 unit of AP in order to maintain neutral conditions in the mine material indefinitely and therefore the ratio of Carb-NP/AP should be greater than 2 to maintain neutral conditions. Type 1, that is non-potentially acid generating (non-PAG) process solids is defined by a Carb-NP/AP ratio greater than 2. Type 2, that is potentially acid generating (PAG) process solids is defined by Carb-NP/AP ratio less than 1, according to the guidance by MEND (Price, 2009). Material with a Carb-NP/AP ratio between 1 and 2 represents an uncertain classification because 1 AP unit can consume between 1 and 2 NP units and is therefore classified conservatively as Type 2 process solids for the Marathon Palladium Project.

A summary of ABA characteristics for the thickened floatation process solids and the scavenger process solids are presented in **Table 2** and **Table 3**, respectively. The ABA results from the former low sulphur and high sulphur process solids analyses (EcoMetrix, 2012) are also presented for comparative analysis. In **Table 2**, all three ore composites (thickened flotation process solids) have a Sobek NP/AP ratio and Carb-NP/AP ratio greater than 2, confirming that these process solids are classified as non-PAG (Type 1). More specifically, a direct comparison between the 2012 Composite thickened flotation process solids and former low sulphur process solids yield a strong agreement. With the exception of Sobek NP/AP ratio, all other ABA results compare within a factor of two.

As for the scavenger process solids, there is more variability in the Carb-NP/AP classification among the three ore composites (**Table 3**). The 2012 composite has a Carb-NP/AP ratio less than 1 and is therefore classified as PAG (Type 2). The 2020 Main Zone is classified as uncertain (Type 2) with a Carb-NP/AP between 1 and 2 and the 2020 W-Horizon is classified as non-PAG with a Carb-NP/AP ratio greater than 2. However, because the 2012 Composite serves as the most appropriate ore composite for comparative analysis, all scavenger process solids should be considered PAG (Type 2) material.

A direct comparison between the 2012 Composite and former high sulphur process solids show strong agreement and ABA results also compare within a factor of two. Similar to the thickened floatation process solids, the 2012 Composite generally exhibits a lower total sulphur value, and by extension, a lower AP in the Type 2 process solids from the 2020 pilot plant test work.

Table 2: ABA Summary of Thickened Floatation (Type 1) Process Solids

Parameter	Unit	Thickened Floatation Tailings (Non-PAG) - Type 1			
		Former Low Sulphur Tailings (EcoMetrix, 2012)	2012 Composite FT-1 Tailings	2020 W-Horizon FT-1 Tailings	2020 Main Zone FT-1 Tailings
Paste pH	--	8.74	9.26	9.29	9.31
Sobek NP	kg-$CaCO_3$/t	20.83	28.4	32.4	21.2
AP (from Sulphide-S)	kg-$CaCO_3$/t	2.50	1.25	1.25	1.25
AP (from Total S)	kg-$CaCO_3$/t	4.45	2.94	0.44	0.28
Net NP	kg-$CaCO_3$/t	18.33	27.2	31.2	20.0
Sobek NP/AP	--	8.91	22.7	25.9	17.0
Total Sulphur	%S	0.14	0.094	0.014	0.009
Acid Leachable SO4-S	%S	0.06	0.05	< 0.04	< 0.04
Sulphide-S	%S	0.08	0.04	< 0.04	< 0.04
Total Carbon	%S	0.12	0.143	0.159	0.082
AP (from Total S)	kg-$CaCO_3$/t	4.45	2.94	0.44	0.28
Carb-NP	kg-$CaCO_3$/t	10.02	12.01	13.36	6.89
Carb-NP/AP	--	2.25	4.09	30.53	24.49

Table 3: ABA Summary of Scavenger (Type 2) Process Solids

Parameter	Unit	Scavenger Tailings (PAG) - Type 2			
		Former High Sulphur Tailings (EcoMetrix, 2012)	2012 Composite ST-3 Tailings	2020 W-Horizon ST-3 Tailings	2020 Main Zone ST-3 Tailings
Paste pH	--	7.64	--	--	--
Sobek NP	kg-$CaCO_3$/t	45.40	--	--	--
AP (from Sulphide-S)	kg-$CaCO_3$/t	191.00	--	--	--
AP (from Total S)	kg-$CaCO_3$/t	208.75	103.44	2.91	9.97
Net NP	kg-$CaCO_3$/t	-145.43	--	--	--
Sobek NP/AP	--	0.24	--	--	--
Total Sulphur	%S	6.68	3.31	0.09	0.32
Acid Leachable SO4-S	%S	0.57	--	--	--
Sulphide-S	%S	6.11	--	--	--
Total Carbon	%S	0.39	0.30	0.39	0.17
AP (from Total S)	kg-$CaCO_3$/t	4.45	--	--	--
Carb-NP	kg-$CaCO_3$/t	32.43	24.78	32.93	14.03
Carb-NP/AP	--	0.16	0.24	11.33	1.41

ICP-MS Bulk Analysis

Samples submitted for metals contents underwent an aqua-regia digestion followed by a full metal scan by inductively coupled plasma mass spectrometry (ICP-MS) analyses, consistent with previous analyses. As recommended by MEND (2009), metal content values were compared to average crustal abundances for measured parameters (in mg/kg).

Elevated concentrations of metals in the solid phase do not necessarily increase the potential for metal leaching, but rather identify parameters for further consideration. Therefore, for screening purposes, process solids process solids contents were compared to 10 times (10X) the average crustal abundances, as outlined by Faure (1998), in order to identify elements that may require additional investigation.

A summary of ICP-MS bulk analysis for the thickened floatation process solids and the scavenger process solids are presented in **Table 4** and **Table 5**, respectively. In both the thickened floatation process solids and the scavenger process solids, there were no samples which exceeded 10 times the average crustal abundance. In general, there is a strong agreement between 2012 Composite thickened flotation process solids and the former low sulphur process solids (**Table 4**). With the exception of barium (Ba), sodium (Na) and strontium (Sr), all metals result within a factor of three. In **Table 5** which summarizes the 2012 Composite scavenger process solids and former high sulphur process solids, all metals are compared within a factor of two showing a strong agreement between the recent and former pilot plant test work.

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Table 4: ICP-MS Metals Summary of Thickened Floatation (Type 1) Process Solids

Parameter	Unit	10X Crustal Abundance	Thickened Flotation Tailings (Non-PAG) - Type 1			
			Former Low Sulphur Tailings (EcoMetrix, 2012)	2012 Composite FT-1 Tailings	2020 W-Horizon FT-1 Tailings	2020 Main Zone FT-1 Tailings
Aluminum (Al)	mg/kg	828000	5850	17000	22000	19000
Arsenic (As)	mg/kg	22	< 0.5	1.3	1.0	0.7
Barium (Ba)	mg/kg	3150	25	78	82	69
Beryllium (Be)	mg/kg	7	0.11	0.13	0.12	0.24
Bismuth (Bi)	mg/kg	1.6	< 0.09	0.10	< 0.09	< 0.09
Calcium (Ca)	mg/kg	720000	7325	18000	19000	15000
Cadmium (Cd)	mg/kg	2.1	0.04	0.04	0.03	< 0.02
Cobalt (Co)	mg/kg	470	24	23	29	31
Chromium (Cr)	mg/kg	1850	290	290	480	280
Copper (Cu)	mg/kg	940	95	57	79	35
Iron (Fe)	mg/kg	860000	46250	55000	49000	82000
Potassium (K)	mg/kg	83000	607.5	850	810	980
Lithium (Li)	mg/kg	160	4.75	5	6	9
Magnesium (Mg)	mg/kg	455000	12500	11000	16000	11000
Manganese (Mn)	mg/kg	17500	445	500	570	440
Molybdenum (Mo)	mg/kg	15	5.85	3.8	5.7	4.1
Sodium (Na)	mg/kg	187000	322.5	2800	3400	2700
Nickel (Ni)	mg/kg	1450	182.5	130	170	150
Phosphorous (P)	mg/kg	11300	1325	2400	560	620
Lead (Pb)	mg/kg	70	1.8	2.8	2.1	1.6
Antimony (Sb)	mg/kg	6	<0.8	< 6	< 6	< 6
Selenium (Se)	mg/kg	0.5	0.925	< 0.7	< 0.7	< 0.7
Tin (Sn)	mg/kg	15	0.5	< 0.5	< 0.5	0.6
Strontium (Sr)	mg/kg	4520	34.5	130	150	110
Titanium (Ti)	mg/kg	114000	635	1300	830	3200
Thallium (Tl)	mg/kg	2.1	< 0.02	0.02	< 0.02	< 0.02
Uranium (U)	mg/kg	7.5	0.34	0.33	0.77	0.46
Vanadium (V)	mg/kg	2250	170	230	120	610
Yttrium (Y)	mg/kg	210	5.25	7.8	2.9	4.9
Zinc (Zn)	mg/kg	1180	29	32	36	35

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Table 5: ICP-MS Metals Summary of Scavenger (Type 2) Process Solids

Parameter	Unit	10X Crustal Abundance	Scavenger Tailings (PAG) - Type 2			
			Fomer High Sulphur Tailings (EcoMetrix, 2012)	2012 Composite ST-3 Tailings	2020 W-Horizon ST-3 Tailings	2020 Main Zone ST-3 Tailings
Aluminum (Al)	mg/kg	828000	26000	24000	32000	28000
Arsenic (As)	mg/kg	22	4.8	2.9	5.7	2.0
Barium (Ba)	mg/kg	3150	79	110	120	110
Beryllium (Be)	mg/kg	7	0.27	0.17	0.14	0.29
Bismuth (Bi)	mg/kg	1.6	0.27	0.50	0.25	0.17
Calcium (Ca)	mg/kg	720000	14000	24000	29000	22000
Cadmium (Cd)	mg/kg	2.1	1.20	0.19	0.06	0.05
Cobalt (Co)	mg/kg	470	100	93	44	40
Chromium (Cr)	mg/kg	1850	700	170	150	86
Copper (Cu)	mg/kg	940	1800	800	510	140
Iron (Fe)	mg/kg	860000	160000	100000	58000	64000
Potassium (K)	mg/kg	83000	1500	1200	1100	1500
Lithium (Li)	mg/kg	160	11	8	7	13
Magnesium (Mg)	mg/kg	455000	24000	14000	22000	14000
Manganese (Mn)	mg/kg	17500	770	570	670	440
Molybdenum (Mo)	mg/kg	15	33	1.5	1.6	1.0
Sodium (Na)	mg/kg	187000	2600	3600	5000	4200
Nickel (Ni)	mg/kg	1450	890	460	160	170
Phosphorous (P)	mg/kg	11300	1100	1200	580	590
Lead (Pb)	mg/kg	70	11	10.0	8.2	3.2
Antimony (Sb)	mg/kg	6	< 0.8	< 6	< 6	< 6
Selenium (Se)	mg/kg	0.5	9.1	3.3	< 0.7	< 0.7
Tin (Sn)	mg/kg	15	2.6	< 0.5	< 0.5	< 0.5
Strontium (Sr)	mg/kg	4520	130	180	220	170
Titanium (Ti)	mg/kg	114000	920	1300	700	2300
Thallium (Tl)	mg/kg	2.1	0.08	0.08	< 0.02	0.04
Uranium (U)	mg/kg	7.5	0.79	0.38	0.27	0.57
Vanadium (V)	mg/kg	2250	160	210	82	340
Yttrium (Y)	mg/kg	210	5.8	5.1	3.2	5.6
Zinc (Zn)	mg/kg	1180	200	47	52	34

QEMSCAN Analysis

High-definition mineralogical analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy) was conducted on both the thickened flotation process solids and scavenger process solids to further assess the distribution of AP (sulphides) and NP (carbonates) minerals. A summary of the QEMSCAN results is presented in **Table 6** and **Figure 2**. For both types of process solids, the main mineral constituents are amphibole/pyroxene and plagioclase. In terms of sulphide modal abundance, the 2012 Composite contains significantly more sulphide than the 2020 W-Horizon and 2020 Main Zone ore samples when comparing between thickened flotation process solids and the scavenger process solids. The main sulphide mineral contributing to

AP is pyrite. In the 2012 Composite scavenger (Type 2) process solids, there are also very minor contributions of AP from chalcopyrite and other sulphides. As for carbonate minerals, calcite ($CaCO_3$) and dolomite ($Ca,Mg(CO_3)_2$) minerals contribute to NP which confirms that the Carb-NP is considered effective NP. Therefore, the Carb-NP/AP ratio can be used as an appropriate measure to classify Type 1 and Type 2 process solids.

Table 6: QEMSCAN Summary of Modal Abundance Mineralogy

Sample		2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
Fraction		-300/+3um	-300/+3um	-300/+3um	-300/+3um	-300/+3um	-300/+3um
Mass Size Distribution (%)		100.0	100.0	100.0	100.0	100.0	100.0
Calculated ESD Particle Size		15	12	15	12	16	11
Mineral Mass (%)	Pyrite	0.24	8.60	0.01	0.24	0.01	0.81
	Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
	Chalcopyrite	0.00	0.37	0.01	0.10	0.00	0.01
	Other Sulphides	0.00	0.05	0.01	0.03	0.00	0.01
	Quartz	1.52	1.96	0.57	0.44	0.16	0.15
	Plagioclase	45.51	30.86	44.81	33.51	37.82	36.06
	Epidote	0.18	0.41	0.11	0.07	0.44	0.33
	Muscovite/Illite	0.93	1.05	1.16	0.70	2.12	1.81
	Chlorite	3.29	4.54	3.65	5.22	4.21	6.08
	Biotite	0.53	0.96	0.39	0.66	0.59	1.13
	Clays	0.66	1.48	0.57	0.60	0.67	0.71
	K-Feldspar	0.80	0.62	0.21	0.16	0.30	0.39
	Talc	0.05	0.27	0.06	1.97	0.03	0.23
	Amphibole/Pyroxene	37.60	42.62	44.00	52.53	41.44	43.60
	Other Silicates	0.18	0.29	0.21	0.33	0.19	0.24
	Ti-(Fe)-Oxides	3.02	1.66	1.32	0.37	6.42	4.56
	Fe-Oxides	2.86	2.05	1.23	1.12	4.52	2.81
	Calcite	0.82	0.96	1.18	1.37	0.55	0.53
	Ankerite/Dolomite	0.07	0.04	0.00	0.00	0.00	0.01
	Apatite	1.70	1.03	0.48	0.57	0.46	0.49
	Other	0.02	0.16	0.01	0.01	0.06	0.06
	Total	100.0	100.0	100.0	100.0	100.0	100.0

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

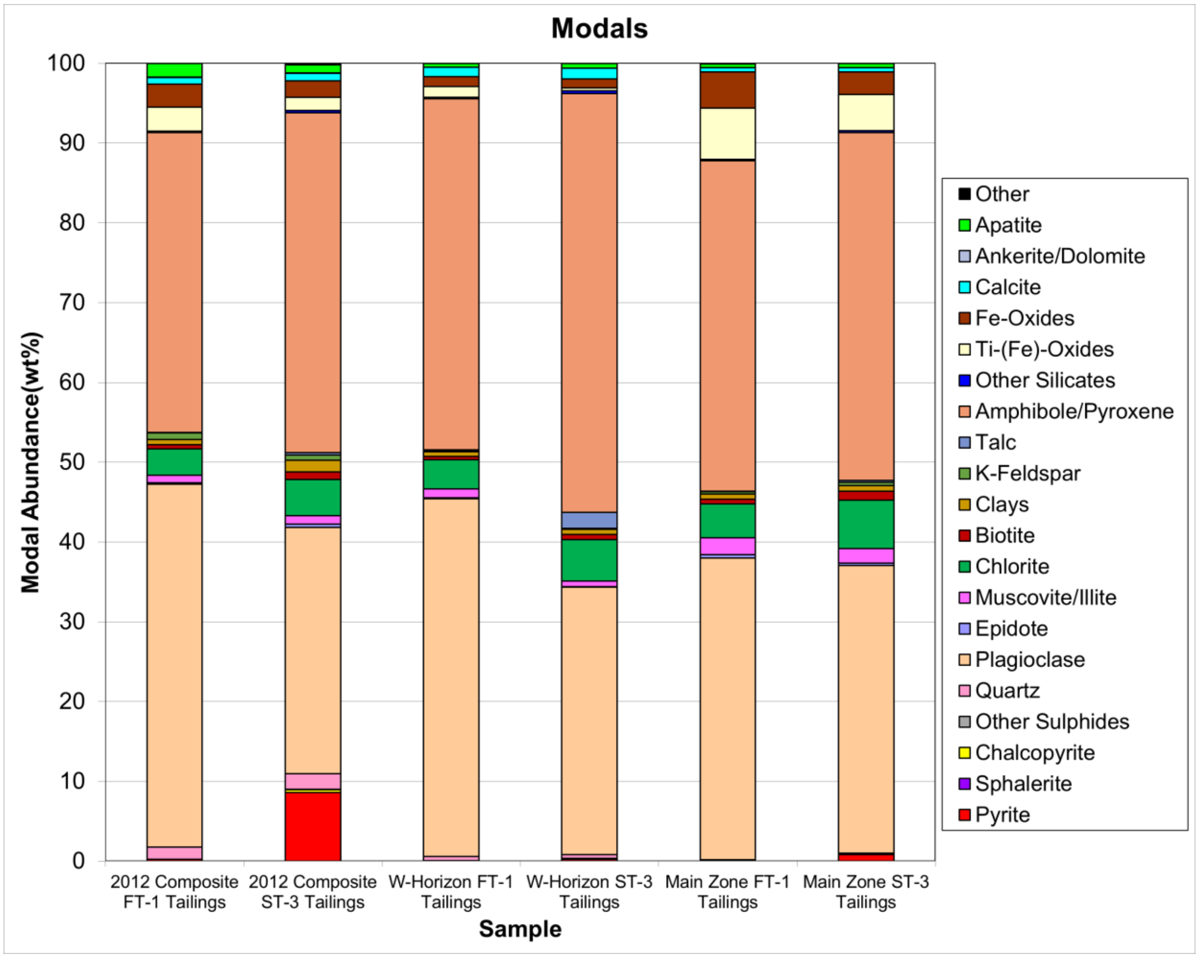

Figure 2: QEMSCAN Summary of Modal Abundance Mineralogy

Process Water

Process water samples in equilibrium with the thickened floatation process solids and the scavenger process solids were analyzed for a variety of parameters to fully characterize the process water entering the process solids storage facility. The full list of parameters measured and the results for the Type 1 and type 2 process waters are summarized in **Table 7** and **Table 8**, respectively.

The results show that the process water with the Type 1 solids (**Table 7**) has a pH of 8 or greater with alkalinity values greater than 100 mg/L as $CaCO_3$. The concentrations of constituents compared with Ontario Provincial Water Quality Objectives (PWQO) or Interim Provincial Water Quality Objectives (IPWQO) were all lower than the objectives with the exception of phosphorous in all process waters and aluminum in the 2020 Main Zone water sample that marginally exceeded the dissolved aluminum PWQO of 0.075 mg/L.

Analysis of the scavenger (Type 2) process water (**Table 8**) showed that the pH values were between 8.2 and 8.7 with alkalinity concentrations in the range of 40 to 60 mg/L as $CaCO_3$. While the concentrations of most constituents were also less than the PWQO values, the dissolved concentrations of aluminum, phosphorus, vanadium in the process solids process water were all greater than the IPWQO/PWQO values. Although it is not practical to directly compare process solids decant chemistry to PWQOs, the comparison provides a screening level approach regarding parameters for which aqueous geochemistry may be an important consideration.

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Table 7: Summary of Thickened Floatation (Type 1) Process Water

Parameter	Unit	IPWQO/PWQO	2012 Composite FT-1 (Aged)	2020 Main Zone FT-1 (Aged)	2020 W-Horizon FT-1 (Aged)
pH	--	6.5 to 8.5	8.06	8.35	8.14
Alkalinity	mg/L as CaCO3	No Value[a]	111	101	118
Conductivity	uS/cm	No Value	328	293	315
Fluoride Dissolved	mg/L	No Value	0.44	0.78	0.96
Chloride	mg/L	No Value	18	19	19
Sulphate	mg/L	No Value	30	20	17
Bromide (dissolved)	mg/L	No Value	< 0.3	< 0.3	< 0.3
Nitrite (as N)	as N mg/L	No Value	< 0.03	< 0.03	< 0.03
Nitrate (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Nitrate + Nitrite (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Dissolved Organic Carbon	mg/L	No Value	6	8	5
Ammonia+Ammonium (N)	as N mg/L	0.02	< 0.1	< 0.1	< 0.1
Mercury (dissolved)	mg/L	0.0002	< 0.00001	< 0.00001	< 0.00001
Silver (dissolved)	mg/L	0.0001[b]	< 0.00005	< 0.00005	< 0.00005
Aluminum (dissolved)	mg/L	0.075[c]	0.069	0.087	0.023
Arsenic (dissolved)	mg/L	0.1	0.0005	0.0004	0.0006
Barium (dissolved)	mg/L	No Value	0.00754	0.00432	0.00467
Boron (dissolved)	mg/L	0.2	0.046	0.025	0.017
Calcium (dissolved)	mg/L	No Value	19.6	18.9	24.8
Cadmium (dissolved)	mg/L	0.0001/0.0005[b]	0.000009	0.000033	0.000031
Cobalt (dissolved)	mg/L	0.0009	0.000047	0.000060	0.000037
Chromium (dissolved)	mg/L	0.0089[b]	0.00008	0.00012	< 0.00008
Copper (dissolved)	mg/L	0.005[b]	0.0005	< 0.0002	0.0002
Iron (dissolved)	mg/L	0.3	0.029	0.076	< 0.007
Potassium (dissolved)	mg/L	No Value	14.9	13.8	8.04
Magnesium (dissolved)	mg/L	No Value	6.64	8.48	8.54
Manganese (dissolved)	mg/L	No Value	0.00989	0.00406	0.00931
Molybdenum (dissolved)	mg/L	0.04	0.0192	0.0201	0.0284
Sodium (dissolved)	mg/L	No Value	32.7	20.2	18.0
Nickel (dissolved)	mg/L	0.025[b]	0.0030	0.0011	0.0013
Phosphorus (dissolved)	mg/L	0.02	0.127	0.535	0.430
Lead (dissolved)	mg/L	0.001 / 0.005	0.00002	< 0.00001	< 0.00001
Sulfur (dissolved)	mg/L	No Value	9	11	7
Selenium (dissolved)	mg/L	0.1	0.00022	0.00057	0.00031
Strontium (dissolved)	mg/L	No Value	0.163	0.129	0.135
Thallium (dissolved)	mg/L	0.0003	< 0.000005	< 0.000005	< 0.000005
Uranium (dissolved)	mg/L	0.005	0.000120	0.000043	0.000154
Vanadium (dissolved)	mg/L	0.006	0.00081	0.00110	0.00036
Tungsten (dissolved)	mg/L	0.03	0.00080	0.00126	0.00090
Zinc (dissolved)	mg/L	0.02[b]	< 0.002	< 0.002	< 0.002

[a] Alkalinity should not be decreased by more than 25% of the natural concentration

[b] Hardness dependant

[c] pH dependant

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Table 8: Summary of Scavenger (Type 2) Process Water

Parameter	Unit	IPWQO/PWQO	2012 Composite ST-3 (Aged)	2020 W-Horizon ST-3 (Aged)	2020 Main Zone ST-3 (Aged)
pH	--	6.5 to 8.5	8.29	8.73	8.20
Alkalinity	mg/L as CaCO3	No Value[a]	37	56	53
Conductivity	uS/cm	No Value	278	197	245
Fluoride Dissolved	mg/L	No Value	0.33	0.27	0.60
Chloride	mg/L	No Value	73	25	44
Sulphate	mg/L	No Value	21	10	21
Bromide (dissolved)	mg/L	No Value	< 0.3	< 0.3	< 0.3
Nitrite (as N)	as N mg/L	No Value	< 0.03	< 0.03	< 0.03
Nitrate (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Nitrate + Nitrite (as N)	as N mg/L	No Value	< 0.06	< 0.06	< 0.06
Dissolved Organic Carbon	mg/L	No Value	108	117	159
Ammonia+Ammonium (N)	as N mg/L	0.02	0.1	< 0.1	< 0.1
Mercury (dissolved)	mg/L	0.0002	< 0.00001	< 0.00001	< 0.00001
Silver (dissolved)	mg/L	0.0001[b]	< 0.00005	< 0.00005	< 0.00005
Aluminum (dissolved)	mg/L	0.075[c]	0.858	0.845	0.199
Arsenic (dissolved)	mg/L	0.1	0.0009	0.0067	0.0059
Barium (dissolved)	mg/L	No Value	0.00140	0.00192	0.00107
Boron (dissolved)	mg/L	0.2	0.039	0.023	0.041
Calcium (dissolved)	mg/L	No Value	16.6	12.8	12.0
Cadmium (dissolved)	mg/L	0.0001/0.0005[b]	< 0.000003	0.000007	0.000012
Cobalt (dissolved)	mg/L	0.0009	0.000064	0.000069	0.000068
Chromium (dissolved)	mg/L	0.0089[b]	0.00177	0.00191	0.00122
Copper (dissolved)	mg/L	0.005[b]	< 0.0002	0.0028	0.0002
Iron (dissolved)	mg/L	0.3	0.008	0.013	0.034
Potassium (dissolved)	mg/L	No Value	10.1	6.1	11.30
Magnesium (dissolved)	mg/L	No Value	0.04	0.05	0.13
Manganese (dissolved)	mg/L	No Value	0.00015	< 0.00001	0.00069
Molybdenum (dissolved)	mg/L	0.04	0.0126	0.0080	0.0158
Sodium (dissolved)	mg/L	No Value	24.9	22.8	26.6
Nickel (dissolved)	mg/L	0.025[b]	0.0011	0.0012	0.0016
Phosphorus (dissolved)	mg/L	0.02	0.875	0.582	1.390
Lead (dissolved)	mg/L	0.001 / 0.005	< 0.00001	< 0.00001	< 0.00001
Sulfur (dissolved)	mg/L	No Value	54	7	24
Selenium (dissolved)	mg/L	0.1	0.00205	0.00124	0.00132
Strontium (dissolved)	mg/L	No Value	0.121	0.092	0.070
Thallium (dissolved)	mg/L	0.0003	< 0.000005	< 0.000005	< 0.000005
Uranium (dissolved)	mg/L	0.005	0.000008	0.000026	0.000019
Vanadium (dissolved)	mg/L	0.006	0.04750	0.02340	0.07870
Tungsten (dissolved)	mg/L	0.03	0.00142	0.00067	0.00350
Zinc (dissolved)	mg/L	0.02[b]	< 0.002	< 0.002	< 0.002

[a]Alkalinity should not be decreased by more than 25% of the natural concentration

[b]Hardness dependant

[c]pH dependant

Reference: Marathon Palladium Project: Geochemical Characterization of Process Solids and Process Water from the Metallurgical Pilot Plant Test Program

Conclusions

Results from the geochemical characterization of process solids from the metallurgical pilot plant test program confirmed that the thickened flotation process solids are to be classified as Type 1 (non-PAG) and the scavenger (1st cleaner) process solids are to be classified as Type 2 (PAG) when managed in the PSMF. Comparative analysis also confirmed that the results from the 2020 pilot plant testing are consistent with those from the previous metallurgical test program, with respect to ABA analyses and ICP-MS bulk metals analysis. Therefore, it is concluded that no additional kinetic geochemistry testing for process solids material is necessary to support the process solids source terms and model calculations. The previously determined kinetic test results remain valid for the process solids from the Marathon Palladium Project and can therefore continue to be used to assess water quality in the updated water balance and water quality model.

Process water was also characterized for both the Type 1 and Type 2 process solids. It is concluded that the water quality model source terms for process waters should be updated to include the values as determined by the recent 2020 metallurgical pilot plant test program for the water quality model used to predict discharge requirements and water treatment design from the Marathon Palladium Project.

Closure

We trust this serves your needs at this time and are available to discuss any questions you may have surrounding this proposed analytical program at your convenience

References

EcoMetrix. 2012. Supporting Information Document (SID) No.5 – Geochemical Assessment of Mine Components at the Marathon PGM-Cu Project, July.

Faure, G. 1998. Principles and Applications of Geochemistry. Prentice Hall. New Jersey.

MEND (Mine Environment Neutral Drainage) 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. by Price, W.A., MEND Report 1.20.1, Natural Resources Canada, December, 2009.

Appendix A: Laboratory Certificate of Analysis

SGS

ABA - Modified Sobek

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21-January-2021

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Phone: 905-876-5726
Fax:905-794-2338

Date Rec. : 05 January 2021
LR Report: **CA14024-JAN21**
Reference: Marathon Palladium Project

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite HF-0 Tailings	6: 2012 Composite FT-1 Tailings	7: 2012 Composite TT-2 Tailings	8: 2012 Composite ST-3 Tailings	9: W-Horizon HF-0 Tailings
Sample Date & Time					N/A	N/A	N/A	N/A	N/A
Paste pH [no unit]	12-Jan-21	08:45	14-Jan-21	09:45	---	9.26	---	---	---
Fizz Rate [no unit]	12-Jan-21	08:45	14-Jan-21	09:45	---	1	---	---	---
Sample weight [g]	12-Jan-21	08:45	14-Jan-21	09:45	---	1.99	---	---	---
HCl_add [mL]	13-Jan-21	06:45	14-Jan-21	09:45	---	30.70	---	---	---
HCl [Normality]	12-Jan-21	08:45	14-Jan-21	09:45	---	0.10	---	---	---
NaOH [Normality]	12-Jan-21	08:45	14-Jan-21	09:45	---	0.10	---	---	---
Vol NaOH to pH=8.3 [mL]	13-Jan-21	08:45	14-Jan-21	09:45	---	19.38	---	---	---
Final pH [no unit]	13-Jan-21	08:45	14-Jan-21	09:45	---	1.75	---	---	---
NP [t CaCO3/1000 t]	13-Jan-21	08:45	14-Jan-21	09:45	---	28.4	---	---	---
AP [t CaCO3/1000 t]	20-Jan-21	11:19	20-Jan-21	11:19	---	1.25	---	---	---
Net NP [t CaCO3/1000 t]	20-Jan-21	11:19	20-Jan-21	11:19	---	27.2	---	---	---
NP/AP [ratio]	20-Jan-21	11:19	20-Jan-21	11:19	---	22.7	---	---	---
S [%]	14-Jan-21	09:53	20-Jan-21	11:19	1.81	0.094	0.045	3.31	0.089
Acid Leachable SO4-S [%]	18-Jan-21	14:00	20-Jan-21	11:19	---	0.05	---	---	---
Sulphide [%]	12-Jan-21	14:27	20-Jan-21	11:19	---	0.04	---	---	---
C [%]	12-Jan-21	09:27	13-Jan-21	09:48	0.147	0.143	0.145	0.295	0.184
CO3 [%]	13-Jan-21	09:35	13-Jan-21	09:48	---	0.365	---	---	---
C(g) [%]	19-Jan-21	19:00	21-Jan-21	06:18	---	< 0.05	---	---	---

Analysis	10: W-Horizon FT-1 Tailings	11: W-Horizon TT-2 Tailings	12: W-Horizon ST-3 Tailings	13: Main Zone HF-0 Tailings	14: Main Zone FT-1 Tailings	15: Main Zone TT-2 Tailings	16: Main Zone ST-3 Tailings
Sample Date & Time	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paste pH [no unit]	9.29	---	---	---	9.31	---	---
Fizz Rate [no unit]	2	---	---	---	2	---	---
Sample weight [g]	2.00	---	---	---	2.00	---	---
HCl_add [mL]	34.70	---	---	---	25.50	---	---
HCl [Normality]	0.10	---	---	---	0.10	---	---
NaOH [Normality]	0.10	---	---	---	0.10	---	---
Vol NaOH to pH=8.3 [mL]	21.75	---	---	---	17.01	---	---
Final pH [no unit]	1.76	---	---	---	1.70	---	---

OnLine LIMS

0002382864

SGS

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ABA - Modified Sobek

LR Report : **CA14024-JAN21**

Analysis	10: W-Horizon FT-1 Tailings	11: W-Horizon TT-2 Tailings	12: W-Horizon ST-3 Tailings	13: Main Zone HF-0 Tailings	14: Main Zone FT-1 Tailings	15: Main Zone TT-2 Tailings	16: Main Zone ST-3 Tailings
NP [t CaCO3/1000 t]	32.4	---	---	---	21.2	---	---
AP [t CaCO3/1000 t]	1.25	---	---	---	1.25	---	---
Net NP [t CaCO3/1000 t]	31.2	---	---	---	20.0	---	---
NP/AP [ratio]	25.9	---	---	---	17.0	---	---
S [%]	0.014	0.018	0.093	0.420	0.009	0.013	0.319
Acid Leachable SO4-S [%]	< 0.04	---	---	---	< 0.04	---	---
Sulphide [%]	< 0.04	---	---	---	< 0.04	---	---
C [%]	0.159	0.182	0.392	0.092	0.082	0.078	0.167
CO3 [%]	0.475	---	---	---	0.260	---	---
C(g) [%]	< 0.05	---	---	---	< 0.05	---	---

```
*NP (Neutralization Potential)
 = 50 x (N of HCL x Total HCL added - N NaOH x NaOH added)
   ------------------------------------------------------
                        Weight of Sample

*AP (Acid Potential) = % Sulphide Sulphur x 31.25
*Net NP (Net Neutralization Potential) = NP-AP
NP/AP Ratio = NP/AP
*Results expressed as tonnes CaCO3 equivalent/1000 tonnes of material
Samples with a % Sulphide value of <0.04 will be calculated using a 0.04 value.
```

Catharine Arnold, B.Sc., C.Chem
Project Specialist,
Environment, Health & Safety

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Carbon/Sulphur - QCBatchID: ECS0017-JAN21													
Carbonate	0.025	%	< 0.025			2	20				98	70	130
Carbon/Sulphur - QCBatchID: ECS0018-JAN21													
Sulphide	0.04	%	< 0.04			0	20	114	80	120			
Carbon/Sulphur - QCBatchID: ECS0019-JAN21													
Carbon (total)	0.005	%	<0.005			NV	20				100	70	130
Sulphur (total)	0.005	%	<0.005			1	20				109	70	130
Carbon/Sulphur - QCBatchID: ECS0023-JAN21													
Sulphide	0.04	%	< 0.04			10	20	106	80	120			
Carbon/Sulphur - QCBatchID: ECS0026-JAN21													
Sulphur (total)	0.005	%	<0.005			3	20				99	70	130

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Date Rec. : 05 January 2021
LR Report: **CA14025-JAN21**
Reference: Marathon Palladium Project

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	6: 2012 Composite FT-1 Tailings	8: 2012 Composite ST-3 Tailings	10: W-Horizon FT-1 Tailings	12: W-Horizon ST-3 Tailings	13: Main Zone HF-0 Tailings	14: Main Zone FT-1 Tailings	15: Main Zone TT-2 Tailings	16: Main Zone ST-3 Tailings
Sample Date & Time					N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ag [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	< 1	1	< 1	< 1	1	< 1	< 1	< 1
As [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	1.3	2.9	1.0	5.7	3.3	0.7	0.7	2.0
Al [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	17000	24000	22000	32000	19000	19000	22000	28000
Ba [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	78	110	82	120	68	69	82	110
Be [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	0.13	0.17	0.12	0.14	0.22	0.24	0.25	0.29
Bi [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	0.10	0.50	< 0.09	0.25	0.27	< 0.09	< 0.09	0.17
Ca [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	18000	24000	19000	29000	14000	15000	18000	22000
Cd [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	0.04	0.19	0.03	0.06	0.20	< 0.02	< 0.02	0.05
Co [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	23	93	29	44	46	31	18	40
Cr [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	290	170	480	150	64	280	42	86
Cu [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	57	800	79	510	2400	35	43	140
Fe [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	55000	100000	49000	58000	67000	82000	28000	64000
K [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	850	1200	810	1100	1000	980	1100	1500
Li [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	5	8	6	7	11	9	10	13
Mg [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	11000	14000	16000	22000	12000	11000	12000	14000
Mn [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	500	570	570	670	390	440	320	440
Mo [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	3.8	1.5	5.7	1.6	1.1	4.1	0.7	1.0
Na [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	2800	3600	3400	5000	2600	2700	3300	4200
Ni [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	130	460	170	160	190	150	54	170

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LR Report : **CA14025-JAN21**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	6: 2012 Composite FT-1 Tailings	8: 2012 Composite ST-3 Tailings	10: W-Horizon FT-1 Tailings	12: W-Horizon ST-3 Tailings	13: Main Zone HF-0 Tailings	14: Main Zone FT-1 Tailings	15: Main Zone TT-2 Tailings	16: Main Zone ST-3 Tailings
P [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	2400	1200	560	580	630	620	720	590
Pb [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	2.8	10	2.1	8.2	4.7	1.6	1.8	3.2
Sb [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
Se [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	< 0.7	3.3	< 0.7	< 0.7	1.2	< 0.7	< 0.7	< 0.7
Sn [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	< 0.5	< 0.5
Sr [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	130	180	150	220	110	110	130	170
Ti [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	1300	1300	830	700	2200	3200	880	2300
Tl [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	0.02	0.08	< 0.02	< 0.02	0.04	< 0.02	< 0.02	0.04
U [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	0.33	0.38	0.77	0.27	0.50	0.46	0.53	0.57
V [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	230	210	120	82	430	610	69	340
Y [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	7.8	5.1	2.9	3.2	5.3	4.9	5.6	5.6
Zn [µg/g]	11-Jan-21	20:30	12-Jan-21	11:13	32	47	36	52	54	35	20	34

Catharine Arnold

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OnLine LIMS

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Metals in Soil - Aqua-regia/ICP-MS - QCBatchID: EMS0049-JAN21													
Aluminum	3	µg/g	<3			2	20	96	70	130	93	70	130
Antimony	6	µg/g	<0.8			ND	20	107	70	130	NV	70	130
Arsenic	0.5	µg/g	<0.5			16	20	104	70	130	118	70	130
Barium	0.01	µg/g	<0.01			0	20	102	70	130	96	70	130
Beryllium	0.02	µg/g	<0.02			4	20	97	70	130	NV	70	130
Bismuth	0.09	µg/g	<0.09			15	20	98	70	130	NV	70	130
Cadmium	0.02	µg/g	<0.02			17	20	100	70	130	NV	70	130
Calcium	3	µg/g	<3			0	20	103	70	130	NV	70	130
Chromium	0.5	µg/g	<0.5			2	20	101	70	130	80	70	130
Cobalt	0.01	µg/g	<0.01			1	20	101	70	130	98	70	130
Copper	0.1	µg/g	<0.1			1	20	101	70	130	96	70	130
Iron	3	µg/g	<3			3	20	105	70	130	95	70	130
Lead	0.05	µg/g	<0.05			1	20	100	70	130	112	70	130
Lithium	2	µg/g	<2			10	20	101	70	130	NV	70	130
Magnesium	3	µg/g	<3			0	20	103	70	130	NV	70	130
Manganese	0.1	µg/g	<0.1			1	20	96	70	130	104	70	130
Molybdenum	0.1	µg/g	<0.1			1	20	97	70	130	NV	70	130
Nickel	0.1	µg/g	<0.1			2	20	100	70	130	85	70	130
Phosphorus	3	µg/g	<3			2	20	98	70	130	NV	70	130
Potassium	3	µg/g	<3			2	20	102	70	130	NV	70	130
Selenium	0.7	µg/g	<0.7			ND	20	97	70	130	NV	70	130
Silver	1	µg/g	<0.01			8	20	93	70	130	109	70	130
Sodium	3	µg/g	<3			5	20	104	70	130	NV	70	130
Strontium	0.02	µg/g	<0.02			2	20	97	70	130	NV	70	130
Thallium	0.02	µg/g	<0.02			7	20	100	70	130	NV	70	130
Tin	0.5	µg/g	<0.5			ND	20	105	70	130	NV	70	130
Titanium	0.1	µg/g	<0.1			2	20	97	70	130	NV	70	130
Uranium	0.002	µg/g	<0.002			13	20	97	70	130	NV	70	130
Vanadium	1	µg/g	<1			1	20	95	70	130	97	70	130
Yttrium	0.004	µg/g	<0.004			1	20	101	70	130	NV	70	130
Zinc	0.7	µg/g	<0.7			1	20	103	70	130	81	70	130

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09-February-2021

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 05 January 2021
LR Report: **CA14027-JAN21**
Reference: Marathon Palladium Project

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite HF-0 Tailings	6: 2012 Composite FT-1 Tailings	7: 2012 Composite TT-2 Tailings
Sample Date & Time						N/A	
Particle Size [no unit]	---	---	---	---	---	09-Feb-21	---
Malvern	---	---	---	---	---	09-Feb-21	---

Analysis	8: 2012 Composite ST-3 Tailings	9: W-Horizon HF-0 Tailings	10: W-Horizon FT-1 Tailings	11: W-Horizon TT-2 Tailings	12: W-Horizon ST-3 Tailings	13: Main Zone HF-0 Tailings	14: Main Zone FT-1 Tailings
Sample Date & Time	N/A		N/A		N/A		N/A
Particle Size [no unit]	09-Feb-21	---	09-Feb-21	---	09-Feb-21	---	09-Feb-21
Malvern	09-Feb-21	---	09-Feb-21	---	09-Feb-21	---	09-Feb-21

Analysis	15: Main Zone TT-2 Tailings	16: Main Zone ST-3 Tailings
Sample Date & Time	N/A	N/A
Particle Size [no unit]	09-Feb-21	09-Feb-21
Malvern	09-Feb-21	09-Feb-21

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08-December-2020

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L5N 2L8, Canada

Phone: 905-876-5726
Fax:905-794-2338

Date Rec. : 18 November 2020
LR Report: **CA14536-NOV20**

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite FT-1 (Fresh)	6: 2012 Composite ST-3 (Fresh)
Sample Date & Time					N/A	N/A
pH [No unit]	18-Nov-20	16:34	20-Nov-20	09:40	8.30	11.44
Alkalinity [mg/L as CaCO3]	18-Nov-20	16:34	24-Nov-20	10:14	113	130
Conductivity [uS/cm]	18-Nov-20	16:34	20-Nov-20	09:41	332	650
Fluoride Dissolved [mg/L]	20-Nov-20	09:28	20-Nov-20	13:30	0.60	0.22
Cl [mg/L]	27-Nov-20	15:27	30-Nov-20	10:14	22	33
SO4 [mg/L]	27-Nov-20	15:22	30-Nov-20	10:14	28	28
Br (diss) [mg/L]	23-Nov-20	10:34	23-Nov-20	15:37	< 0.3	< 0.3
NO2 [as N mg/L]	23-Nov-20	10:34	23-Nov-20	15:37	< 0.03	< 0.03
NO3 [as N mg/L]	23-Nov-20	10:34	23-Nov-20	15:37	< 0.06	< 0.06
NO2+NO3 [as N mg/L]	23-Nov-20	10:34	23-Nov-20	15:37	< 0.06	< 0.06
DOC [mg/L]	19-Nov-20	06:52	19-Nov-20	12:55	7	72
NH3+NH4 [as N mg/L]	19-Nov-20	21:53	20-Nov-20	14:40	< 0.1	< 0.1
Hg (diss) [mg/L]	19-Nov-20	15:07	20-Nov-20	16:58	< 0.00001	0.00001
Ag (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	< 0.00005	< 0.00005
Al (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.083	1.59
As (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.0004	0.0017
Ba (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.00790	0.00521
B (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.052	0.022
Ca (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	18.2	71.2
Cd (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.000007	0.000003
Co (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.000038	0.000023
Cr (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	< 0.00008	0.00147
Cu (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	< 0.0002	0.0007
Fe (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.023	0.008
K (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	18.5	6.24
Mg (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	7.28	0.023
Mn (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.00604	0.00003

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Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite FT-1 (Fresh)	6: 2012 Composite ST-3 (Fresh)
Mo (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.0203	0.00702
Na (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	28.2	12.8
Ni (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.0012	< 0.0001
P (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.403	0.425
Pb (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	< 0.00001	< 0.00001
S (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	12	22
Se (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.00026	0.00151
Sr (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.143	0.185
Tl (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.000006	< 0.000005
U (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.000102	0.000003
V (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.00096	0.0102
W (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	0.00081	0.00071
Zn (diss) [mg/L]	23-Nov-20	18:27	24-Nov-20	14:20	< 0.002	< 0.002

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0434-NOV20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0312-NOV20													
Alkalinity	2	mg/L as Ca	2			1	20	99	80	120	NA		
Alkalinity - QCBatchID: EWL0344-NOV20													
Alkalinity	2	mg/L as Ca	< 2			2	20	104	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0219-NOV20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			ND	10	100	90	110	101	75	125
Anions by discrete analyzer - QCBatchID: DIO5113-NOV20													
Chloride	1	mg/L	<1			0	20	105	80	120	94	75	125
Sulphate	2	mg/L	<2			1	20	96	80	120	94	75	125
Anions by IC - QCBatchID: DIO0434-NOV20													
Nitrate (as N)	0.06	mg/L	<0.06			ND	20	102	80	120	105	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			ND	20	102	80	120	107	75	125
Carbon by SFA - QCBatchID: SKA0203-NOV20													
Dissolved Organic Carbon	1	mg/L	<1			2	20	100	90	110	83	75	125
Conductivity - QCBatchID: EWL0312-NOV20													
Conductivity	2	uS/cm	< 2			0	20	97	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0026-NOV20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	105	80	120	116	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0121-NOV20													
Aluminum (dissolved)	0.001	mg/L	<0.001			6	20	92	90	110	93	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			6	20	99	90	110	96	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			3	20	101	90	110	99	70	130
Boron (dissolved)	0.002	mg/L	<0.002			6	20	95	90	110	NV	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			8	20	97	90	110	95	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			5	20	102	90	110	97	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			2	20	96	90	110	94	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			5	20	96	90	110	94	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			13	20	97	90	110	100	70	130
Iron (dissolved)	0.007	mg/L	<0.007			0	20	106	90	110	NV	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			2	20	101	90	110	96	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			4	20	105	90	110	97	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			2	20	96	90	110	93	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			0	20	102	90	110	96	70	130

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Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Nickel (dissolved)	0.0001	mg/L	<0.0001			ND	20	96	90	110	98	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			3	20	103	90	110	NV	70	130
Potassium (dissolved)	0.009	mg/L	<0.009			18	20	107	90	110	92	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			2	20	96	90	110	95	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	98	90	110	89	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			13	20	105	90	110	101	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			6	20	94	90	110	94	70	130
Sulfur (dissolved)	1	mg/L	<1			15	20	101	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	103	90	110	98	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			7	20	100	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			5	20	101	90	110	97	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			2	20	95	90	110	94	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			ND	20	95	90	110	118	70	130
pH - QCBatchID: EWL0312-NOV20													
pH	0.05	No unit	NA			0		100			NA		

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11-December-2020

Ecometrix
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Date Rec. : 26 November 2020
LR Report: **CA14775-NOV20**

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: Main Zone FT-1 (Fresh Water)	6: 2012 Composite FT-1 (Aged Water)
Sample Date & Time					N/A	N/A
pH [No unit]	27-Nov-20	06:33	30-Nov-20	08:06	8.07	8.06
Alkalinity [mg/L as CaCO3]	27-Nov-20	06:33	30-Nov-20	08:06	106	111
Conductivity [uS/cm]	27-Nov-20	06:33	30-Nov-20	08:06	283	328
Fluoride Dissolved [mg/L]	28-Nov-20	10:12	30-Nov-20	10:30	0.65	0.44
Cl [mg/L]	02-Dec-20	11:50	04-Dec-20	12:14	19	18
SO4 [mg/L]	02-Dec-20	11:45	04-Dec-20	12:14	15	30
Br (diss) [mg/L]	01-Dec-20	16:06	04-Dec-20	11:37	< 0.3	< 0.3
NO2 [as N mg/L]	01-Dec-20	16:06	04-Dec-20	11:37	< 0.03	< 0.03
NO3 [as N mg/L]	01-Dec-20	16:06	04-Dec-20	11:37	< 0.06	< 0.06
NO2+NO3 [as N mg/L]	01-Dec-20	16:06	04-Dec-20	11:38	< 0.06	< 0.06
DOC [mg/L]	01-Dec-20	13:02	02-Dec-20	11:49	8	6
NH3+NH4 [as N mg/L]	27-Nov-20	21:18	30-Nov-20	10:49	< 0.1	< 0.1
Hg (diss) [mg/L]	09-Dec-20	15:56	10-Dec-20	17:00	< 0.00001	< 0.00001
Ag (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	< 0.00005	< 0.00005
Al (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.326	0.069
As (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.0005	0.0005
Ba (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.00681	0.00754
B (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.019	0.046
Ca (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	20.4	19.6
Cd (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.000011	0.000009
Co (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.000232	0.000047
Cr (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.00039	0.00008
Cu (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.0016	0.0005
Fe (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.403	0.029
K (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	13.7	14.9
Mg (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	8.14	6.64
Mn (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.00773	0.00989

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LR Report : **CA14775-NOV20**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: Main Zone FT-1 (Fresh Water)	6: 2012 Composite FT-1 (Aged Water)
Mo (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.0164	0.0192
Na (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	21.4	32.7
Ni (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.0023	0.0030
P (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.122	0.127
Pb (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.00006	0.00002
S (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	5	9
Se (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.00022	0.00022
Sr (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.142	0.163
Tl (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	< 0.000005	< 0.000005
U (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.000065	0.000120
V (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.00273	0.00081
W (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	0.00073	0.00080
Zn (diss) [mg/L]	30-Nov-20	14:01	01-Dec-20	17:22	< 0.002	< 0.002

ODWS - Ontario Drinking Water Standards
MAC/IMAC - Maximum / Interim Maximum Acceptable Concentration
AO/OG - Aesthetic Objective / Operational Guideline
* Exceeds ODWS limit
** No ODWS limit

Catharine Arnold

ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO
CHARTERED
CATHARINE ARNOLD
CHEMIST

Catharine Arnold, B.Sc., C.Chem
Project Specialist,
Environment, Health & Safety

OnLine LIMS

0002348109

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0012-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0479-NOV20													
Alkalinity	2	mg/L as Ca	< 2			4	20	109	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0300-NOV20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			9	10	101	90	110	100	75	125
Anions by discrete analyzer - QCBatchID: DIO5016-DEC20													
Chloride	1	mg/L	<1			1	20	109	80	120	108	75	125
Sulphate	2	mg/L	<2			5	20	103	80	120	103	75	125
Anions by IC - QCBatchID: DIO0012-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			0	20	102	80	120	89	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			ND	20	96	80	120	104	75	125
Carbon by SFA - QCBatchID: SKA0011-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			7	20	93	90	110	92	75	125
Conductivity - QCBatchID: EWL0479-NOV20													
Conductivity	2	uS/cm	< 2			1	20	99	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0009-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	116	80	120	116	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0171-NOV20													
Aluminum (dissolved)	0.001	mg/L	<0.001			15	20	106	90	110	121	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			2	20	108	90	110	118	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			2	20	108	90	110	105	70	130
Boron (dissolved)	0.002	mg/L	<0.002			2	20	103	90	110	106	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			11	20	107	90	110	116	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			8	20	107	90	110	108	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			5	20	105	90	110	110	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			1	20	105	90	110	111	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			0	20	107	90	110	114	70	130
Iron (dissolved)	0.007	mg/L	<0.007			6	20	109	90	110	NV	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			5	20	103	90	110	102	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			1	20	106	90	110	109	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			2	20	103	90	110	113	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			2	20	102	90	110	115	70	130
Nickel (dissolved)	0.0001	mg/L	<0.0001			1	20	106	90	110	116	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			8	20	110	90	110	NV	70	130

OnLine LIMS

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Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Potassium (dissolved)	0.009	mg/L	<0.009			5	20	109	90	110	108	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			9	20	102	90	110	110	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	109	90	110	109	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			1	20	110	90	110	110	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			3	20	103	90	110	114	70	130
Sulfur (dissolved)	1	mg/L	<1			4	20	101	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	104	90	110	104	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			6	20	102	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			3	20	101	90	110	100	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			1	20	107	90	110	117	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			ND	20	101	90	110	117	70	130
pH - QCBatchID: EWL0479-NOV20													
pH	0.05	No unit	NA			0		100			NA		

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08-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 27 November 2020
LR Report: **CA14809-NOV20**

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: Main Zone HF-0 (Fresh)	6: Main Zone ST-3 (Fresh)
Sample Date & Time					N/A	N/A
pH [No unit]	30-Nov-20	08:11	04-Dec-20	14:16	7.72	10.8
Alkalinity [mg/L as CaCO3]	30-Nov-20	08:11	04-Dec-20	14:16	63	71
Conductivity [uS/cm]	30-Nov-20	08:11	04-Dec-20	14:16	217	320
Fluoride Dissolved [mg/L]	28-Nov-20	10:12	30-Nov-20	10:30	0.23	0.56
Cl [mg/L]	03-Dec-20	07:48	04-Dec-20	14:21	15	45
SO4 [mg/L]	03-Dec-20	07:45	04-Dec-20	14:21	11	13
Br (diss) [mg/L]	02-Dec-20	15:47	04-Dec-20	12:35	< 0.3	0.4
NO2 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:35	< 0.03	< 0.03
NO3 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:35	< 0.06	< 0.06
NO2+NO3 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:35	< 0.06	< 0.06
DOC [mg/L]	01-Dec-20	13:02	03-Dec-20	13:17	3	174
NH3+NH4 [as N mg/L]	30-Nov-20	11:34	01-Dec-20	11:05	< 0.1	< 0.1
Hg (diss) [mg/L]	02-Dec-20	09:00	02-Dec-20	14:49	< 0.00001	< 0.00001
Ag (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	< 0.00005	< 0.00005
Al (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.481	0.841
As (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.0007	0.0016
Ba (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00651	0.00263
B (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.019	0.029
Ca (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	22.4	19.9
Cd (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	< 0.000003	< 0.000003
Co (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.000397	0.000210
Cr (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00072	0.00146
Cu (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.0063	0.0007
Fe (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.358	0.206
K (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	3.73	8.70
Mg (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	3.87	0.126
Mn (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00807	0.00234
Mo (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00474	0.0108

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LR Report : CA14809-NOV20

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: Main Zone HF-0 (Fresh)	6: Main Zone ST-3 (Fresh)
Na (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	11.1	23.2
Ni (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.0038	0.0019
P (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	< 0.003	1.13
Pb (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00013	< 0.00001
S (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	5	25
Se (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00016	0.00108
Sr (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.148	0.0999
Tl (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.000007	< 0.000005
U (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.000109	0.000008
V (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00176	0.0922
W (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	0.00028	0.00177
Zn (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:48	< 0.002	< 0.002

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0034-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0011-DEC20													
Alkalinity	2	mg/L as Ca	< 2			0	20	106	80	120	NA		
Alkalinity - QCBatchID: EWL0075-DEC20													
Alkalinity	2	mg/L as Ca	< 2			4	20	100	80	120	NA		
Alkalinity - QCBatchID: EWL0498-NOV20													
Alkalinity	2	mg/L as Ca	< 2			2	20	100	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0310-NOV20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			ND	10	96	90	110	100	75	125
Anions by discrete analyzer - QCBatchID: DIO5021-DEC20													
Chloride	1	mg/L	<1			1	20	105	80	120	104	75	125
Sulphate	2	mg/L	<2			5	20	99	80	120	101	75	125
Anions by IC - QCBatchID: DIO0034-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			0	20	102	80	120	100	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			ND	20	96	80	120	93	75	125
Carbon by SFA - QCBatchID: SKA0011-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			7	20	93	90	110	92	75	125
Carbon by SFA - QCBatchID: SKA0023-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			6	20	95	90	110	91	75	125
Conductivity - QCBatchID: EWL0011-DEC20													
Conductivity	2	uS/cm	< 2			ND	20	100	90	110	NA		
Conductivity - QCBatchID: EWL0075-DEC20													
Conductivity	2	uS/cm	< 2			2	20	102	90	110	NA		
Conductivity - QCBatchID: EWL0498-NOV20													
Conductivity	2	uS/cm	2			0	20	97	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0002-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	115	80	120	130	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0006-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			1	20	102	90	110	NV	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			1	20	103	90	110	115	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			0	20	98	90	110	117	70	130
Boron (dissolved)	0.002	mg/L	<0.002			9	20	101	90	110	108	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			ND	20	100	90	110	117	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			2	20	100	90	110	104	70	130

OnLine LIMS

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Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Chromium (dissolved)	0.00008	mg/L	<0.00008			5	20	100	90	110	121	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			0	20	100	90	110	115	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			2	20	101	90	110	118	70	130
Iron (dissolved)	0.007	mg/L	<0.007			0	20	102	90	110	NV	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			ND	20	97	90	110	117	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			4	20	104	90	110	99	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			2	20	101	90	110	119	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			1	20	97	90	110	108	70	130
Nickel (dissolved)	0.0001	mg/L	<0.0001			5	20	100	90	110	112	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			ND	20	103	90	110	NV	70	130
Potassium (dissolved)	0.009	mg/L	<0.009			2	20	108	90	110	105	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			4	20	101	90	110	128	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	101	90	110	111	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			2	20	108	90	110	107	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			0	20	101	90	110	111	70	130
Sulfur (dissolved)	1	mg/L	<1			7	20	100	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	101	90	110	119	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			ND	20	101	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			7	20	98	90	110	113	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			6	20	100	90	110	117	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			2	20	100	90	110	NV	70	130
pH - QCBatchID: EWL0011-DEC20													
pH	0.05	No unit	NA			0		101			NA		
pH - QCBatchID: EWL0075-DEC20													
pH	0.05	No unit	NA			0		100			NA		
pH - QCBatchID: EWL0498-NOV20													
pH	0.05	No unit	NA			1		101			NA		

OnLine LIMS

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08-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 27 November 2020
LR Report: **CA14810-NOV20**

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite HF-0 (Fresh)	6: 2012 Composite HF-0 (Aged)
Sample Date & Time					N/A	N/A
pH [No unit]	30-Nov-20	08:11	02-Dec-20	14:33	8.15	8.12
Alkalinity [mg/L as CaCO3]	30-Nov-20	08:11	02-Dec-20	14:33	83	88
Conductivity [uS/cm]	30-Nov-20	08:11	02-Dec-20	14:33	240	268
Fluoride Dissolved [mg/L]	28-Nov-20	10:12	30-Nov-20	10:30	0.20	0.25
Cl [mg/L]	03-Dec-20	07:48	04-Dec-20	14:21	16	17
SO4 [mg/L]	03-Dec-20	07:45	04-Dec-20	14:21	15	20
Br (diss) [mg/L]	02-Dec-20	15:47	04-Dec-20	12:45	< 0.3	< 0.3
NO2 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:37	< 0.03	< 0.03
NO3 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:46	< 0.06	< 0.06
NO2+NO3 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:46	< 0.06	< 0.06
DOC [mg/L]	01-Dec-20	13:02	02-Dec-20	11:51	4	4
NH3+NH4 [as N mg/L]	30-Nov-20	11:34	01-Dec-20	11:05	< 0.1	< 0.1
Hg (diss) [mg/L]	02-Dec-20	09:00	02-Dec-20	14:49	< 0.00001	< 0.00001
Ag (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.00005	< 0.00005
Al (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	3.64	0.255
As (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0006	0.0004
Ba (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0181	0.00669
B (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.022	0.028
Ca (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	19.2	19.6
Cd (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.000029	0.000004
Co (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00227	0.000217
Cr (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00726	0.00022
Cu (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0303	0.0038
Fe (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	3.73	0.107
K (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	5.33	6.50
Mg (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	4.86	4.35
Mn (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0520	0.00966

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LR Report : **CA14810-NOV20**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite HF-0 (Fresh)	6: 2012 Composite HF-0 (Aged)
Mo (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00462	0.00555
Na (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	20.2	22.2
Ni (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0117	0.0046
P (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.100	< 0.003
Pb (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00194	0.00005
S (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	5	7
Se (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00036	0.00033
Sr (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.165	0.163
Tl (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.000005	< 0.000005
U (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.000115	0.000125
V (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00583	0.00088
W (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00046	0.00052
Zn (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.007	< 0.002

Catharine Arnold

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Project Specialist,
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OnLine LIMS

0002344422

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0034-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0011-DEC20													
Alkalinity	2	mg/L as Ca	< 2			0	20	106	80	120	NA		
Alkalinity - QCBatchID: EWL0498-NOV20													
Alkalinity	2	mg/L as Ca	< 2			2	20	100	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0310-NOV20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			ND	10	96	90	110	100	75	125
Anions by discrete analyzer - QCBatchID: DIO5021-DEC20													
Chloride	1	mg/L	<1			1	20	105	80	120	104	75	125
Sulphate	2	mg/L	<2			5	20	99	80	120	101	75	125
Anions by IC - QCBatchID: DIO0034-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			0	20	102	80	120	100	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			ND	20	96	80	120	93	75	125
Anions by IC - QCBatchID: DIO0074-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			ND	20	101	80	120	103	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Carbon by SFA - QCBatchID: SKA0011-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			7	20	93	90	110	92	75	125
Conductivity - QCBatchID: EWL0011-DEC20													
Conductivity	2	uS/cm	< 2			ND	20	100	90	110	NA		
Conductivity - QCBatchID: EWL0498-NOV20													
Conductivity	2	uS/cm	2			0	20	97	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0002-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	115	80	120	130	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0006-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			1	20	102	90	110	NV	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			1	20	103	90	110	115	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			0	20	98	90	110	117	70	130
Boron (dissolved)	0.002	mg/L	<0.002			9	20	101	90	110	108	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			ND	20	100	90	110	117	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			2	20	100	90	110	104	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			5	20	100	90	110	121	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			0	20	100	90	110	115	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			2	20	101	90	110	118	70	130

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Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Iron (dissolved)	0.007	mg/L	<0.007			0	20	102	90	110	NV	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			ND	20	97	90	110	117	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			4	20	104	90	110	99	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			2	20	101	90	110	119	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			1	20	97	90	110	108	70	130
Nickel (dissolved)	0.0001	mg/L	<0.0001			5	20	100	90	110	112	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			ND	20	103	90	110	NV	70	130
Potassium (dissolved)	0.009	mg/L	<0.009			2	20	108	90	110	105	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			4	20	101	90	110	128	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	101	90	110	111	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			2	20	108	90	110	107	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			0	20	101	90	110	111	70	130
Sulfur (dissolved)	1	mg/L	<1			7	20	100	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	101	90	110	119	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			ND	20	101	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			7	20	98	90	110	113	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			6	20	100	90	110	117	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			2	20	100	90	110	NV	70	130
pH - QCBatchID: EWL0011-DEC20													
pH	0.05	No unit	NA			0		101			NA		
pH - QCBatchID: EWL0498-NOV20													
pH	0.05	No unit	NA			1		101			NA		

OnLine LIMS

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08-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 27 November 2020
LR Report: **CA14811-NOV20**

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CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite ST-3 (Aged)
Sample Date & Time					N/A
pH [No unit]	30-Nov-20	08:11	02-Dec-20	14:34	8.29
Alkalinity [mg/L as CaCO3]	30-Nov-20	08:11	02-Dec-20	14:34	37
Conductivity [uS/cm]	30-Nov-20	08:11	02-Dec-20	14:34	278
Fluoride Dissolved [mg/L]	28-Nov-20	10:12	30-Nov-20	10:30	0.33
Cl [mg/L]	03-Dec-20	07:48	04-Dec-20	14:21	73
SO4 [mg/L]	03-Dec-20	07:45	04-Dec-20	14:21	21
Br (diss) [mg/L]	02-Dec-20	15:47	04-Dec-20	12:36	< 0.3
NO2 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:36	< 0.03
NO3 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:36	< 0.06
NO2+NO3 [as N mg/L]	02-Dec-20	15:47	04-Dec-20	12:36	< 0.06
DOC [mg/L]	01-Dec-20	13:02	03-Dec-20	13:17	108
NH3+NH4 [as N mg/L]	30-Nov-20	11:34	01-Dec-20	11:05	0.1
Hg (diss) [mg/L]	02-Dec-20	09:00	02-Dec-20	14:49	< 0.00001
Ag (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.00005
Al (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.858
As (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0009
Ba (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00140
B (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.039
Ca (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	16.6
Cd (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.000003
Co (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.000064
Cr (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00177
Cu (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.0002
Fe (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.008
K (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	10.1
Mg (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.042
Mn (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00015
Mo (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0126

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LR Report : **CA14811-NOV20**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: 2012 Composite ST-3 (Aged)
Na (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	24.9
Ni (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0011
P (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.875
Pb (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.00001
S (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	54
Se (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00205
Sr (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.121
Tl (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.000005
U (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.000008
V (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.0475
W (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	0.00142
Zn (diss) [mg/L]	02-Dec-20	14:22	03-Dec-20	16:49	< 0.002

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0034-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0011-DEC20													
Alkalinity	2	mg/L as Ca	< 2			0	20	106	80	120	NA		
Alkalinity - QCBatchID: EWL0498-NOV20													
Alkalinity	2	mg/L as Ca	< 2			2	20	100	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0310-NOV20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			ND	10	96	90	110	100	75	125
Anions by discrete analyzer - QCBatchID: DIO5021-DEC20													
Chloride	1	mg/L	<1			1	20	105	80	120	104	75	125
Sulphate	2	mg/L	<2			5	20	99	80	120	101	75	125
Anions by IC - QCBatchID: DIO0034-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			0	20	102	80	120	100	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			ND	20	96	80	120	93	75	125
Carbon by SFA - QCBatchID: SKA0011-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			7	20	93	90	110	92	75	125
Carbon by SFA - QCBatchID: SKA0023-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			6	20	95	90	110	91	75	125
Conductivity - QCBatchID: EWL0011-DEC20													
Conductivity	2	uS/cm	< 2			ND	20	100	90	110	NA		
Conductivity - QCBatchID: EWL0498-NOV20													
Conductivity	2	uS/cm	2			0	20	97	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0002-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	115	80	120	130	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0006-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			1	20	102	90	110	NV	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			1	20	103	90	110	115	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			0	20	98	90	110	117	70	130
Boron (dissolved)	0.002	mg/L	<0.002			9	20	101	90	110	108	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			ND	20	100	90	110	117	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			2	20	100	90	110	104	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			5	20	100	90	110	121	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			0	20	100	90	110	115	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			2	20	101	90	110	118	70	130
Iron (dissolved)	0.007	mg/L	<0.007			0	20	102	90	110	NV	70	130

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Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Lead (dissolved)	0.00001	mg/L	<0.00001			ND	20	97	90	110	117	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			4	20	104	90	110	99	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			2	20	101	90	110	119	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			1	20	97	90	110	108	70	130
Nickel (dissolved)	0.0001	mg/L	<0.0001			5	20	100	90	110	112	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			ND	20	103	90	110	NV	70	130
Potassium (dissolved)	0.009	mg/L	<0.009			2	20	108	90	110	105	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			4	20	101	90	110	128	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	101	90	110	111	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			2	20	108	90	110	107	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			0	20	101	90	110	111	70	130
Sulfur (dissolved)	1	mg/L	<1			7	20	100	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	101	90	110	119	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			ND	20	101	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			7	20	98	90	110	113	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			6	20	100	90	110	117	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			2	20	100	90	110	NV	70	130
pH - QCBatchID: EWL0011-DEC20													
pH	0.05	No unit	NA			0		101			NA		
pH - QCBatchID: EWL0498-NOV20													
pH	0.05	No unit	NA			1		101			NA		

OnLine LIMS

0002344425

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22-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 07 December 2020
LR Report: **CA14097-DEC20**

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: Main Zone HF-0 (Aged)	6: Main Zone ST-3 (Aged)
pH [No unit]	07-Dec-20	15:30	09-Dec-20	11:24	8.19	8.20
Alkalinity [mg/L as CaCO3]	07-Dec-20	15:30	09-Dec-20	11:24	84	53
Conductivity [uS/cm]	07-Dec-20	15:30	09-Dec-20	11:24	238	245
Fluoride Dissolved [mg/L]	08-Dec-20	11:04	09-Dec-20	07:55	0.39	0.60
Chloride [mg/L]	10-Dec-20	15:51	15-Dec-20	09:21	16	44
Sulphate [mg/L]	10-Dec-20	15:57	15-Dec-20	09:21	15	21
Bromide (dissolved) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	< 0.3	< 0.3
Nitrite (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	< 0.03	< 0.03
Nitrate (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	< 0.06	< 0.06
Nitrate + Nitrite (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	< 0.06	< 0.06
Dissolved Organic Carbon [mg/L]	09-Dec-20	14:53	10-Dec-20	11:27	4	159
Ammonia+Ammonium (N) [as N mg/L]	08-Dec-20	18:09	09-Dec-20	15:18	< 0.1	< 0.1
Mercury (dissolved) [mg/L]	08-Dec-20	16:00	10-Dec-20	11:04	< 0.00001	< 0.00001
Silver (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.00042	< 0.00005
Aluminum (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.157	0.199
Arsenic (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.0011	0.0059
Barium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.00478	0.00107
Boron (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.023	0.041
Calcium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	23.6	12.0
Cadmium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	< 0.000003	0.000012
Cobalt (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.000133	0.000068
Chromium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.00012	0.00122
Copper (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.0039	0.0002
Iron (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.087	0.034
Potassium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	5.18	11.3
Magnesium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	4.51	0.134
Manganese (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.00393	0.00069
Molybdenum (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.00594	0.0158
Sodium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	11.2	26.6
Nickel (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:16	0.0026	0.0016
Phosphorus (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	< 0.003	1.39
Lead (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	< 0.00001	< 0.00001

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LR Report : **CA14097-DEC20**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: Main Zone HF-0 (Aged)	6: Main Zone ST-3 (Aged)
Sulfur (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	6	24
Selenium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.00046	0.00132
Strontium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.138	0.0704
Thallium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	< 0.000005	< 0.000005
Uranium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.000048	0.000019
Vanadium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.00091	0.0787
Tungsten (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.00467	0.00350
Zinc (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	< 0.002	< 0.002

Chris Sullivan

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Christopher Sullivan
CHEMIST

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Project Specialist,
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OnLine LIMS

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0169-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0108-DEC20													
Alkalinity	2	mg/L as Ca	< 2			0	20	109	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0078-DEC20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			0	10	98	90	110	97	75	125
Anions by discrete analyzer - QCBatchID: DIO5045-DEC20													
Chloride	1	mg/L	<1			1	20	106	80	120	103	75	125
Sulphate	2	mg/L	<2			2	20	102	80	120	102	75	125
Anions by IC - QCBatchID: DIO0169-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			NV	20	101	80	120	NV	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			NV	20	96	80	120	NV	75	125
Carbon by SFA - QCBatchID: SKA0088-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			6	20	92	90	110	94	75	125
Conductivity - QCBatchID: EWL0108-DEC20													
Conductivity	2	uS/cm	< 2			1	20	100	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0008-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	99	80	120	127	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0039-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			1	20	103	90	110	118	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			11	20	95	90	110	99	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			7	20	92	90	110	92	70	130
Boron (dissolved)	0.002	mg/L	<0.002			1	20	96	90	110	97	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			ND	20	94	90	110	100	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			2	20	98	90	110	96	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			1	20	96	90	110	102	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			8	20	93	90	110	95	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			ND	20	96	90	110	85	70	130
Iron (dissolved)	0.007	mg/L	<0.007			6	20	100	90	110	NV	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			ND	20	90	90	110	83	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			0	20	109	90	110	94	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			16	20	94	90	110	94	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			1	20	98	90	110	102	70	130
Nickel (dissolved)	0.0001	mg/L	<0.0001			12	20	91	90	110	86	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			ND	20	96	90	110	NV	70	130

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Inorganic Analysis

Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Potassium (dissolved)	0.009	mg/L	<0.009			6	20	106	90	110	89	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			11	20	95	90	110	101	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	95	90	110	91	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			6	20	99	90	110	91	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			11	20	90	90	110	94	70	130
Sulfur (dissolved)	1	mg/L	<1			4	20	105	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	92	90	110	88	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			3	20	95	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			0	20	92	90	110	93	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			10	20	94	90	110	97	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			20	20	97	90	110	72	70	130
pH - QCBatchID: EWL0108-DEC20													
pH	0.05	No unit	NA			0		101			NA		

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22-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 07 December 2020
LR Report: **CA14098-DEC20**

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CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: W-Horizon-FT-1 (Fresh)	6: Main Zone FT-1 (Aged)
pH [No unit]	07-Dec-20	15:30	09-Dec-20	11:24	8.37	8.35
Alkalinity [mg/L as CaCO3]	07-Dec-20	15:30	09-Dec-20	11:24	113	101
Conductivity [uS/cm]	07-Dec-20	15:30	09-Dec-20	11:24	299	293
Fluoride Dissolved [mg/L]	08-Dec-20	11:04	09-Dec-20	07:57	0.94	0.78
Chloride [mg/L]	10-Dec-20	15:51	15-Dec-20	09:21	21	19
Sulphate [mg/L]	10-Dec-20	15:57	15-Dec-20	09:21	14	20
Bromide (dissolved) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	< 0.3	< 0.3
Nitrite (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	0.05	< 0.03
Nitrate (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	0.13	< 0.06
Nitrate + Nitrite (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	0.18	< 0.06
Dissolved Organic Carbon [mg/L]	09-Dec-20	14:53	14-Dec-20	11:46	6	8
Ammonia+Ammonium (N) [as N mg/L]	08-Dec-20	18:09	09-Dec-20	15:18	< 0.1	< 0.1
Mercury (dissolved) [mg/L]	08-Dec-20	16:00	10-Dec-20	11:04	< 0.00001	< 0.00001
Silver (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	< 0.00005	< 0.00005
Aluminum (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.139	0.087
Arsenic (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.0006	0.0004
Barium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.00491	0.00432
Boron (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.024	0.025
Calcium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	24.9	18.9
Cadmium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.000031	0.000033
Cobalt (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.000096	0.000060
Chromium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.00084	0.00012
Copper (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.0006	< 0.0002
Iron (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.113	0.076
Potassium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	7.73	13.8
Magnesium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	9.04	8.48
Manganese (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.00788	0.00406
Molybdenum (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.0275	0.0201
Sodium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	17.9	20.2
Nickel (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:17	0.0015	0.0011
Phosphorus (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.412	0.535

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LR Report : CA14098-DEC20

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: W-Horizon-FT-1 (Fresh)	6: Main Zone FT-1 (Aged)
Lead (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.00001	< 0.00001
Sulfur (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	15	11
Selenium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00040	0.00057
Strontium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.128	0.129
Thallium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.000005	< 0.000005
Uranium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.000153	0.000043
Vanadium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00069	0.00110
Tungsten (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00171	0.00126
Zinc (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.002	< 0.002

Chris Sullivan

CHARTERED Christopher Sullivan CHEMIST — Association of the Chemical Profession of Ontario

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OnLine LIMS

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0169-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
**QCR_SubCategory* - QCBatchID: DIO0214-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3			ND	20	95	80	120	106	75	125
Alkalinity - QCBatchID: EWL0108-DEC20													
Alkalinity	2	mg/L as Ca	< 2			0	20	109	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0078-DEC20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			0	10	98	90	110	97	75	125
Anions by discrete analyzer - QCBatchID: DIO5045-DEC20													
Chloride	1	mg/L	<1			1	20	106	80	120	103	75	125
Sulphate	2	mg/L	<2			2	20	102	80	120	102	75	125
Anions by IC - QCBatchID: DIO0169-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			NV	20	101	80	120	NV	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			NV	20	96	80	120	NV	75	125
Anions by IC - QCBatchID: DIO0216-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			2	20	99	80	120	100	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			ND	20	96	80	120	100	75	125
Carbon by SFA - QCBatchID: SKA0088-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			6	20	92	90	110	94	75	125
Carbon by SFA - QCBatchID: SKA0121-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			2	20	98	90	110	94	75	125
Conductivity - QCBatchID: EWL0108-DEC20													
Conductivity	2	uS/cm	< 2			1	20	100	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0008-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	99	80	120	127	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0039-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			1	20	103	90	110	118	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			11	20	95	90	110	99	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			7	20	92	90	110	92	70	130
Boron (dissolved)	0.002	mg/L	<0.002			1	20	96	90	110	97	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			ND	20	94	90	110	100	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			2	20	98	90	110	96	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			1	20	96	90	110	102	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			8	20	93	90	110	95	70	130

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Env ICP-MS Metals Dissolved

LR Report : CA14098-DEC20

Inorganic Analysis														
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material			
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)		
							%		Low	High		Low	High	
Copper (dissolved)	0.0002	mg/L	<0.0002			ND	20	96	90	110	85	70	130	
Iron (dissolved)	0.007	mg/L	<0.007			6	20	100	90	110	NV	70	130	
Lead (dissolved)	0.00001	mg/L	<0.00001			ND	20	90	90	110	83	70	130	
Magnesium (dissolved)	0.001	mg/L	<0.001			0	20	109	90	110	94	70	130	
Manganese (dissolved)	0.00001	mg/L	<0.00001			16	20	94	90	110	94	70	130	
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			1	20	98	90	110	102	70	130	
Nickel (dissolved)	0.0001	mg/L	<0.0001			12	20	91	90	110	86	70	130	
Phosphorus (dissolved)	0.003	mg/L	<0.003			ND	20	96	90	110	NV	70	130	
Potassium (dissolved)	0.009	mg/L	<0.009			6	20	106	90	110	89	70	130	
Selenium (dissolved)	0.00004	mg/L	<0.00004			11	20	95	90	110	101	70	130	
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	95	90	110	91	70	130	
Sodium (dissolved)	0.01	mg/L	<0.01			6	20	99	90	110	91	70	130	
Strontium (dissolved)	0.00002	mg/L	<0.00002			11	20	90	90	110	94	70	130	
Sulfur (dissolved)	1	mg/L	<1			4	20	105	90	110	NV	70	130	
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	92	90	110	88	70	130	
Tungsten (dissolved)	0.00002	mg/L	<0.00002			3	20	95	90	110	NV	70	130	
Uranium (dissolved)	0.000002	mg/L	<0.000002			0	20	92	90	110	93	70	130	
Vanadium (dissolved)	0.00001	mg/L	<0.00001			10	20	94	90	110	97	70	130	
Zinc (dissolved)	0.002	mg/L	<0.002			20	20	97	90	110	72	70	130	
pH - QCBatchID: EWL0108-DEC20														
pH	0.05	No unit	NA			0		101			NA			

OnLine LIMS

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22-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
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Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 07 December 2020
LR Report: **CA14099-DEC20**

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CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: W Horizon HF-0 (Fresh)	6: W Horizon ST-3 (Fresh)
pH [No unit]	07-Dec-20	15:30	09-Dec-20	11:24	8.56	11.3
Alkalinity [mg/L as CaCO3]	07-Dec-20	15:30	09-Dec-20	11:24	86	149
Conductivity [uS/cm]	07-Dec-20	15:30	09-Dec-20	11:24	233	496
Fluoride Dissolved [mg/L]	08-Dec-20	11:04	09-Dec-20	07:57	0.13	0.29
Chloride [mg/L]	10-Dec-20	15:51	15-Dec-20	09:22	20	26
Sulphate [mg/L]	10-Dec-20	15:57	15-Dec-20	09:22	7	10
Bromide (dissolved) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	< 0.3	< 0.3
Nitrite (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	< 0.03	0.07
Nitrate (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	0.67	0.15
Nitrate + Nitrite (as N) [mg/L]	09-Dec-20	23:38	15-Dec-20	11:12	0.67	0.22
Dissolved Organic Carbon [mg/L]	09-Dec-20	14:53	14-Dec-20	11:46	4	103
Ammonia+Ammonium (N) [as N mg/L]	08-Dec-20	18:09	09-Dec-20	15:19	0.3	0.3
Mercury (dissolved) [mg/L]	08-Dec-20	16:00	10-Dec-20	11:04	< 0.00001	< 0.00001
Silver (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.00005	< 0.00005
Aluminum (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	1.69	1.76
Arsenic (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.0005	0.0035
Barium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00854	0.00120
Boron (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.024	0.030
Calcium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	19.0	29.4
Cadmium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.000003	0.000101
Cobalt (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.000710	0.000043
Chromium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00221	0.00205
Copper (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.0100	0.0048
Iron (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	1.04	0.011
Potassium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	3.13	5.07
Magnesium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	5.32	0.022
Manganese (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.0210	0.00016
Molybdenum (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00357	0.0981
Sodium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	19.2	18.6
Nickel (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.0032	0.0006
Phosphorus (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.003	0.661

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Env ICP-MS Metals Dissolved

LR Report : **CA14099-DEC20**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: W Horizon HF-0 (Fresh)	6: W Horizon ST-3 (Fresh)
Lead (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00008	< 0.00001
Sulfur (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	3	16
Selenium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00014	0.00172
Strontium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.109	0.122
Thallium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.000005	< 0.000005
Uranium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.000058	0.000008
Vanadium (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00212	0.0219
Tungsten (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	0.00126	0.0527
Zinc (dissolved) [mg/L]	09-Dec-20	19:06	11-Dec-20	13:18	< 0.002	< 0.002

CHARTERED
Christopher Sullivan
CHEMIST

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OnLine LIMS

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0169-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0108-DEC20													
Alkalinity	2	mg/L as Ca	< 2			0	20	109	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0078-DEC20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			0	10	98	90	110	97	75	125
Anions by discrete analyzer - QCBatchID: DIO5045-DEC20													
Chloride	1	mg/L	<1			1	20	106	80	120	103	75	125
Sulphate	2	mg/L	<2			2	20	102	80	120	102	75	125
Anions by IC - QCBatchID: DIO0169-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			NV	20	101	80	120	NV	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			NV	20	96	80	120	NV	75	125
Carbon by SFA - QCBatchID: SKA0088-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			6	20	92	90	110	94	75	125
Carbon by SFA - QCBatchID: SKA0121-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			2	20	98	90	110	94	75	125
Conductivity - QCBatchID: EWL0108-DEC20													
Conductivity	2	uS/cm	< 2			1	20	100	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0008-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	99	80	120	127	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0039-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			1	20	103	90	110	118	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			11	20	95	90	110	99	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			7	20	92	90	110	92	70	130
Boron (dissolved)	0.002	mg/L	<0.002			1	20	96	90	110	97	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			ND	20	94	90	110	100	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			2	20	98	90	110	96	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			1	20	96	90	110	102	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			8	20	93	90	110	95	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			ND	20	96	90	110	85	70	130
Iron (dissolved)	0.007	mg/L	<0.007			6	20	100	90	110	NV	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			ND	20	90	90	110	83	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			0	20	109	90	110	94	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			16	20	94	90	110	94	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			1	20	98	90	110	102	70	130

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Env ICP-MS Metals Dissolved

LR Report : CA14099-DEC20

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Nickel (dissolved)	0.0001	mg/L	<0.0001			12	20	91	90	110	86	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			ND	20	96	90	110	NV	70	130
Potassium (dissolved)	0.009	mg/L	<0.009			6	20	106	90	110	89	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			11	20	95	90	110	101	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	95	90	110	91	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			6	20	99	90	110	91	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			11	20	90	90	110	94	70	130
Sulfur (dissolved)	1	mg/L	<1			4	20	105	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	92	90	110	88	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			3	20	95	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			0	20	92	90	110	93	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			10	20	94	90	110	97	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			20	20	97	90	110	72	70	130
pH - QCBatchID: EWL0108-DEC20													
pH	0.05	No unit	NA			0		101			NA		

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22-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 10 December 2020
LR Report: **CA14279-DEC20**

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: W-Horizon-FT-1 (Aged)
pH [No unit]	10-Dec-20	15:38	11-Dec-20	14:23	8.14
Alkalinity [mg/L as CaCO3]	10-Dec-20	15:38	11-Dec-20	14:23	118
Conductivity [uS/cm]	10-Dec-20	15:38	11-Dec-20	14:23	315
Fluoride Dissolved [mg/L]	10-Dec-20	12:27	11-Dec-20	09:35	0.96
Chloride [mg/L]	16-Dec-20	13:54	16-Dec-20	16:38	19
Sulphate [mg/L]	16-Dec-20	13:53	16-Dec-20	16:38	17
Bromide (dissolved) [mg/L]	15-Dec-20	11:25	16-Dec-20	15:05	< 0.3
Nitrite (as N) [mg/L]	15-Dec-20	11:25	16-Dec-20	15:05	< 0.03
Nitrate (as N) [mg/L]	15-Dec-20	11:25	16-Dec-20	15:05	< 0.06
Nitrate + Nitrite (as N) [mg/L]	15-Dec-20	11:25	16-Dec-20	15:05	< 0.06
Dissolved Organic Carbon [mg/L]	12-Dec-20	08:37	14-Dec-20	11:55	5
Ammonia+Ammonium (N) [as N mg/L]	10-Dec-20	08:07	11-Dec-20	12:54	< 0.1
Mercury (dissolved) [mg/L]	11-Dec-20	16:46	14-Dec-20	15:02	< 0.00001
Silver (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	< 0.00005
Aluminum (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.023
Arsenic (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.0006
Barium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.00467
Boron (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.017
Calcium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	24.8
Cadmium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.000031
Cobalt (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.000037
Chromium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	< 0.00008
Copper (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.0002
Iron (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	< 0.007
Potassium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	8.04
Magnesium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	8.54
Manganese (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.00931
Molybdenum (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.0284
Sodium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	18.0
Nickel (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.0013
Phosphorus (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.430

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LR Report : **CA14279-DEC20**

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: W-Horizon-FT-1 (Aged)
Lead (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	< 0.00001
Sulfur (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	7
Selenium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.00031
Strontium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.135
Thallium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	< 0.000005
Uranium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.000154
Vanadium (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.00036
Tungsten (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	0.00090
Zinc (dissolved) [mg/L]	14-Dec-20	15:15	15-Dec-20	16:03	< 0.002

Chris Sullivan

ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO
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CHEMIST

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OnLine LIMS

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Quality Control Report

Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
**QCR_SubCategory* - QCBatchID: DIO0261-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3										
Alkalinity - QCBatchID: EWL0177-DEC20													
Alkalinity	2	mg/L as Ca	< 2			0	20	109	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0109-DEC20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			ND	10	98	90	110	99	75	125
Anions by discrete analyzer - QCBatchID: DIO5055-DEC20													
Chloride	1	mg/L	<1			4	20	107	80	120	106	75	125
Sulphate	2	mg/L	<2			3	20	101	80	120	99	75	125
Anions by IC - QCBatchID: DIO0261-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			0	20	101	80	120	94	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			0	20	97	80	120	99	75	125
Carbon by SFA - QCBatchID: SKA0121-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			2	20	98	90	110	94	75	125
Conductivity - QCBatchID: EWL0177-DEC20													
Conductivity	2	uS/cm	< 2			0	20	99	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0012-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	117	80	120	119	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0057-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			1	20	108	90	110	129	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			2	20	109	90	110	107	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			0	20	104	90	110	103	70	130
Boron (dissolved)	0.002	mg/L	<0.002			0	20	102	90	110	99	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			0	20	102	90	110	108	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			2	20	101	90	110	95	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			6	20	107	90	110	109	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			17	20	107	90	110	103	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			3	20	108	90	110	102	70	130
Iron (dissolved)	0.007	mg/L	<0.007			ND	20	105	90	110	NV	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			3	20	98	90	110	99	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			2	20	110	90	110	102	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			8	20	106	90	110	106	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			4	20	101	90	110	106	70	130
Nickel (dissolved)	0.0001	mg/L	<0.0001			5	20	108	90	110	103	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			ND	20	109	90	110	NV	70	130

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Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Potassium (dissolved)	0.009	mg/L	<0.009			1	20	108	90	110	109	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			6	20	106	90	110	114	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	106	90	110	95	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			4	20	104	90	110	103	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			2	20	99	90	110	99	70	130
Sulfur (dissolved)	1	mg/L	<1			1	20	100	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			1	20	95	90	110	97	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			ND	20	98	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			2	20	97	90	110	98	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			4	20	108	90	110	108	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			ND	20	102	90	110	114	70	130
pH - QCBatchID: EWL0177-DEC20													
pH	0.05	No unit	NA			1		100			NA		

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24-December-2020

Ecometrix
Attn : Neal Sullivan

6800 Campobello Road, Mississauga
Canada, L5N 2L8
Phone: 905-876-5726, Fax:905-794-2338

Date Rec. : 16 December 2020
LR Report: **CA14506-DEC20**

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CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: W-Horizon ST-3 (Aged)	6: W-Horizon HF-0 (Aged)
pH [No unit]	16-Dec-20	14:43	17-Dec-20	14:06	8.73	8.08
Alkalinity [mg/L as CaCO3]	16-Dec-20	14:43	17-Dec-20	14:06	56	90
Conductivity [uS/cm]	16-Dec-20	14:43	17-Dec-20	14:06	197	256
Fluoride Dissolved [mg/L]	23-Dec-20	13:29	23-Dec-20	14:46	0.27	0.14
Chloride [mg/L]	22-Dec-20	18:50	24-Dec-20	11:41	25	21
Sulphate [mg/L]	22-Dec-20	18:45	24-Dec-20	11:41	10	8
Bromide (dissolved) [mg/L]	21-Dec-20	19:03	23-Dec-20	14:39	< 0.3	< 0.3
Nitrite (as N) [mg/L]	21-Dec-20	19:03	23-Dec-20	14:39	< 0.03	0.03
Nitrate (as N) [mg/L]	21-Dec-20	19:03	23-Dec-20	14:39	< 0.06	0.51
Nitrate + Nitrite (as N) [mg/L]	21-Dec-20	19:03	23-Dec-20	14:39	< 0.06	0.54
Dissolved Organic Carbon [mg/L]	16-Dec-20	21:41	18-Dec-20	11:10	117	5
Ammonia+Ammonium (N) [as N mg/L]	16-Dec-20	16:53	17-Dec-20	13:04	< 0.1	0.2
Mercury (dissolved) [mg/L]	18-Dec-20	15:32	18-Dec-20	15:37	< 0.00001	< 0.00001
Silver (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	< 0.00005	< 0.00005
Aluminum (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.845	0.255
Arsenic (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.0067	0.0007
Barium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.00192	0.00352
Boron (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.023	0.013
Calcium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	12.8	20.9
Cadmium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.000007	0.000008
Cobalt (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.000069	0.000133
Chromium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.00191	0.00024
Copper (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.0028	0.0044
Iron (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.013	0.085
Potassium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	6.10	3.47
Magnesium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.049	4.86
Manganese (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	< 0.00001	0.00828
Molybdenum (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.00801	0.00383
Sodium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	22.8	20.4
Nickel (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.0012	0.0016
Phosphorus (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.582	0.003
Lead (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	< 0.00001	0.00003
Sulfur (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	7	3
Selenium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.00124	0.00019
Strontium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.0924	0.123
Thallium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	< 0.000005	< 0.000005
Uranium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.000026	0.000234
Vanadium (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.0234	0.00095
Tungsten (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	0.00067	0.00026
Zinc (dissolved) [mg/L]	18-Dec-20	15:06	22-Dec-20	11:28	< 0.002	< 0.002

OnLine LIMS

0002361552

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

LR Report : **CA14506-DEC20**

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Chris Sullivan

CHARTERED
Christopher Sullivan
CHEMIST
ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO

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OnLine LIMS

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Quality Control Report

Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
Inorganic Analysis				Result 1	Result 2	RPD	Acceptance Criteria %	Spike Recovery (%)	Recovery Limits (%) Low	Recovery Limits (%) High	Spike Recovery (%)	Recovery Limits (%) Low	Recovery Limits (%) High
**QCR_SubCategory* - QCBatchID: DIO0371-DEC20*													
Bromide (dissolved)	0.3	mg/L	<0.3			ND	20	102	80	120	99	75	125
Alkalinity - QCBatchID: EWL0265-DEC20													
Alkalinity	2	mg/L as Ca	< 2			3	20	100	80	120	NA		
Ammonia by SFA - QCBatchID: SKA0168-DEC20													
Ammonia+Ammonium (N)	0.1	as N mg/L	<0.1			ND	10	97	90	110	99	75	125
Anions by discrete analyzer - QCBatchID: DIO5063-DEC20													
Chloride	1	mg/L	<1			1	20	108	80	120	105	75	125
Sulphate	2	mg/L	<2			5	20	105	80	120	103	75	125
Anions by IC - QCBatchID: DIO0371-DEC20													
Nitrate (as N)	0.06	mg/L	<0.06			ND	20	102	80	120	99	75	125
Nitrate + Nitrite (as N)	0.06	mg/L	<0.06			NA		NA			NA		
Nitrite (as N)	0.03	mg/L	<0.03			ND	20	95	80	120	94	75	125
Carbon by SFA - QCBatchID: SKA0169-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			0	20	92	90	110	94	75	125
Carbon by SFA - QCBatchID: SKA5076-DEC20													
Dissolved Organic Carbon	1	mg/L	<1			0	20	94	90	110	108	75	125
Conductivity - QCBatchID: EWL0265-DEC20													
Conductivity	2	uS/cm	< 2			0	20	100	90	110	NA		
Mercury by CVAAS - QCBatchID: EHG0017-DEC20													
Mercury (dissolved)	0.00001	mg/L	< 0.00001			ND	20	115	80	120	NV	70	130
Metals in aqueous samples - ICP-MS - QCBatchID: EMS0100-DEC20													
Aluminum (dissolved)	0.001	mg/L	<0.001			4	20	94	90	110	115	70	130
Arsenic (dissolved)	0.0002	mg/L	<0.0002			0	20	101	90	110	115	70	130
Barium (dissolved)	0.00002	mg/L	<0.00002			1	20	102	90	110	115	70	130
Boron (dissolved)	0.002	mg/L	<0.002			1	20	102	90	110	115	70	130
Cadmium (dissolved)	0.000003	mg/L	<0.000003			0	20	99	90	110	115	70	130
Calcium (dissolved)	0.01	mg/L	<0.01			0	20	105	90	110	115	70	130
Chromium (dissolved)	0.00008	mg/L	<0.00008			1	20	103	90	110	115	70	130
Cobalt (dissolved)	0.000004	mg/L	<0.000004			2	20	99	90	110	115	70	130
Copper (dissolved)	0.0002	mg/L	<0.0002			1	20	100	90	110	115	70	130
Iron (dissolved)	0.007	mg/L	<0.007			1	20	109	90	110	115	70	130
Lead (dissolved)	0.00001	mg/L	<0.00001			0	20	108	90	110	115	70	130
Magnesium (dissolved)	0.001	mg/L	<0.001			1	20	107	90	110	115	70	130
Manganese (dissolved)	0.00001	mg/L	<0.00001			0	20	102	90	110	115	70	130
Molybdenum (dissolved)	0.00004	mg/L	<0.00004			4	20	104	90	110	115	70	130

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Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Nickel (dissolved)	0.0001	mg/L	<0.0001			0	20	101	90	110	115	70	130
Phosphorus (dissolved)	0.003	mg/L	<0.003			4	20	99	90	110	NV	70	130
Potassium (dissolved)	0.009	mg/L	<0.009			2	20	108	90	110	115	70	130
Selenium (dissolved)	0.00004	mg/L	<0.00004			10	20	100	90	110	115	70	130
Silver (dissolved)	0.00005	mg/L	<0.00005			ND	20	102	90	110	115	70	130
Sodium (dissolved)	0.01	mg/L	<0.01			13	20	108	90	110	115	70	130
Strontium (dissolved)	0.00002	mg/L	<0.00002			1	20	103	90	110	115	70	130
Sulfur (dissolved)	1	mg/L	<1			10	20	110	90	110	NV	70	130
Thallium (dissolved)	0.000005	mg/L	<0.000005			ND	20	106	90	110	115	70	130
Tungsten (dissolved)	0.00002	mg/L	<0.00002			Error!	20	100	90	110	NV	70	130
Uranium (dissolved)	0.000002	mg/L	<0.000002			9	20	107	90	110	115	70	130
Vanadium (dissolved)	0.00001	mg/L	<0.00001			0	20	100	90	110	115	70	130
Zinc (dissolved)	0.002	mg/L	<0.002			0	20	103	90	110	115	70	130
pH - QCBatchID: EWL0265-DEC20													
pH	0.05	No unit	NA			0		100			NA		

Appendix B: QEMSCAN Report

QEMSCAN DATA

prepared for:

Ecometrix

Project Custom-Min
MI5009-JAN21

January 29, 2021

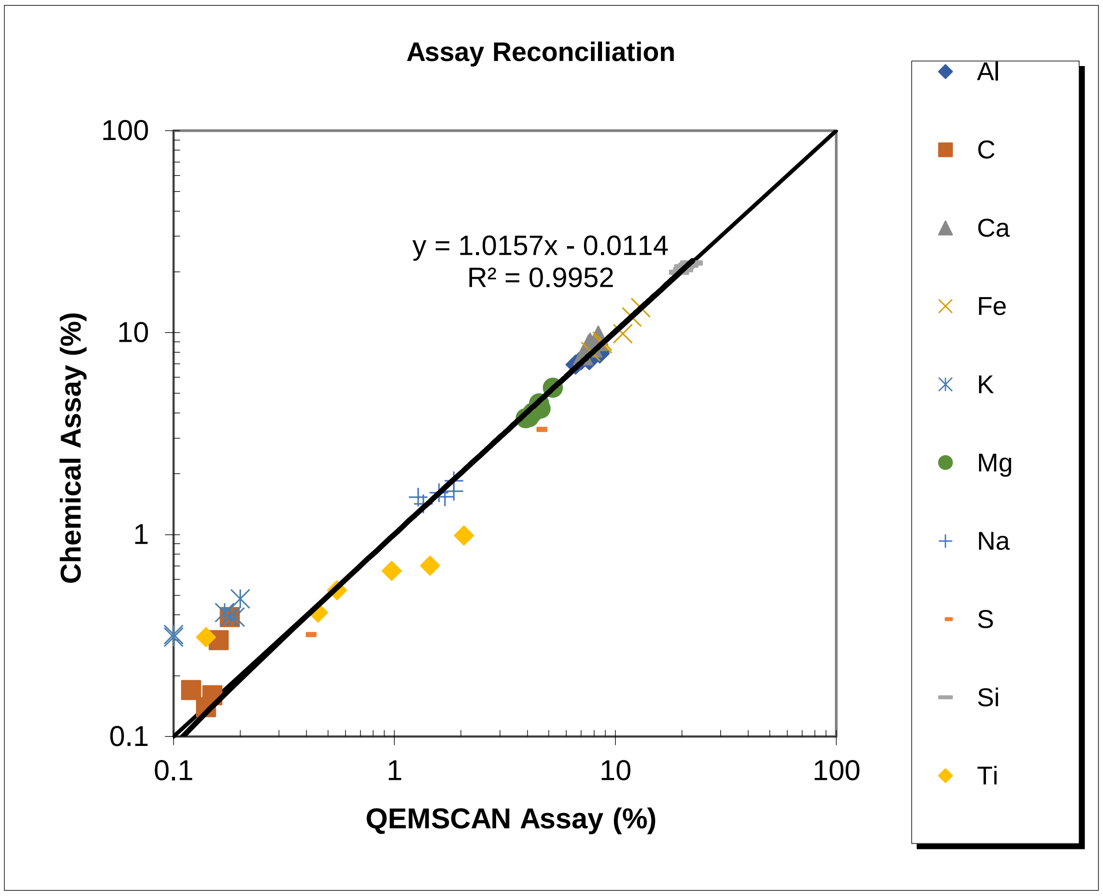
Prepared by:

Margot Aldis/Chris Gunning
Junior/Senior Mineralogist

High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy) (METH# 8.11.1) used by SGS Minerals Services

High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Assay Reconciliation



Sample	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
Element	**-300/+3um**	**-300/+3um**	**-300/+3um**	**-300/+3um**	**-300/+3um**	**-300/+3um**
Al (QEMSCAN)	8.49	6.60	8.49	6.99	7.61	7.56
Al (Chemical)	7.89	6.93	8.10	7.30	7.30	7.83
C (QEMSCAN)	0.14	0.16	0.15	0.18	0.11	0.12
C (Chemical)	0.14	0.30	0.16	0.39	0.08	0.17
Ca (QEMSCAN)	8.34	7.15	8.37	7.86	7.68	7.57
Ca (Chemical)	9.08	7.72	9.65	8.43	8.93	8.72
Fe (QEMSCAN)	8.74	13.02	7.75	8.73	11.86	10.79
Fe (Chemical)	9.09	13.29	8.04	8.81	11.96	9.86
K (QEMSCAN)	0.18	0.19	0.10	0.10	0.17	0.20
K (Chemical)	0.39	0.39	0.32	0.31	0.41	0.48
Mg (QEMSCAN)	3.93	4.06	4.52	5.22	4.23	4.58
Mg (Chemical)	3.77	3.82	4.46	5.34	4.02	4.21
Na (QEMSCAN)	1.86	1.28	1.86	1.35	1.69	1.59
Na (Chemical)	1.85	1.53	1.64	1.42	1.54	1.61
S (QEMSCAN)	0.12	4.42	0.01	0.16	0.01	0.40
S (Chemical)	0.09	3.31	0.01	0.09	0.01	0.32
Si (QEMSCAN)	21.78	19.42	22.38	21.42	20.29	20.47
Si (Chemical)	22.16	19.87	22.16	21.55	20.52	21.18
Ti (QEMSCAN)	0.97	0.55	0.45	0.14	2.06	1.45
Ti (Chemical)	0.66	0.53	0.41	0.31	0.99	0.70

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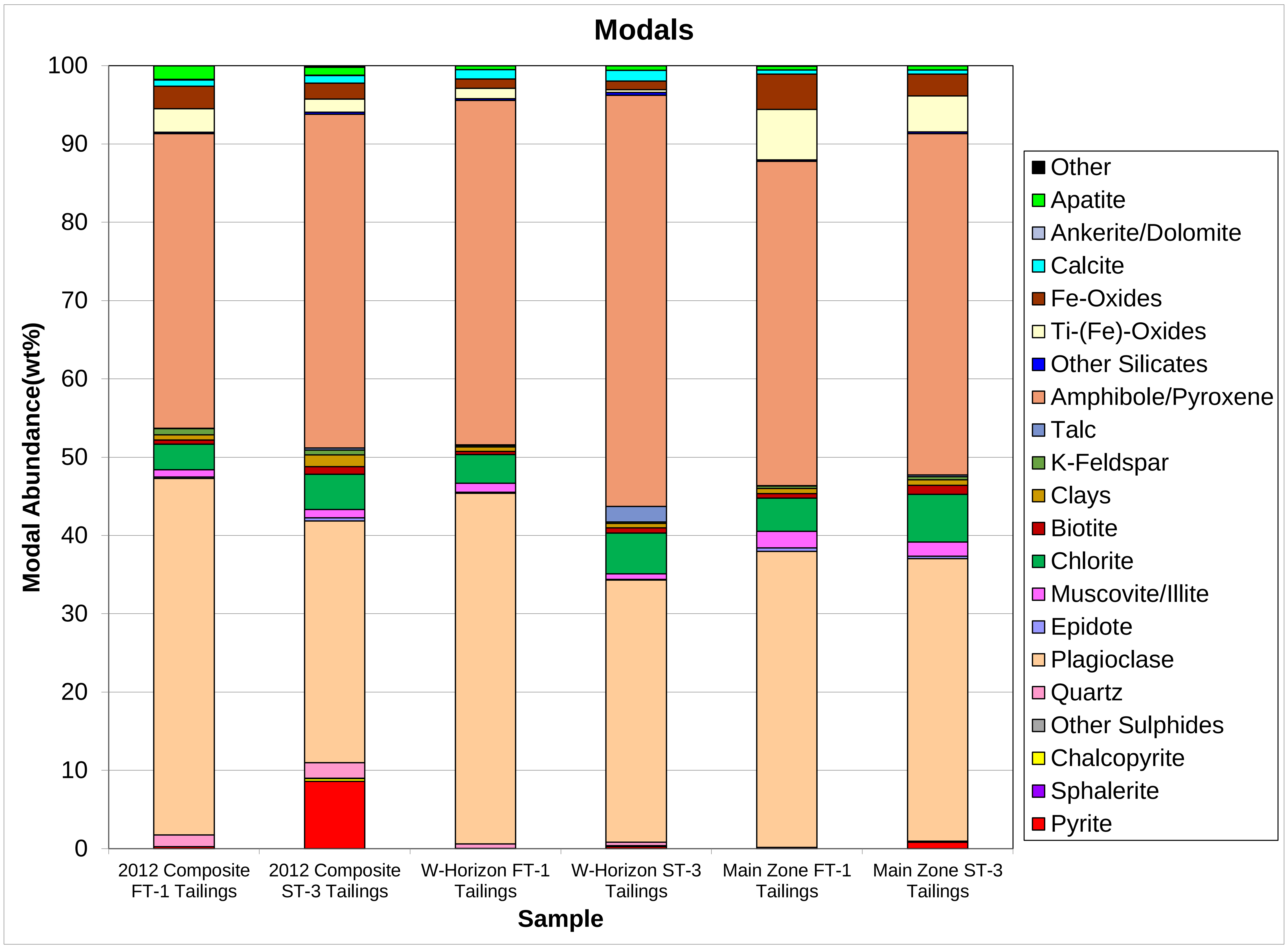
High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Modals

Survey		**Custom-Min / MI5009-JAN21**					
Project		**Ecometrix**					
Sample		**2012 Composite**	**2012 Composite**	**W-Horizon FT-1 Tailings**	**W-Horizon ST-3 Tailings**	**Main Zone FT-1 Tailings**	**Main Zone ST-3 Tailings**
Fraction		**-300/+3um**	**-300/+3um**	**-300/+3um**	**-300/+3um**	**-300/+3um**	**-300/+3um**
Mass Size Distribution (%)		100.0	100.0	100.0	100.0	100.0	100.0
Calculated ESD Particle Size		15	12	15	12	16	11
		Sample	**Sample**	**Sample**	**Sample**	**Sample**	**Sample**
Mineral Mass (%)	Pyrite	0.24	8.60	0.01	0.24	0.01	0.81
	Sphalerite	0.00	0.00	0.00	0.00	0.00	0.00
	Chalcopyrite	0.00	0.37	0.01	0.10	0.00	0.01
	Other Sulphides	0.00	0.05	0.01	0.03	0.00	0.01
	Quartz	1.52	1.96	0.57	0.44	0.16	0.15
	Plagioclase	45.51	30.86	44.81	33.51	37.82	36.06
	Epidote	0.18	0.41	0.11	0.07	0.44	0.33
	Muscovite/Illite	0.93	1.05	1.16	0.70	2.12	1.81
	Chlorite	3.29	4.54	3.65	5.22	4.21	6.08
	Biotite	0.53	0.96	0.39	0.66	0.59	1.13
	Clays	0.66	1.48	0.57	0.60	0.67	0.71
	K-Feldspar	0.80	0.62	0.21	0.16	0.30	0.39
	Talc	0.05	0.27	0.06	1.97	0.03	0.23
	Amphibole/Pyroxene	37.60	42.62	44.00	52.53	41.44	43.60
	Other Silicates	0.18	0.29	0.21	0.33	0.19	0.24
	Ti-(Fe)-Oxides	3.02	1.66	1.32	0.37	6.42	4.56
	Fe-Oxides	2.86	2.05	1.23	1.12	4.52	2.81
	Calcite	0.82	0.96	1.18	1.37	0.55	0.53
	Ankerite/Dolomite	0.07	0.04	0.00	0.00	0.00	0.01
	Apatite	1.70	1.03	0.48	0.57	0.46	0.49
	Other	0.02	0.16	0.01	0.01	0.06	0.06
	Total	100.0	100.0	100.0	100.0	100.0	100.0
Mean Grain Size by Frequency (µm)	Pyrite	15	9	8	7	7	8
	Sphalerite	0	9	0	6	0	6
	Chalcopyrite	8	12	10	9	6	6
	Other Sulphides	6	7	6	7	6	11
	Quartz	14	13	13	9	15	9
	Plagioclase	15	11	14	11	15	11
	Epidote	15	11	11	9	17	19
	Muscovite/Illite	8	7	8	7	9	7
	Chlorite	11	8	10	8	11	9
	Biotite	10	8	9	8	10	9
	Clays	7	7	7	6	7	6
	K-Feldspar	11	9	10	9	9	10
	Talc	8	7	11	9	12	9
	Amphibole/Pyroxene	13	10	12	10	14	10
	Other Silicates	10	10	10	7	10	6
	Ti-(Fe)-Oxides	14	11	12	9	13	14
	Fe-Oxides	10	8	9	8	9	8
	Calcite	7	7	7	6	7	6
	Ankerite/Dolomite	11	7	6	0	6	6
	Apatite	12	8	13	8	14	8
	Other	6	8	8	7	20	16


Modals
Modal Abundance(wt%)
100
90
80
70
60
50
40
30
20
10
0
2012 Composite FT-1 Tailings
2012 Composite ST-3 Tailings
W-Horizon FT-1 Tailings
W-Horizon ST-3 Tailings
Main Zone FT-1 Tailings
Main Zone ST-3 Tailings
Sample
Other
Apatite
Ankerite/Dolomite
Calcite
Fe-Oxides
Ti-(Fe)-Oxides
Other Silicates
Amphibole/Pyroxene
Talc
K-Feldspar
Clays
Biotite
Chlorite
Muscovite/Illite
Epidote
Plagioclase
Quartz
Other Sulphides
Chalcopyrite
Sphalerite
Pyrite

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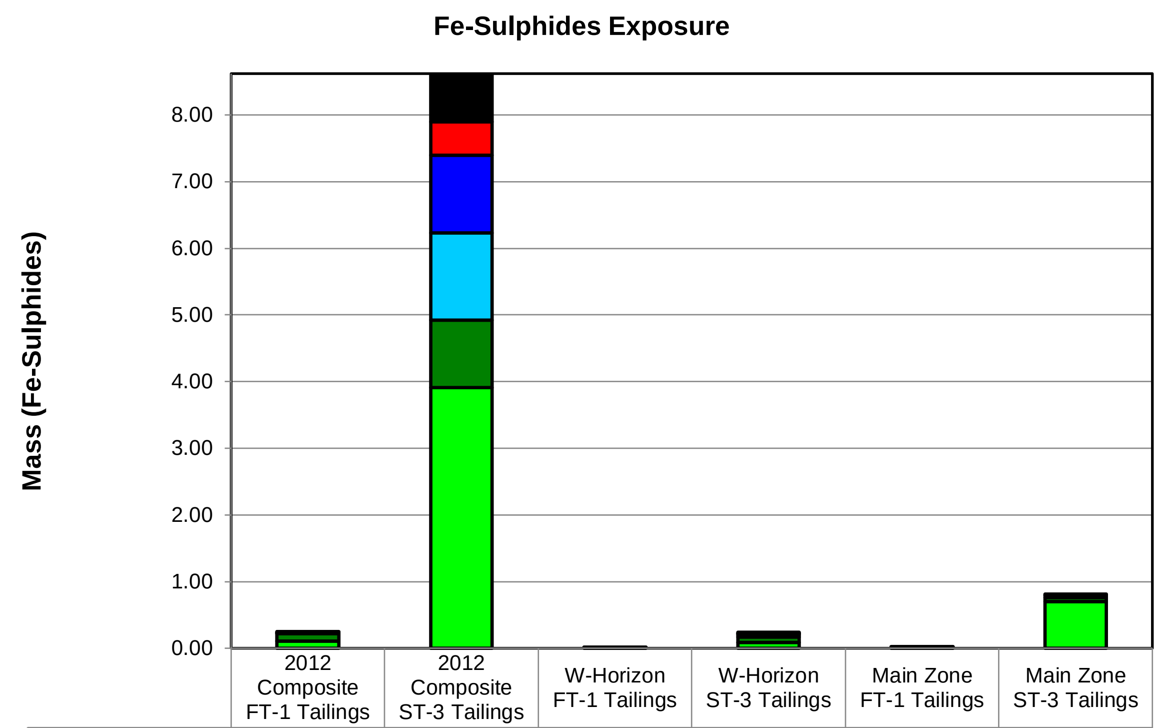
MI5009-JAN21

High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

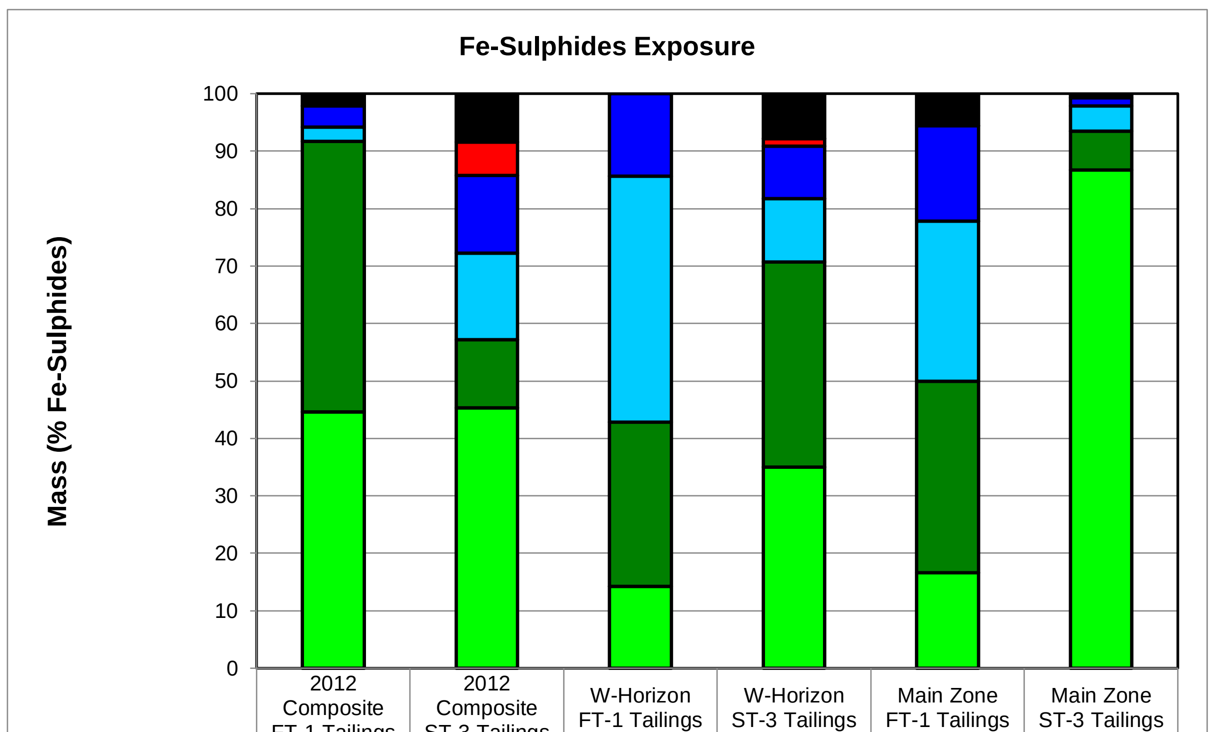
Fe-Sulphides Exposure



	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
0% Exposed	0.01	0.72	0.00	0.02	0.00	0.01
0-20% Exposed	0.00	0.50	0.00	0.00	0.00	0.00
20-40% Exposed	0.01	1.16	0.00	0.02	0.00	0.01
40-60% Exposed	0.01	1.31	0.00	0.03	0.00	0.04
60-80% Exposed	0.11	1.02	0.00	0.09	0.00	0.06
80-100% Exposed	0.11	3.91	0.00	0.08	0.00	0.70

Absolute Mass of Fe-Sulphides Across Samples

Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
80-100% Exposed	0.11	3.91	0.00	0.08	0.00	0.70
60-80% Exposed	0.11	1.02	0.00	0.09	0.00	0.06
40-60% Exposed	0.01	1.31	0.00	0.03	0.00	0.04
20-40% Exposed	0.01	1.16	0.00	0.02	0.00	0.01
0-20% Exposed	0.00	0.50	0.00	0.00	0.00	0.00
0% Exposed	0.01	0.72	0.00	0.02	0.00	0.01
Total	0.24	8.62	0.01	0.24	0.01	0.81



	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
0% Exposed	2.1	8.4	0.0	7.9	5.6	0.8
0-20% Exposed	0.0	5.8	0.0	1.3	0.0	0.0
20-40% Exposed	3.7	13.5	14.3	9.1	16.7	1.4
40-60% Exposed	2.5	15.2	42.9	11.1	27.8	4.4
60-80% Exposed	47.0	11.8	28.5	35.7	33.3	6.8
80-100% Exposed	44.7	45.3	14.3	35.0	16.7	86.7

Normalized Mass of Fe-Sulphides Across Samples

Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
80-100% Exposed	44.7	45.3	14.3	35.0	16.7	86.7
60-80% Exposed	47.0	11.8	28.5	35.7	33.3	6.8
40-60% Exposed	2.5	15.2	42.9	11.1	27.8	4.4
20-40% Exposed	3.7	13.5	14.3	9.1	16.7	1.4
0-20% Exposed	0.0	5.8	0.0	1.3	0.0	0.0
0% Exposed	2.1	8.4	0.0	7.9	5.6	0.8
Total	100.00	100.00	100.00	100.00	100.00	100.00
Total Exposed	91.67	57.13	42.84	70.66	49.99	93.47

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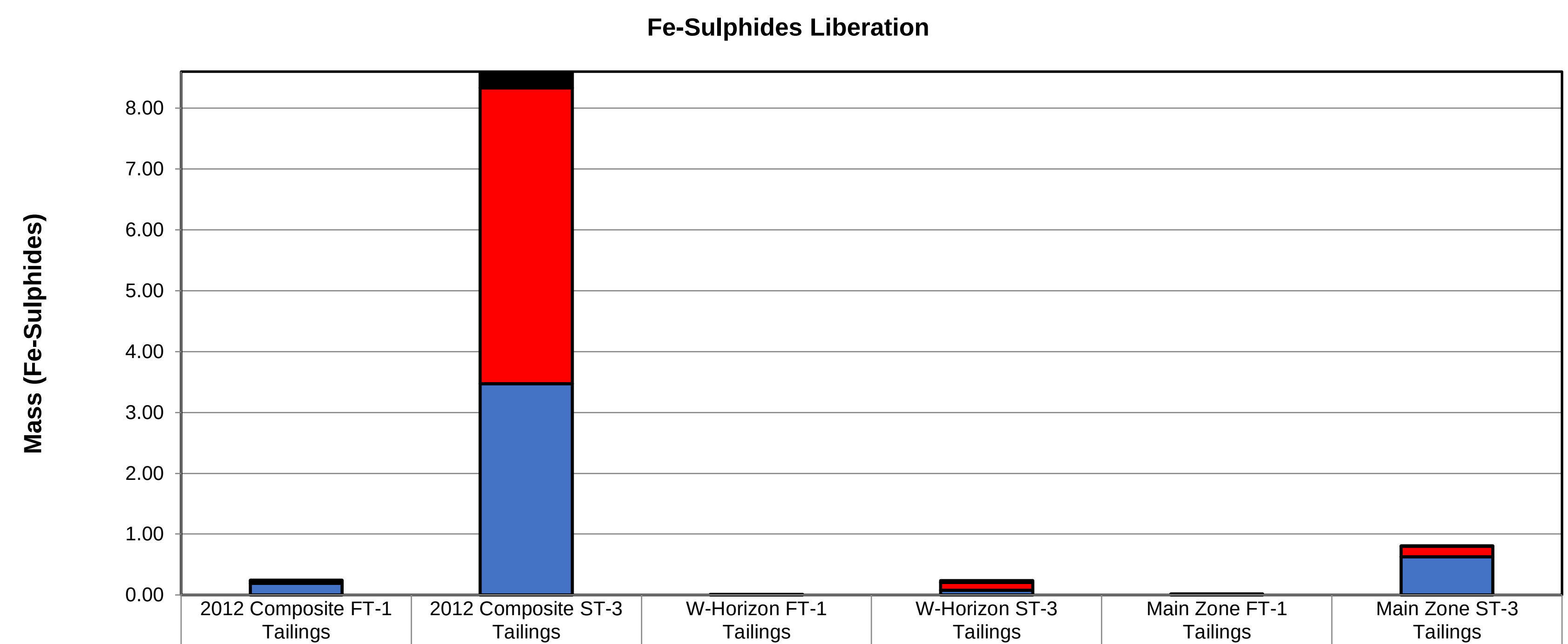
High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

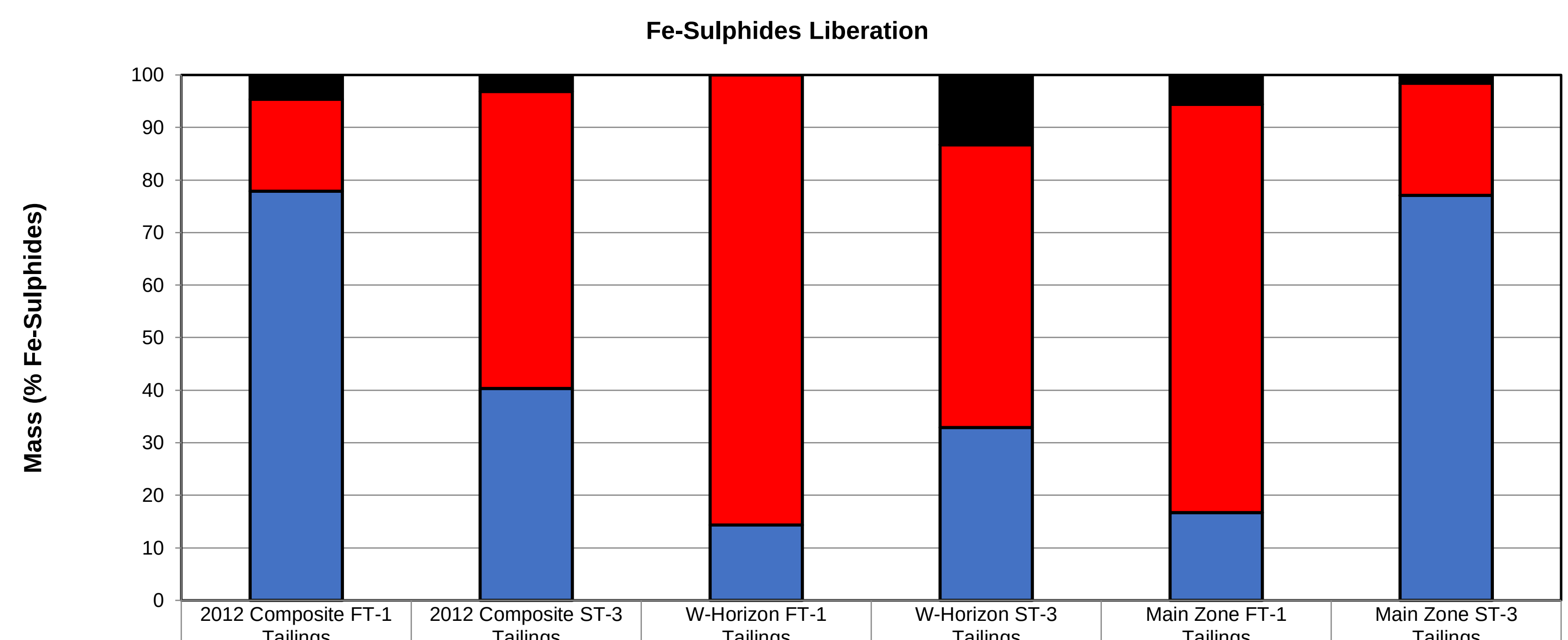
Fe-Sulphides Liberation



	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
FeS Locked	0.01	0.27	0.00	0.03	0.00	0.01
FeS Exposed	0.04	4.86	0.00	0.13	0.01	0.17
FeS Liberated	0.19	3.47	0.00	0.08	0.00	0.62

Absolute Mass of Fe-Sulphides Across Samples

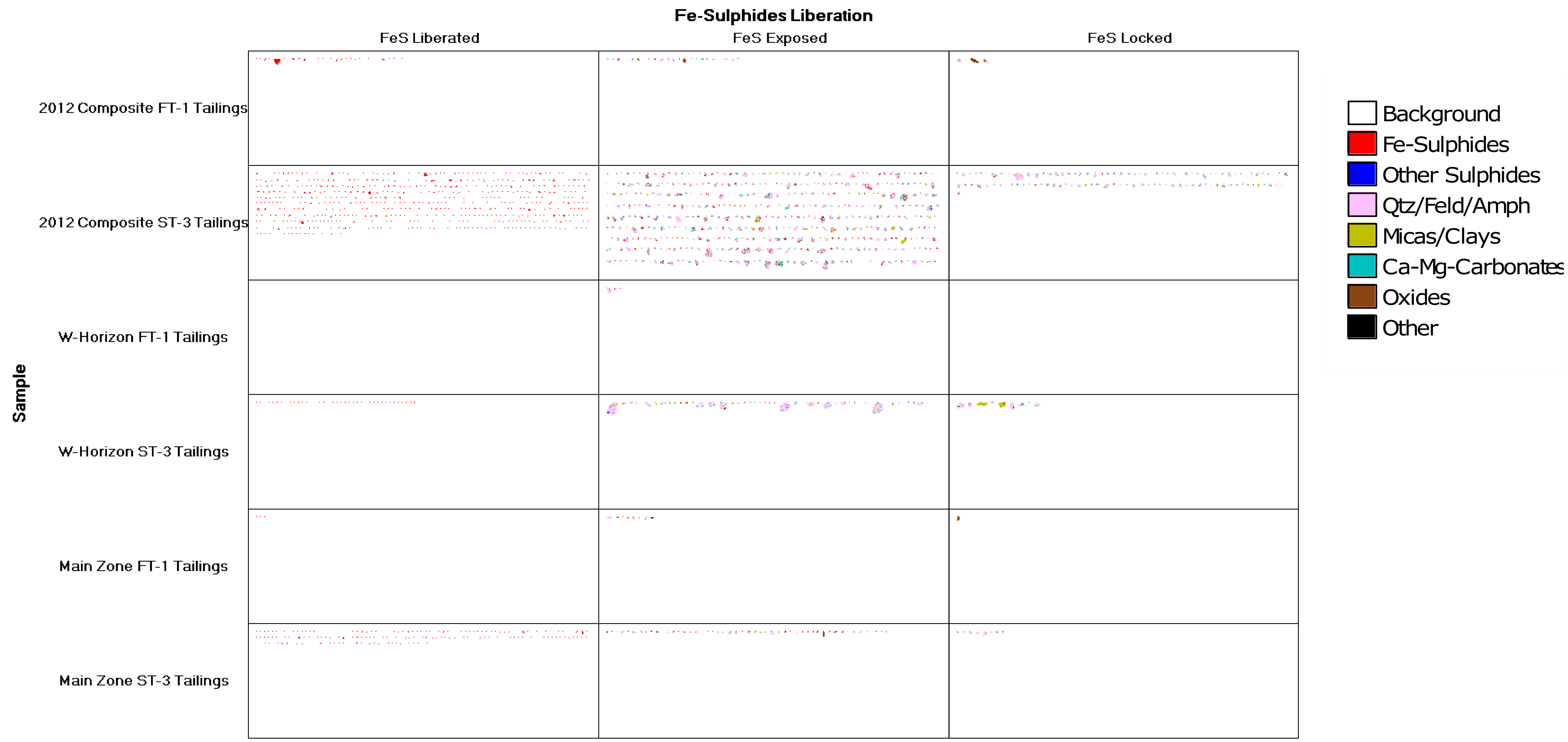
Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
FeS Liberated	0.19	3.47	0.00	0.08	0.00	0.62
FeS Exposed	0.04	4.86	0.00	0.13	0.01	0.17
FeS Locked	0.01	0.27	0.00	0.03	0.00	0.01
Total	0.24	8.60	0.01	0.24	0.01	0.81



	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
FeS Locked	4.6	3.1	0.0	13.3	5.6	1.6
FeS Exposed	17.5	56.5	85.7	53.8	77.8	21.3
FeS Liberated	77.9	40.3	14.3	32.9	16.7	77.1

Normalized Mass of Fe-Sulphides Across Samples

Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
FeS Liberated	77.9	40.3	14.3	32.9	16.7	77.1
FeS Exposed	17.5	56.5	85.7	53.8	77.8	21.3
FeS Locked	4.6	3.1	0.0	13.3	5.6	1.6
Total	100.00	100.00	100.00	100.00	100.00	100.00



Fe-Sulphides Liberation
FeS Liberated
FeS Exposed
FeS Locked
Sample
2012 Composite FT-1 Tailings
2012 Composite ST-3 Tailings
W-Horizon FT-1 Tailings
W-Horizon ST-3 Tailings
Main Zone FT-1 Tailings
Main Zone ST-3 Tailings
Background
Fe-Sulphides
Other Sulphides
Qtz/Feld/Amph
Micas/Clays
Ca-Mg-Carbonates
Oxides
Other

Ecometrix
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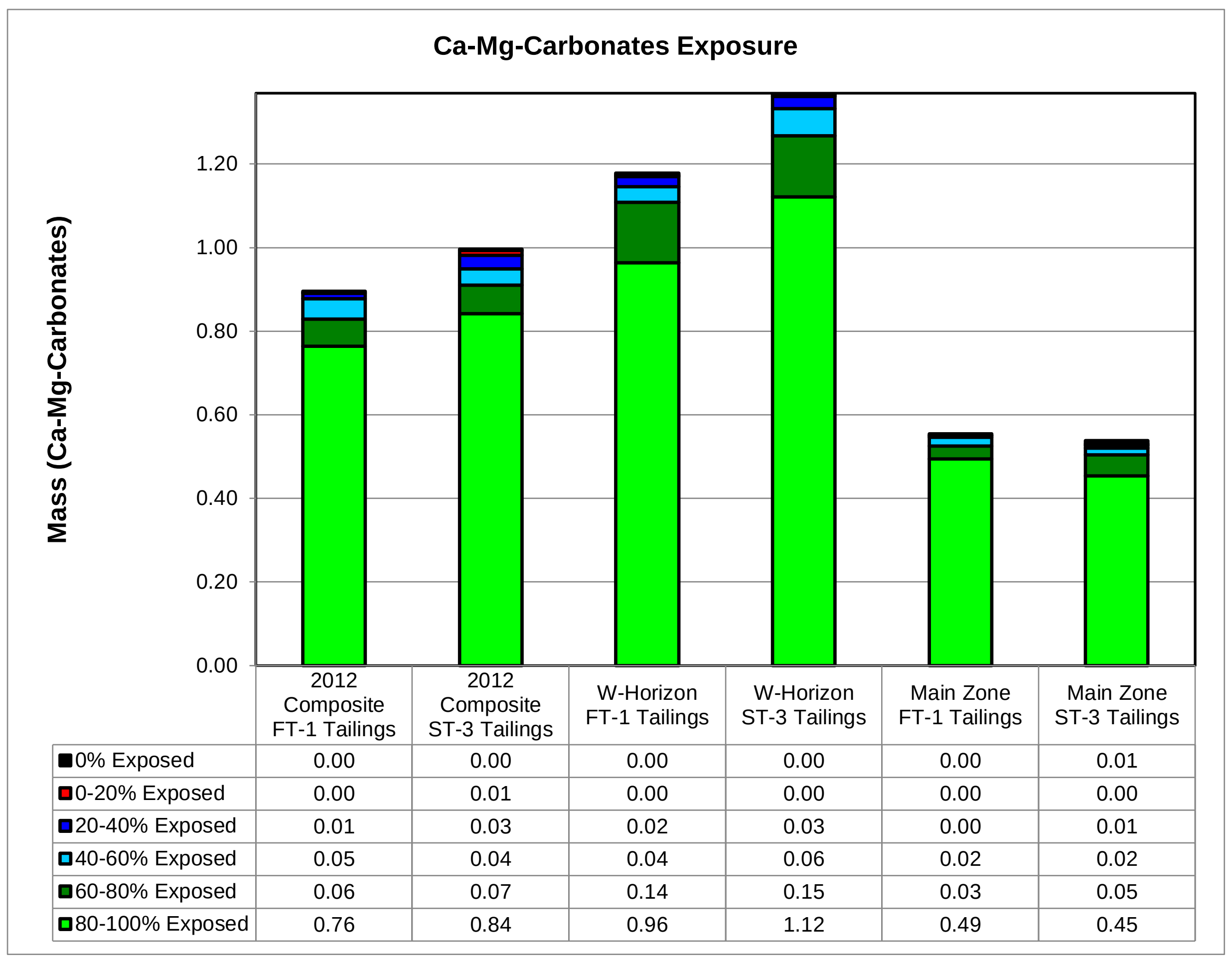
MI5009-JAN21

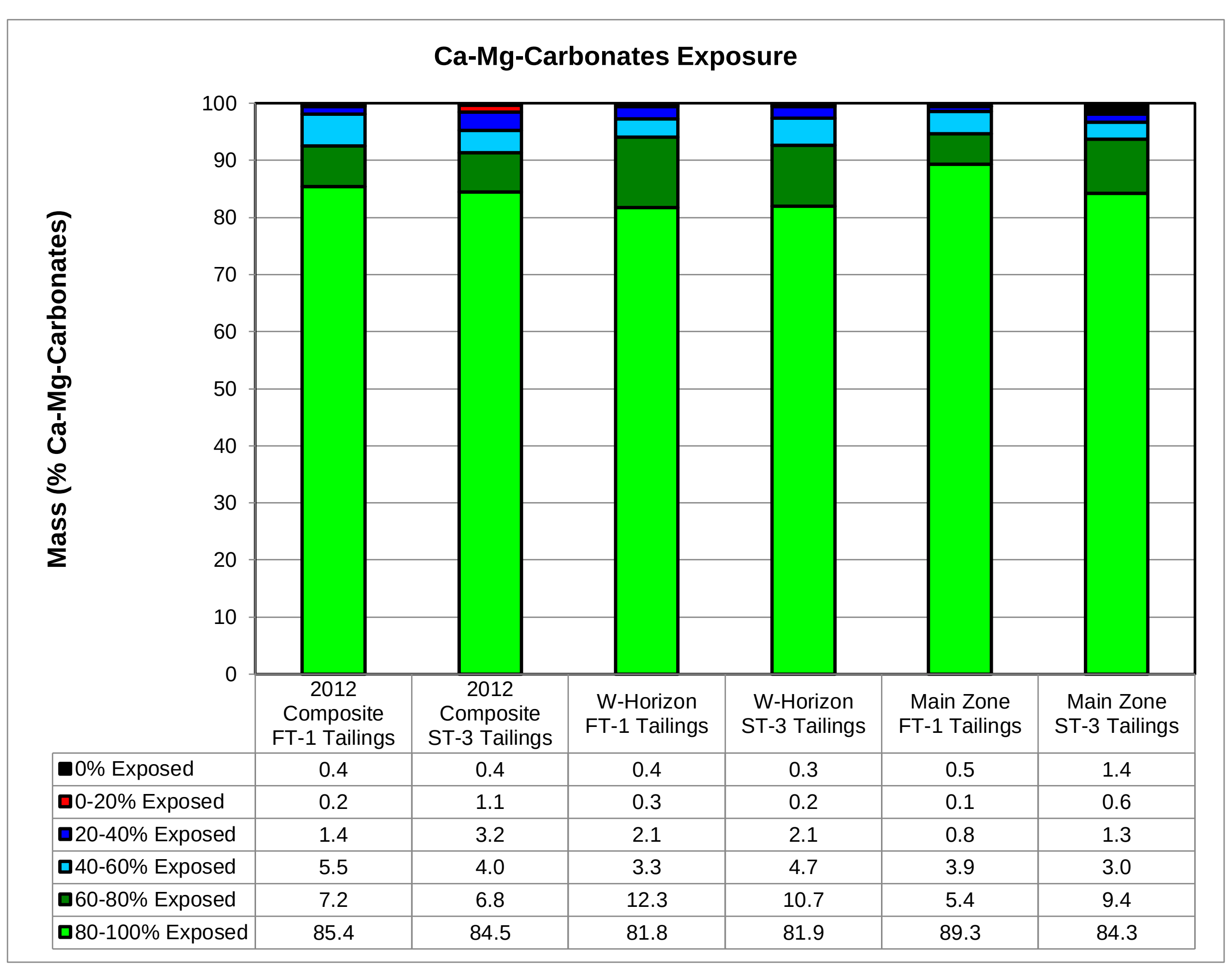
High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Ca-Mg-Carbonates Exposure



Absolute Mass of Ca-Mg-Carbonates Across Samples

Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
80-100% Exposed	0.76	0.84	0.96	1.12	0.49	0.45
60-80% Exposed	0.06	0.07	0.14	0.15	0.03	0.05
40-60% Exposed	0.05	0.04	0.04	0.06	0.02	0.02
20-40% Exposed	0.01	0.03	0.02	0.03	0.00	0.01
0-20% Exposed	0.00	0.01	0.00	0.00	0.00	0.00
0% Exposed	0.00	0.00	0.00	0.00	0.00	0.01
Total	0.89	1.00	1.18	1.37	0.55	0.54

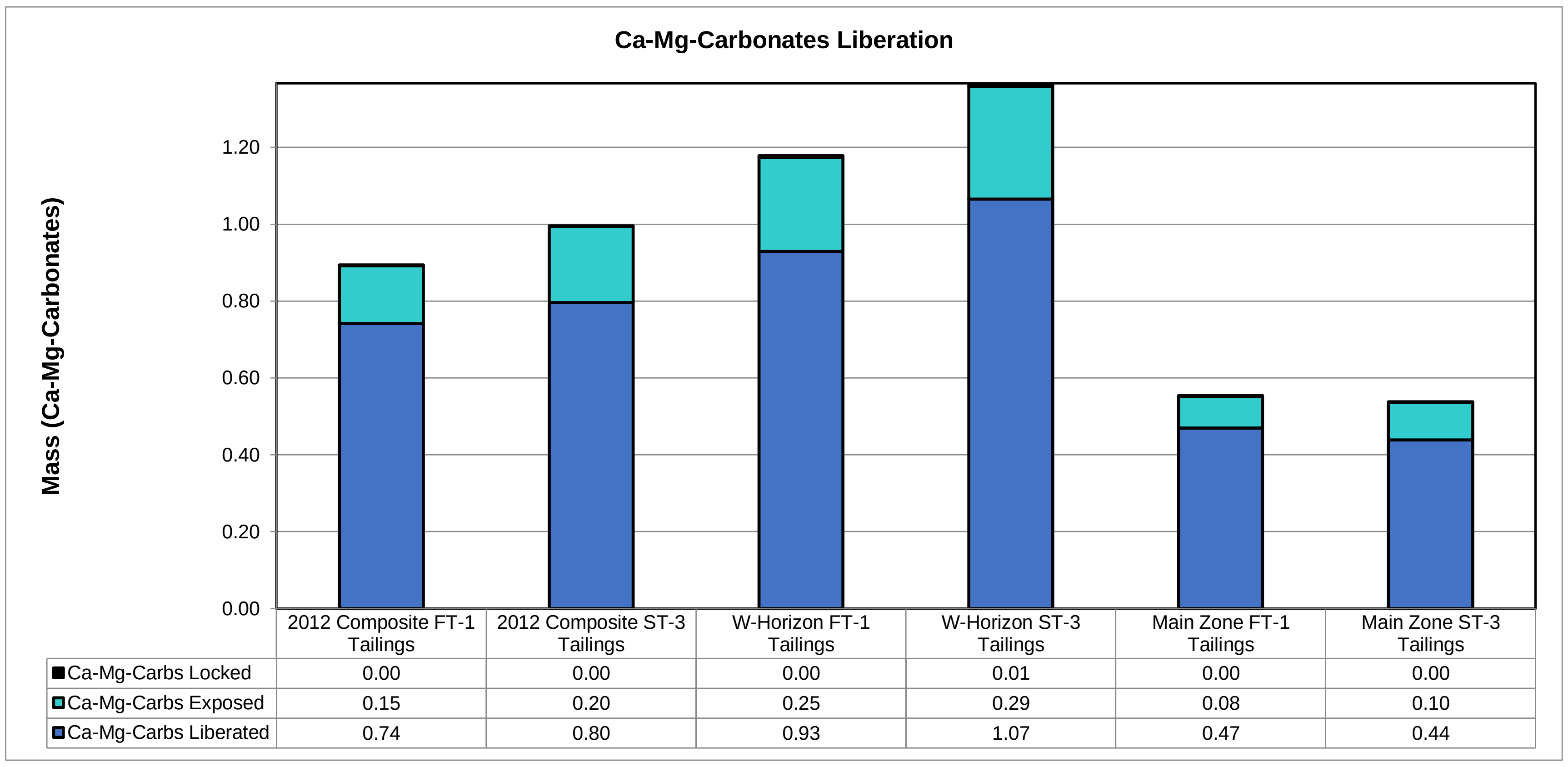


Normalized Mass of Ca-Mg-Carbonates Across Samples

Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
80-100% Exposed	85.4	84.5	81.8	81.9	89.3	84.3
60-80% Exposed	7.2	6.8	12.3	10.7	5.4	9.4
40-60% Exposed	5.5	4.0	3.3	4.7	3.9	3.0
20-40% Exposed	1.4	3.2	2.1	2.1	0.8	1.3
0-20% Exposed	0.2	1.1	0.3	0.2	0.1	0.6
0% Exposed	0.4	0.4	0.4	0.3	0.5	1.4
Total	100.00	100.00	100.00	100.00	100.00	100.00
Total Exposed	92.55	91.31	94.03	92.60	94.69	93.70

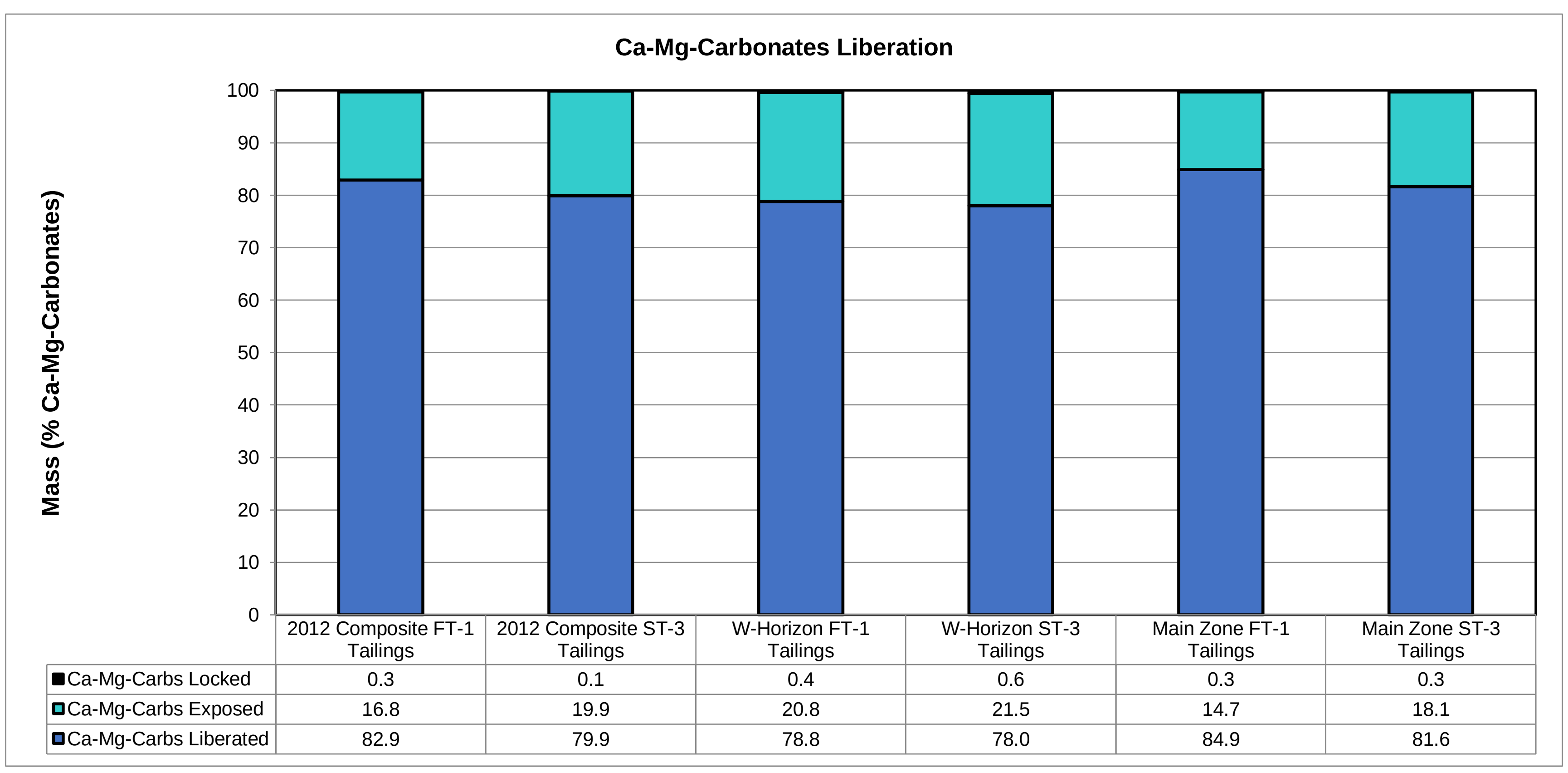
High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Ca-Mg-Carbonates Liberation



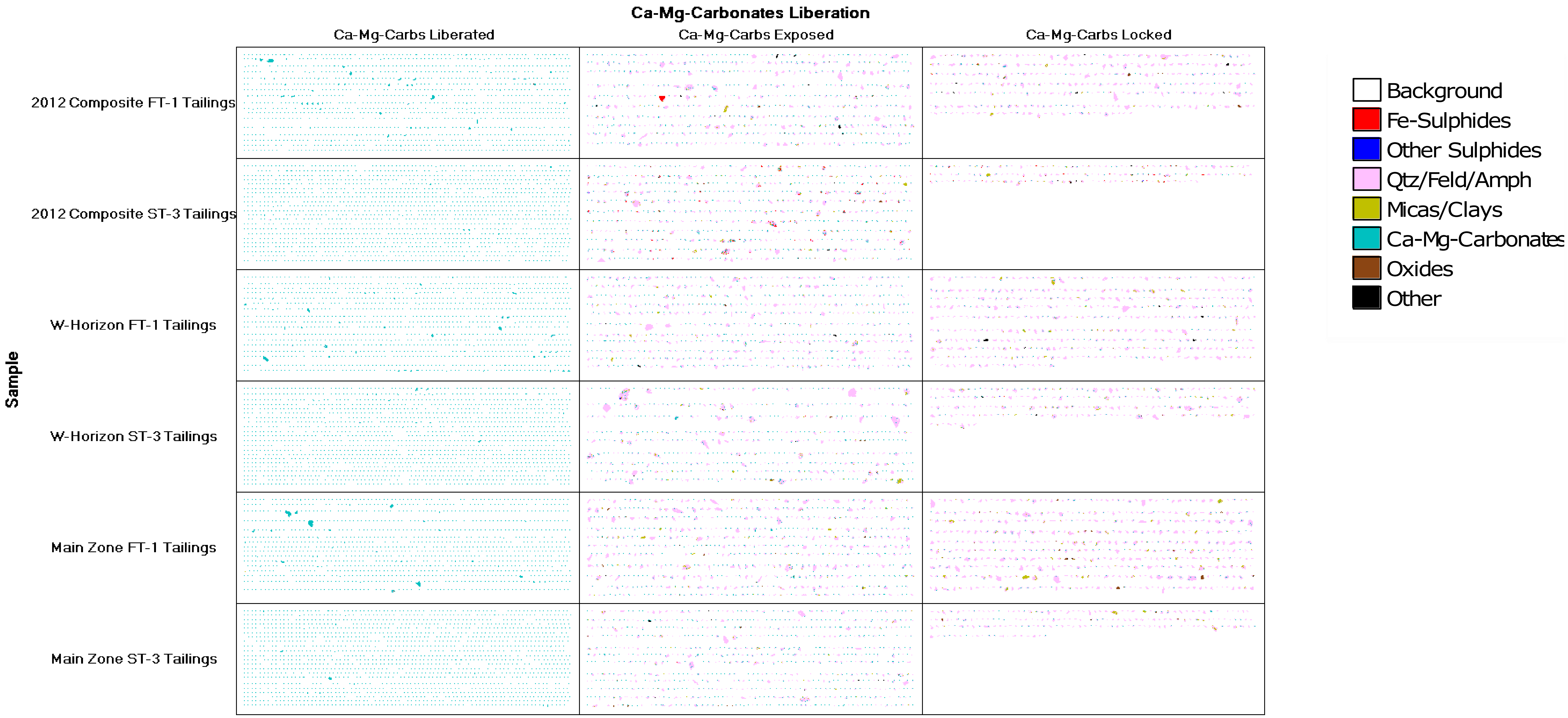
Absolute Mass of Ca-Mg-Carbonates Across Samples

Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
Ca-Mg-Carbs Liberated	0.74	0.80	0.93	1.07	0.47	0.44
Ca-Mg-Carbs Exposed	0.15	0.20	0.25	0.29	0.08	0.10
Ca-Mg-Carbs Locked	0.00	0.00	0.00	0.01	0.00	0.00
Total	0.89	1.00	1.18	1.37	0.55	0.54



Normalized Mass of Ca-Mg-Carbonates Across Samples

Mineral Name	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
Ca-Mg-Carbs Liberated	82.9	79.9	78.8	78.0	84.9	81.6
Ca-Mg-Carbs Exposed	16.8	19.9	20.8	21.5	14.7	18.1
Ca-Mg-Carbs Locked	0.3	0.1	0.4	0.6	0.3	0.3
Total	100.00	100.00	100.00	100.00	100.00	100.00



Ca-Mg-Carbonates Liberation
Ca-Mg-Carbs Liberated
Ca-Mg-Carbs Exposed
Ca-Mg-Carbs Locked
Sample
2012 Composite FT-1 Tailings
2012 Composite ST-3 Tailings
W-Horizon FT-1 Tailings
W-Horizon ST-3 Tailings
Main Zone FT-1 Tailings
Main Zone ST-3 Tailings
Background
Fe-Sulphides
Other Sulphides
Qtz/Feld/Amph
Micas/Clays
Ca-Mg-Carbonates
Oxides
Other

Ecometrix
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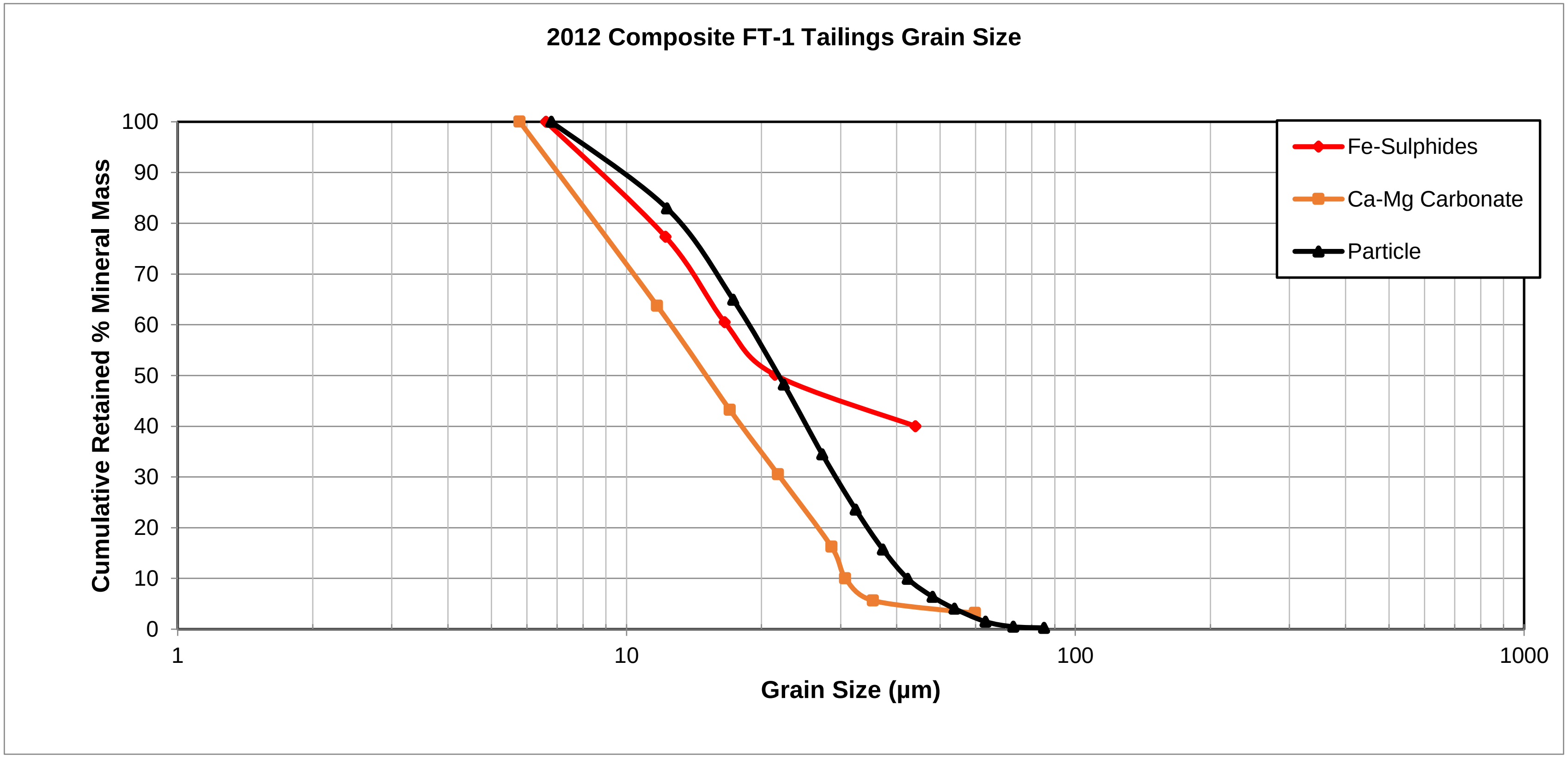
MI5009-JAN21

High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Cumulative Retained Grain Size Distribution



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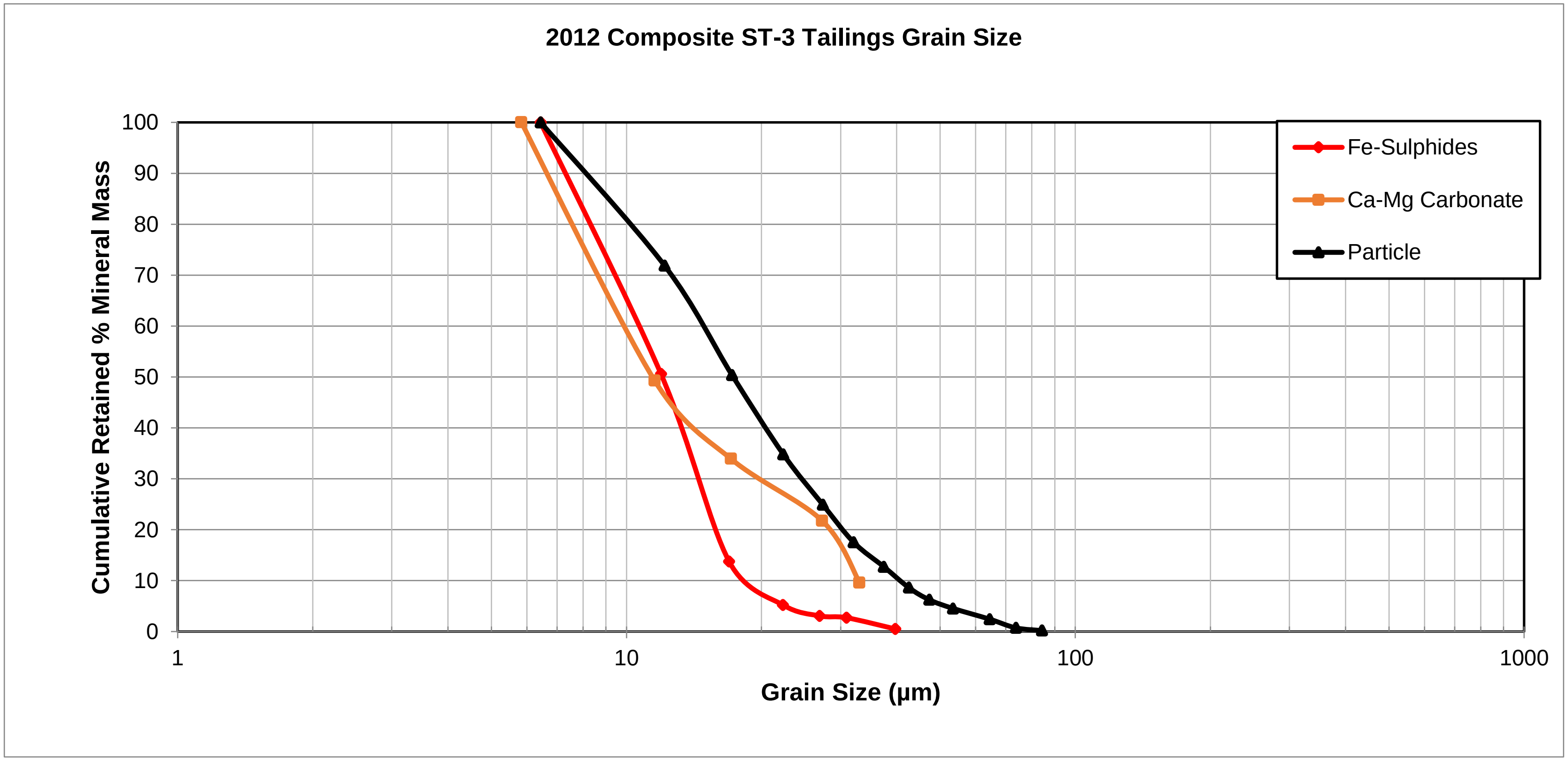
High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Cumulative Retained Grain Size Distribution



Ecometrix
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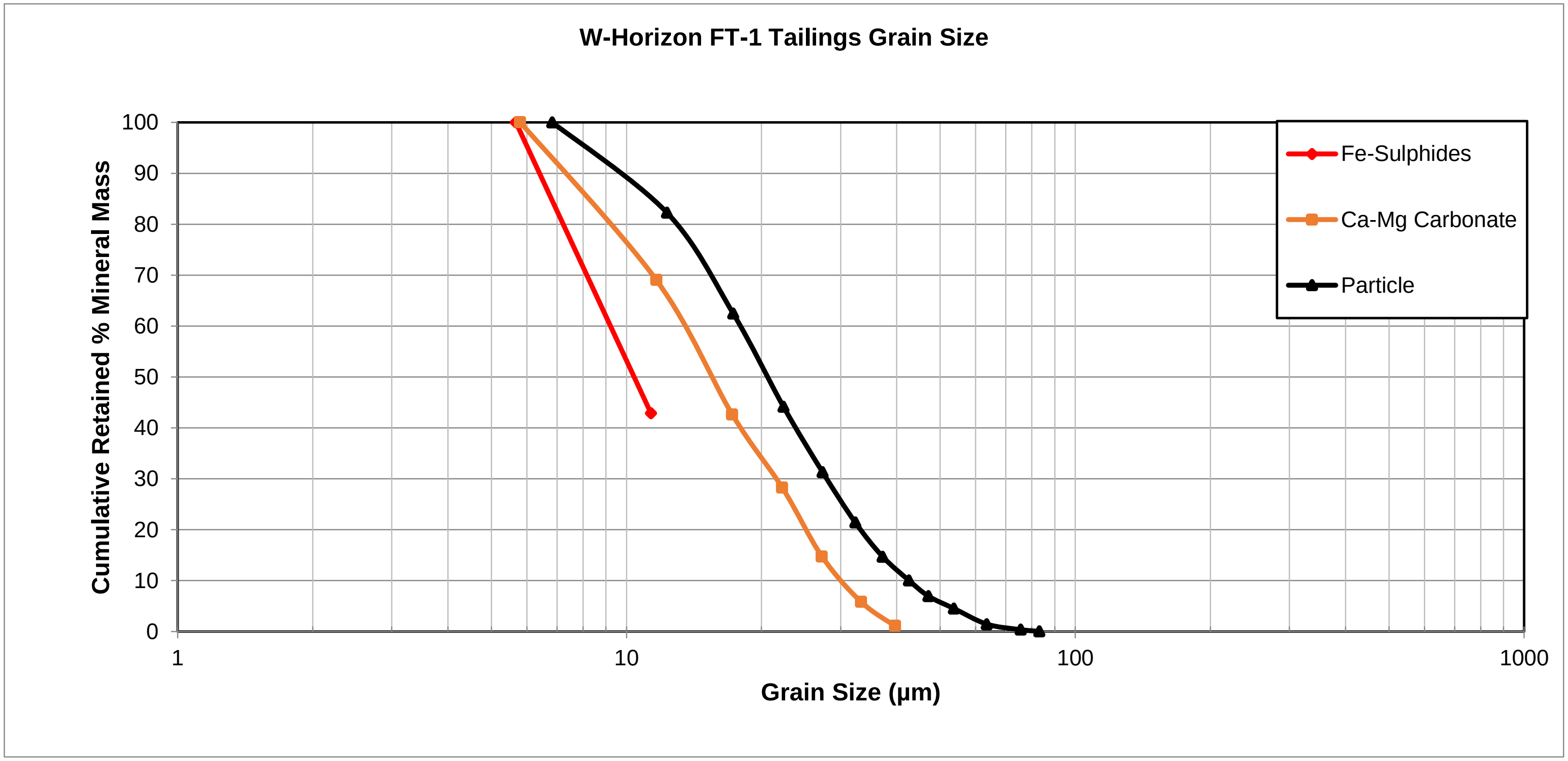
MI5009-JAN21

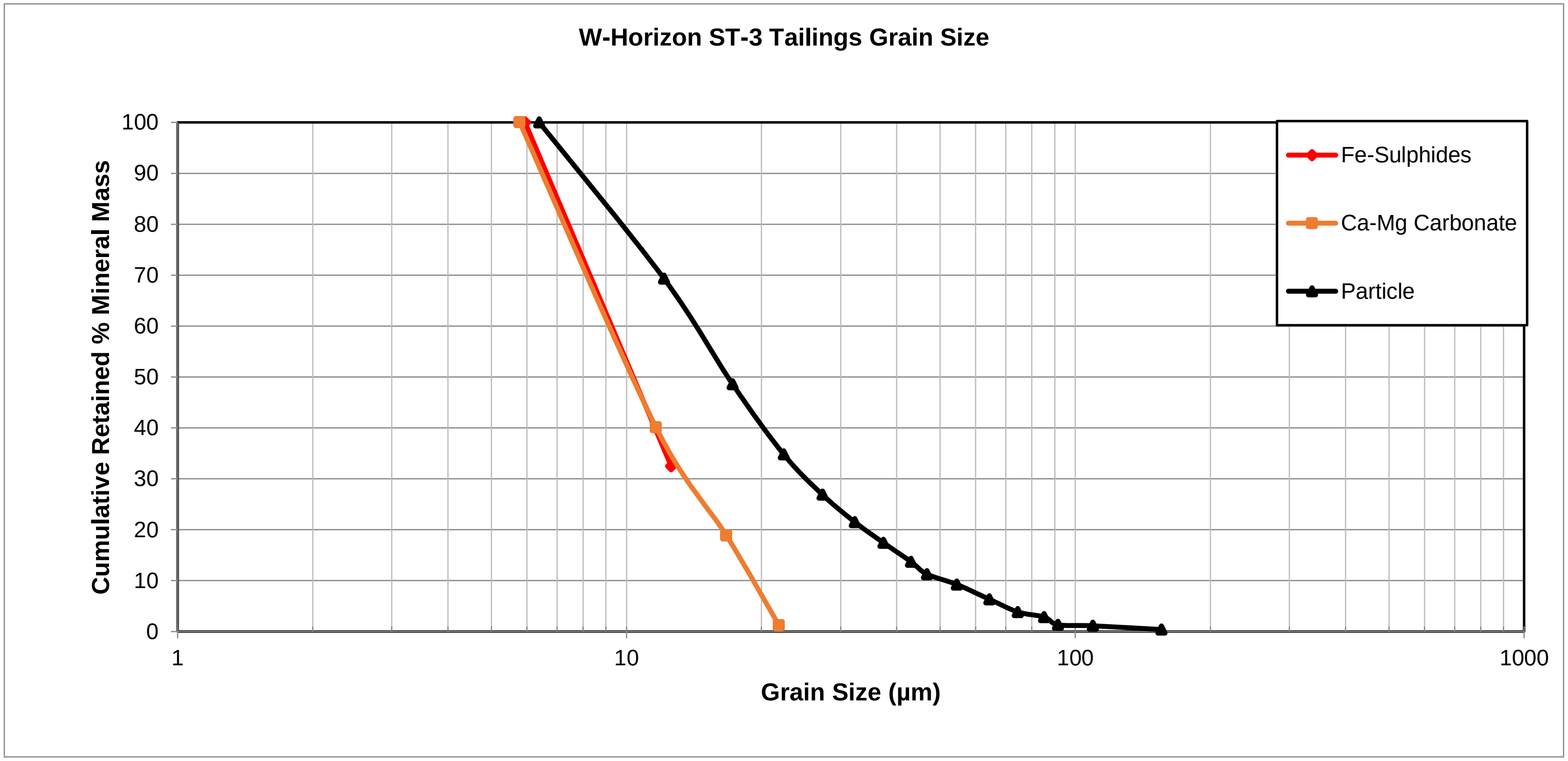
High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Cumulative Retained Grain Size Distribution



High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Cumulative Retained Grain Size Distribution



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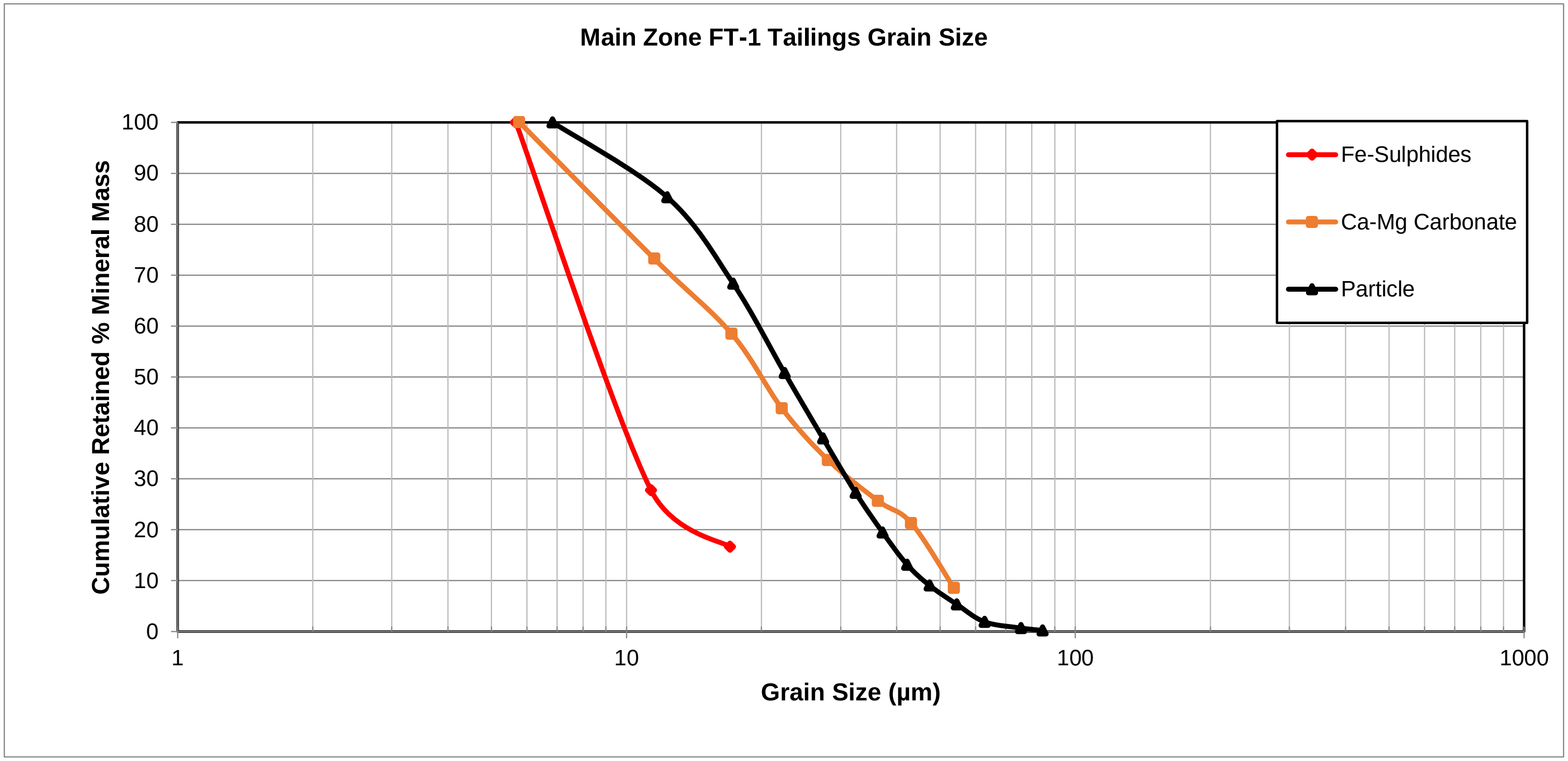
High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

<u>Cumulative Retained Grain Size Distribution</u>



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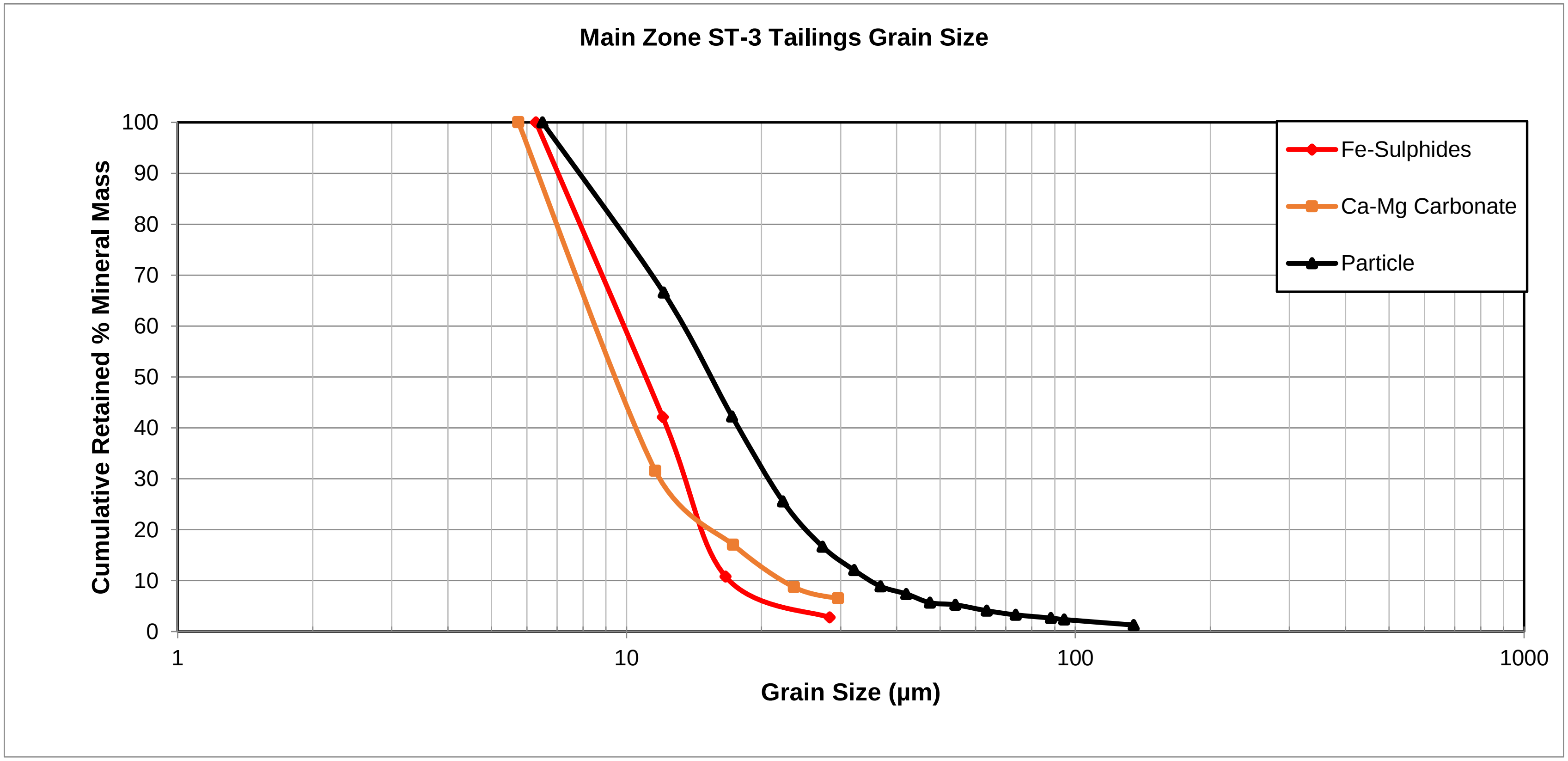
MI5009-JAN21

High Definition Mineralogical Analysis using QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Cumulative Retained Grain Size Distribution



GRI Inc
Custom-Min
MI5008-JUL20

High Definition Mineralogical Analysis using QEMSCAN
(Quantitative Evaluation of Materials by Scanning Electron Microscopy)

Mineralogical Acid-Base Accounting

Parameter/Sample	2012 Composite FT-1 Tailings	2012 Composite ST-3 Tailings	W-Horizon FT-1 Tailings	W-Horizon ST-3 Tailings	Main Zone FT-1 Tailings	Main Zone ST-3 Tailings
NP from Ca-Mg Carbonates (tonnes CaCO3/1000 tonnes)	8.9	10.0	11.8	13.7	5.5	5.4
AP from Fe-Sulphides (tonnes CaCO3/1000 tonnes)	4.0	143.5	0.2	4.0	0.2	13.5
NP/AP	2.2	0.1	70.7	3.4	33.0	0.4
Available NP/AP	2.2	0.1	155.2	4.5	62.4	0.4

Notes:
NP = Neutralization Potential
AP = Acid Generation Potential
"Available NP/AP" takes into account the exposure of Ca-Mg-carbonates and Fe-sulphides

A carbonate/sulphide ratio > 2 indicates probable net neutralizing conditions. Only net acid consuming carbonates (Ca-Mg carbonates) are used for the mineralogical neutralization potential (NP) determination. Only Fe-sulphides are used for the mineralogical acid generation potential (AGP) as they are the main sulphides to contribute to net acidity.

In cases of low carbonate and sulphide abundance (typically <0.5 wt.% of each), values are only semi-quantitative due to low particle statistics for study. More replicate analyses are recommended to properly quantify the NP/AGP potential of these samples.

MEMO

To:	Tabatha LeBlanc, Generation PGM Inc.	From:	Neal Sullivan Ron Nicholson
Ref:	**Revision of the Sulphur Cut-off Value to Determine Type 1 (Non-PAG) and Type 2 (PAG) Mine Rock for the Marathon Palladium Project**	Date:	22 January 2021

Generation PGM Inc. (GenPGM) is advancing their Marathon Palladium Project through a feasibility study (FS) to optimize mine planning and ore processing. It is anticipated that the 2020 pit shell and mine plan will result in the production of approximately 326 Mt of total mine rock.

A mine rock sampling and characterization program was designed and executed in October 2020 by Ecometrix to compliment existing samples and to fill gaps within the 2020 optimized three pit shells. This characterization program included all the required static testing to compare results with the mine rock results from the 2010 pit shell for the rock types expected to report to the mine rock storage area (MRSA). The 2020 samples were selected in a manner consistent with those in previous sampling events, referred to as the Golder (2007), Ecometrix (2010) and Stillwater (2013) samples, to represent mine rock within the pit shell and outside of the ore zone. All samples were also composites of multiple samples from diamond drill holes over approximately 10 m lengths, representing the planned bench heights in the pits.

In SID #5 (EcoMetrix 2012), a 0.3% S value was investigated in detail, specific to the mine rock for the proposed mine site. In the report by EcoMetrix (2012; SID #5), acid base accounting (ABA) methodology was used to measure the neutralization potential (NP) using the Sobek method, the acid potential (AP) as determined by total sulphur content, and by extension, the calculation of NP/AP ratio. EcoMetrix (2012; SID #5) concluded that mine rock with a sulphur content less than 0.3% S will correspond to material with a NP/AP ratio greater than 2 and would be classified as non-potentially acid generating (non-PAG) and can be safely stored in on-land stockpiles without a need for mitigation. Mine rock with a sulphur content greater than 0.3% S accounted for about 6% of the total mine rock inventory and was to be segregated and managed separately to mitigate the potential for acid generation.

A more conservative determination of non-potentially acid generating (non-PAG) mine rock (Type 1) and potentially acid generating (PAG) mine rock (Type 2) can be calculated by considering the NP that is strictly attributed to carbonate minerals (Carb-NP) and use of the Carb-NP/AP ratio in place of the Sobek-NP/AP ratio. In a follow up report by EcoMetrix (2013 original IR 9.4.1, 2013 SIR 3 and AIR 5), it was shown that a more conservative discrimination of Type 1 and Type 2 mine rock could be defined by the calculated Carb-NP/AP ratio, rather than the sulphur cut-off of 0.3% S.

Type 1 mine rock is defined by a Carb-NP/AP ratio greater than 2 and Type 2 mine rock is defined by Carb-NP/AP ratio less than 1, according to the guidance by MEND (Price, 2009). Carb-NP/AP ratio between 1 and 2 is determined as uncertain and is classified conservatively as Type 2 mine rock for the Marathon Palladium project. **Table 1** summarizes the discrimination of non-PAG and PAG material in relation to the Carb-NP/AP ratio.

Table 1: Discrimination of Type 1 and Type 2 mine rock as a function of the Carb-NP/AP ratio

	Carb-NP/AP Ratio
Non-PAG (Type 1)	Greater than 2
Uncertain (Type 2)	Between 1-2
PAG (Type 2)	Less than 1

While the Carb-NP/AP ratio is an effective measure to predict the potential for acid generation, it requires both carbonate, represented by total carbon and sulphide, represented by total sulphur analyses to calculate the Carb-NP/AP ratio. Including total carbon and total sulphur analyses from the recent 2020 static geochemistry program, there are 436 samples with Carb-NP/AP ratios. Considering the strong inverse relationship between the NP/AP ratio and total sulphur observed for both the Sobek NP/AP (**Figure 1**) and the Carb-NP/AP (**Figure 2**), an appropriate sulphur cut-off value may be used operationally to discriminate between Type 1 and Type 2 mine rock.

Table 2 summarizes the frequency of samples isolated in bins, representing the classifications for Type 1 and Type 2 as determined by Carb-NP/AP values. Of the 436 total samples, it is observed that 4.4% are considered PAG, 5.3% uncertain and 90.4% considered Non-PAG as determined by the Carb-NP/AP ratios. Assuming uncertain samples are included as Type 2, this would suggest 9.6% of the mine rock will be classified as Type 2 with 90.4% of the rock classified as Type 1. This is also illustrated as a frequency histogram in **Figure 3**.

Reference: Revision of the Sulphur Cut-off Value to Determine Non-PAG (Type 1) and PAG (Type 2) Mine Rock for the Marathon Palladium Project

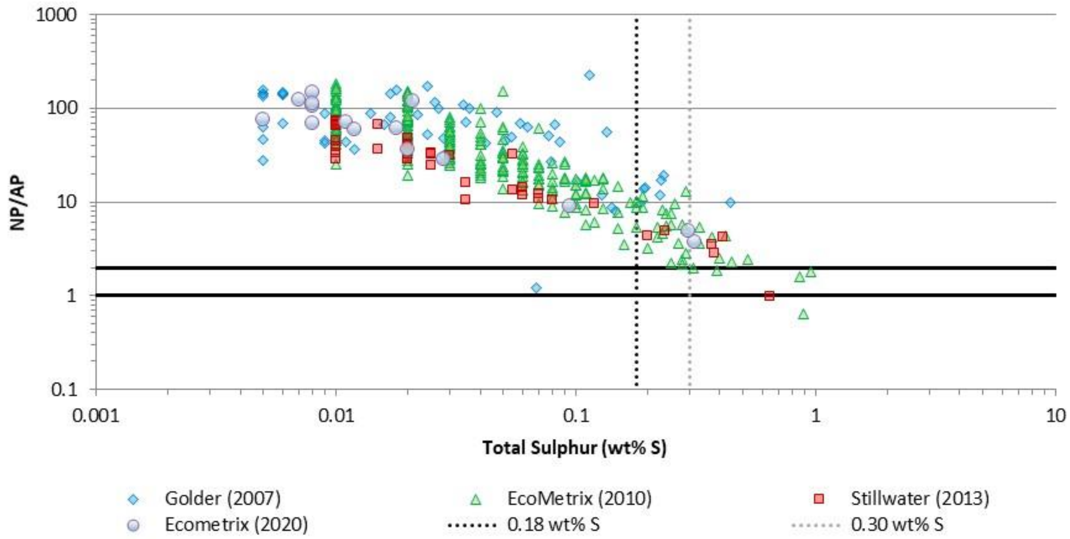


Figure 1: Sobek NP/AP ratio versus Total Sulphur

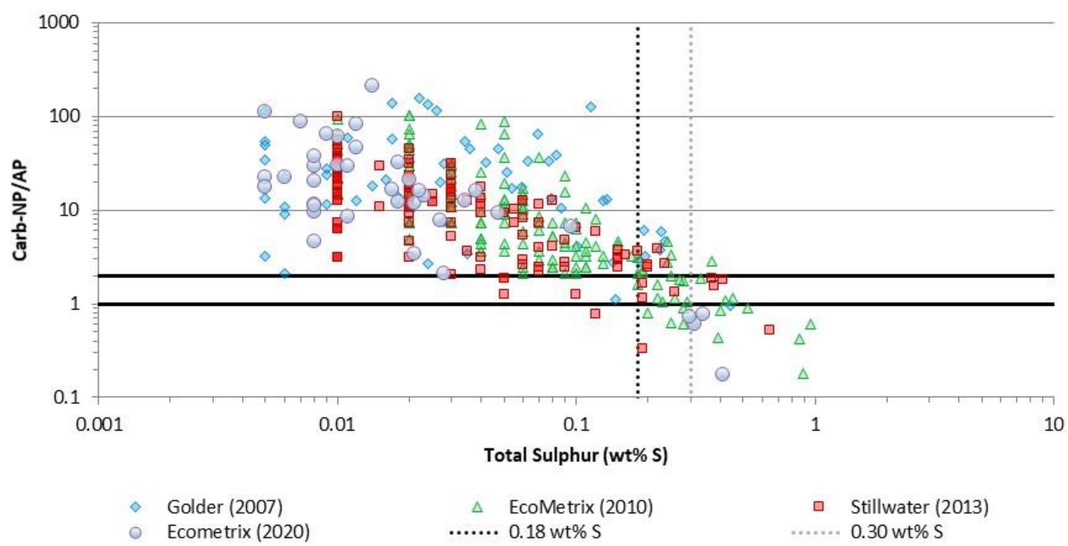


Figure 2: Carb-NP/AP ratio versus Total Sulphur

Table 2: Frequency distribution of Carb-NP/AP values

Bin	*Frequency*	*Frequency (%)*	*Cumulative (%)*
<=1	19	4.4%	4.4%
1+ to 2	23	5.3%	9.6%
>2	394	90.4%	100.0%
Total	436	100.0%	

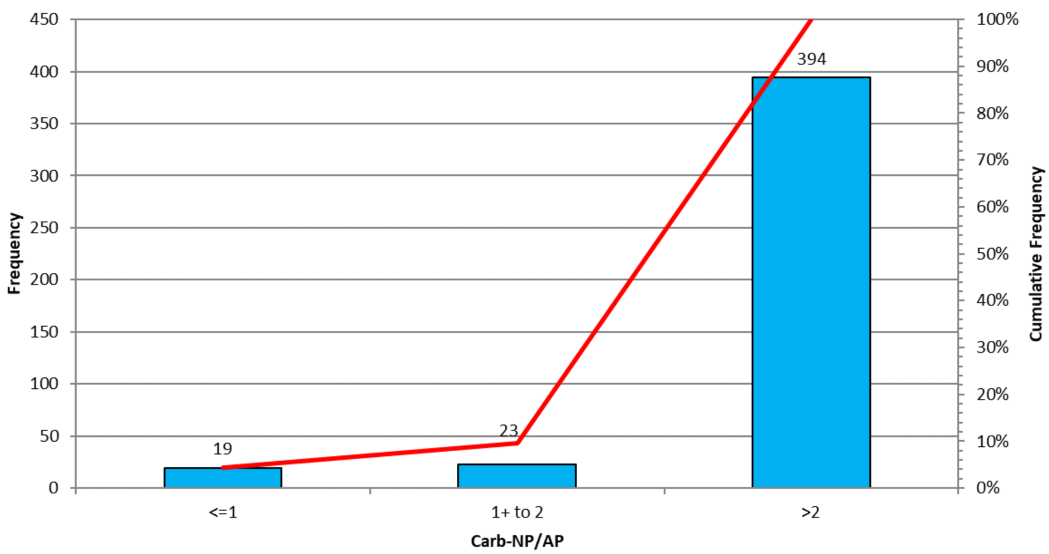


Figure 3: Frequency histogram for Carb-NP/AP values

A similar frequency distribution assessment can be applied by using total sulphur values. Note that the sample population for total sulphur values is slightly larger than the Carb-NP/AP data set, totaling 493 samples, as not all samples were analyzed for total carbon. This frequency distribution is summarized in **Table 3**. This is also illustrated as a frequency histogram in **Figure 4**. Between 0.1% S and 0.3% S, the frequency bins are broken down in

Reference: Revision of the Sulphur Cut-off Value to Determine Non-PAG (Type 1) and PAG (Type 2) Mine Rock for the Marathon Palladium Project

0.02 %S intervals. The frequency of samples above 0.3 %S is 4.1% of the total which is below the 9.6% frequency for Type 2 mine rock as determined by the Carb-NP/AP ratios.

Table 3: Frequency distribution of total sulphur values

Bin	*Frequency*	*Frequency (%)*	*Cumulative (%)*
<=0.1	402	81.5%	81.5%
0.10+ to 0.12	14	2.8%	84.4%
0.12+ to 0.14	6	1.2%	85.6%
0.14+ to 0.16	11	2.2%	87.8%
0.16+ to 0.18	5	1.0%	88.8%
0.18+ to 0.20	11	2.2%	91.1%
0.20+ to 0.22	3	0.6%	91.7%
0.22+ to 0.24	8	1.6%	93.3%
0.24+ to 0.26	5	1.0%	94.3%
0.26+ to 0.28	4	0.8%	95.1%
0.28+ to 0.30	4	0.8%	95.9%
>0.30	20	4.1%	100.0%
Total	493	100%	

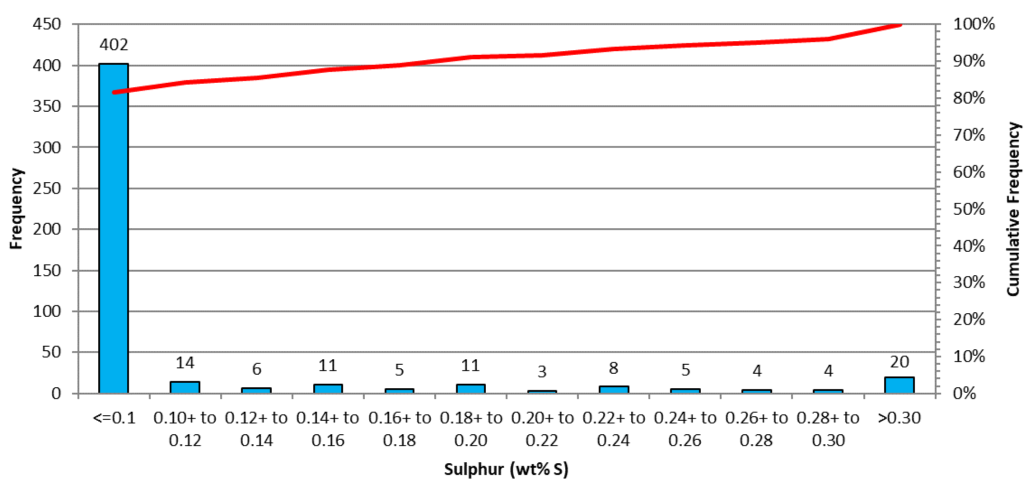


Figure 4: Frequency histogram for total sulphur values

As a more conservative approach to determining a sulphur cut-off value, we suggest using 0.18% S, resulting in 11.2% of the mine rock that will be classified and managed as Type 2. Using a sulphur cut-off of 0.18% S, 5 samples remain in the uncertain category (2.2%) and 1 outlier remains in the PAG category (0.4%). This is illustrated in **Figure 2** as the sulphur value of 0.18% S is shown by the vertical dotted line where 97.4% of the data points located to the left of the sulphur cut-off value of 0.18% S have a Carb-NP/AP ratio greater than 2. In addition, a sulphur cut-off value of 0.18% S results in a greater percentage of samples than the 9.6% defined by the Carb-NP/AP values of less than 2 (**Table 2**), providing additional support that this cut-off value is a conservative and appropriate value to identify Type 1 and Type 2 mine rock.

While we retain that the primary criterion for the identification of Type 2 mine rock will be based on the Carb-NP/AP ratio, we suggest that the revised sulphur cut-off value of 0.18% S is to be used as an additional criterion to classify Type 2 rock. In a follow up report by EcoMetrix (2013 AIR 5; 2013, original IR 9.6), it was agreed that the sorting of Type 1 and Type 2 mine rock during mining operations would be determined by on-site analysis of sulphur and carbon from the closely spaced blast-holes in the benches. During open pit mining, the rock will be blasted to produce minable units in step-like terraces in the pit referred to as “benches”.

A block will be blasted to the depth of a design bench. Sampling all of the blast holes will therefore provide a good representation of the entire bench that will be blasted at that location, and by extension, an accurate sorting of Type 1 and 2 mine rock can be conducted by defining both Carb-NP/AP ratio of greater than 2 and a sulphur cut-off of 0.18% S from on-site analysis of sulphur and carbon. It is expected that rock with sulphur values less than 0.18 % S will have Carb-NP/AP values greater than 2. Initially, both sulphur and carbon will be analyzed. As the data are reviewed and the relationship between sulphur content and Carb-NP/AP is confirmed, the bulk of the analyses can be limited to sulphur contents with some confirmatory carbon analyses for quality control.

Closure

We trust this memorandum serves your needs at this time. Should you have any questions please contact the authors at your convenience.

References

EcoMetrix. 2012. Supporting Information Document No.5 – Geochemical Assessment of Mine Components at the Marathon PGM-Cu Project.

EcoMetrix. 2013. AIR 5 in response to: *IR 9.6*.

EcoMetrix. 2013. IR 9.4.1 in response to: *EcoMetrix. 2012. Supporting Information Document No.5 – Geochemical Assessment of Mine Components at the Marathon PGM-Cu Project.*

EcoMetrix. 2013. IR 9.6 in response to: *EcoMetrix. 2012. Supporting Information Document No.5 – Geochemical Assessment of Mine Components at the Marathon PGM-Cu Project.*

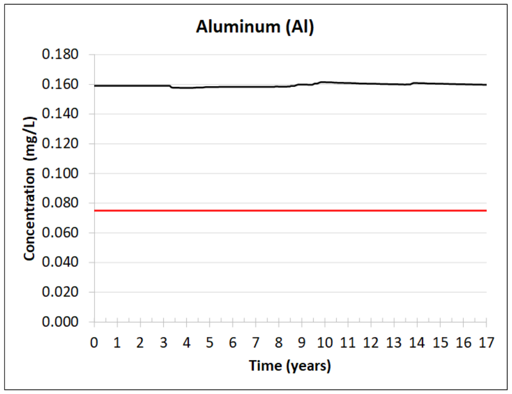
EcoMetrix. 2013. SIR 3 in response to: *IR 9.4.1*.

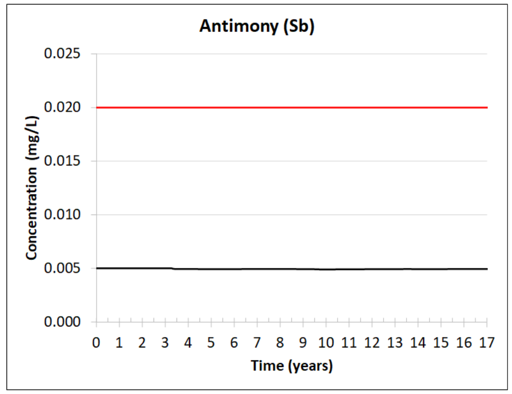
Price, W.A. 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. Canadian MEND Report 1.20.1, Natural Resources Canada, December, 2009.

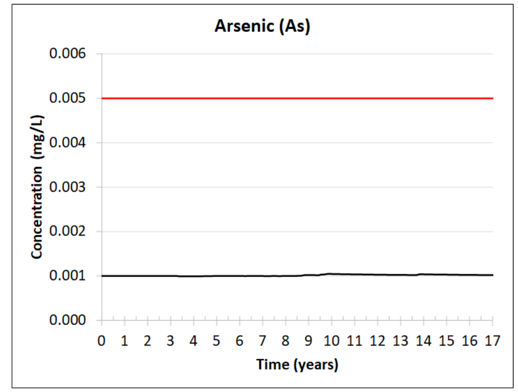
Appendix B Water Quality in Hare Lake during Operations – Supporting Information

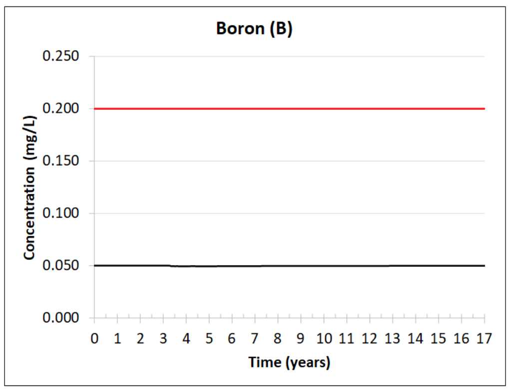
The following graphs show temporal trends in Hare Lake over the period of operations. The time period shown includes predischarge conditions with operations ceasing in year "17" as noted.

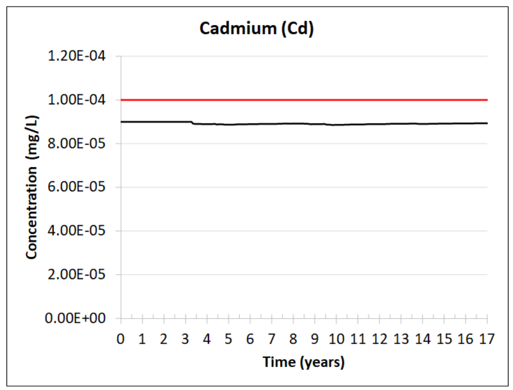
Modelled Water Quality in Hare Lake











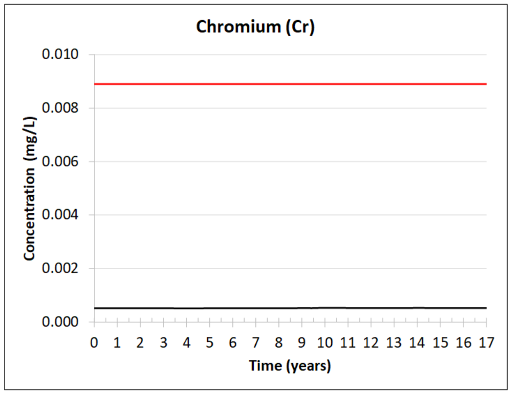
Modelled Concentration Plots 1/5

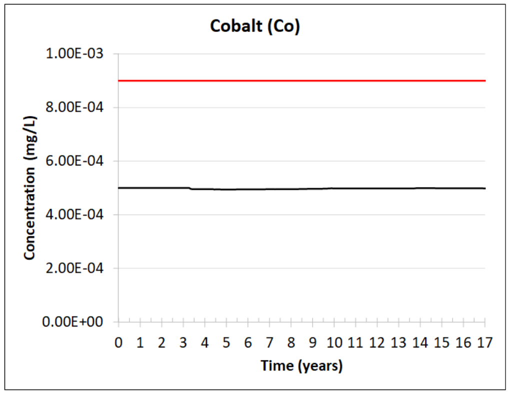
End of Operations: Year 17 (2037)

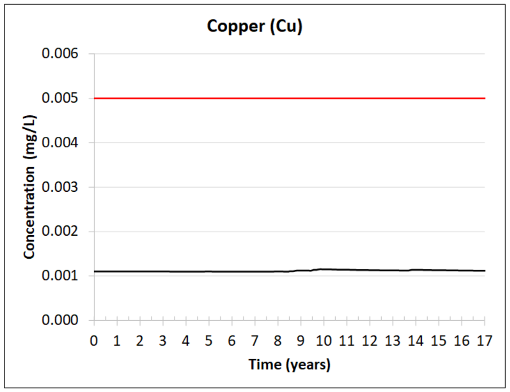
Predicted Concentration

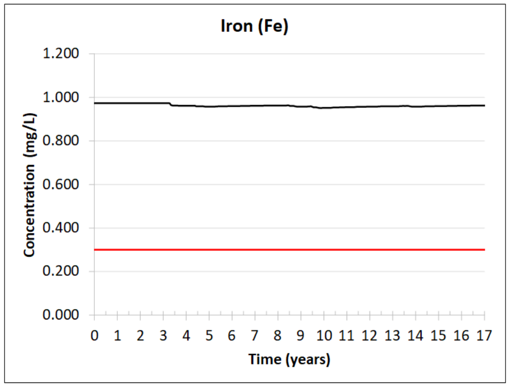
Benchmark Concentration

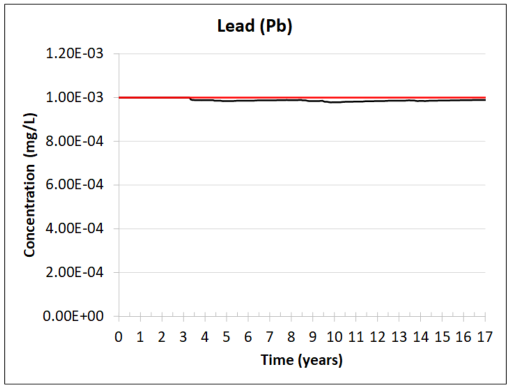
Modelled Water Quality in Hare Lake











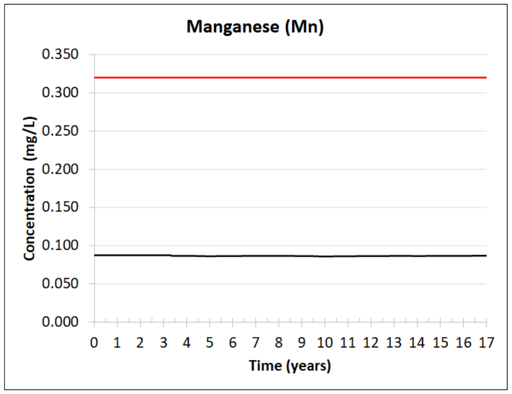
Modelled Concentration Plots 2/5

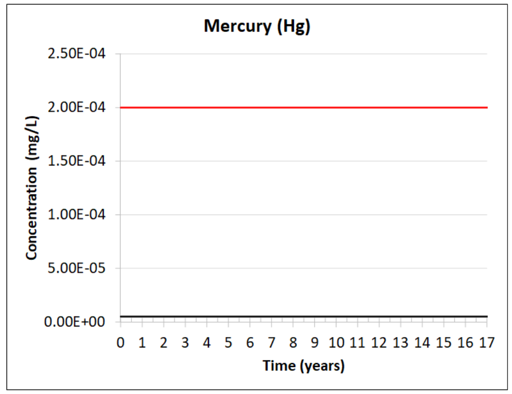
End of Operations: Year 17 (2037)

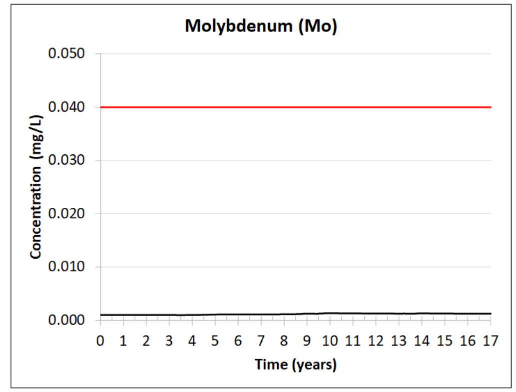
Predicted Concentration

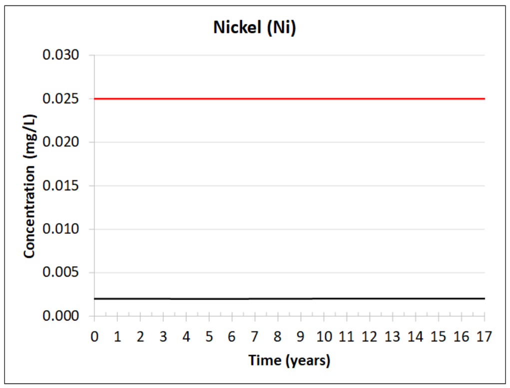
Benchmark Concentration

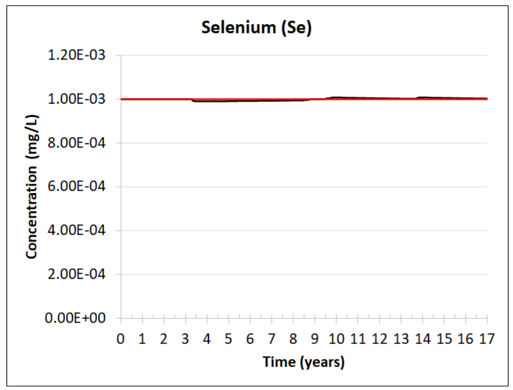
Modelled Water Quality in Hare Lake











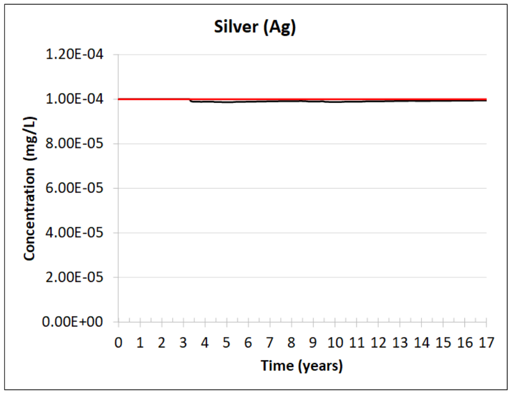
Modelled Concentration Plots 3/5

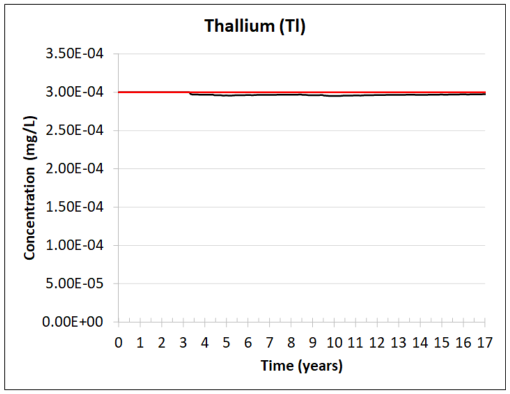
End of Operations: Year 17 (2037)

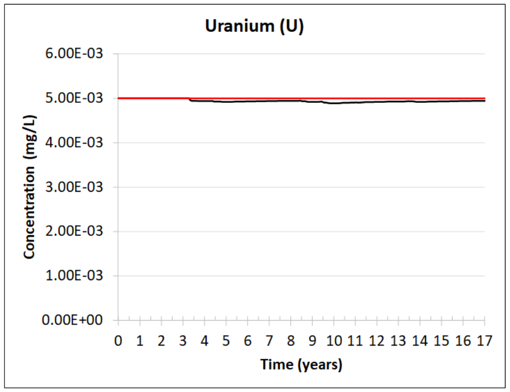
Predicted Concentration

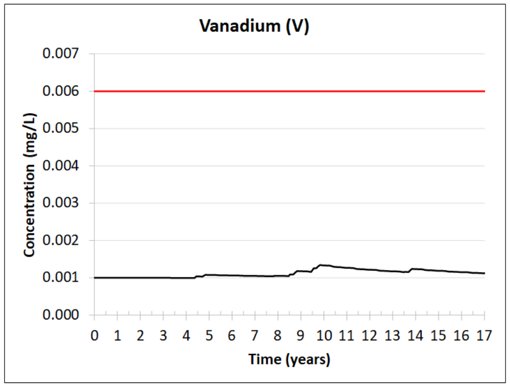
Benchmark Concentration

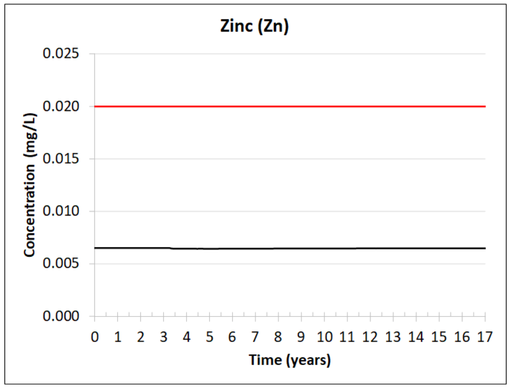
Modelled Water Quality in Hare Lake











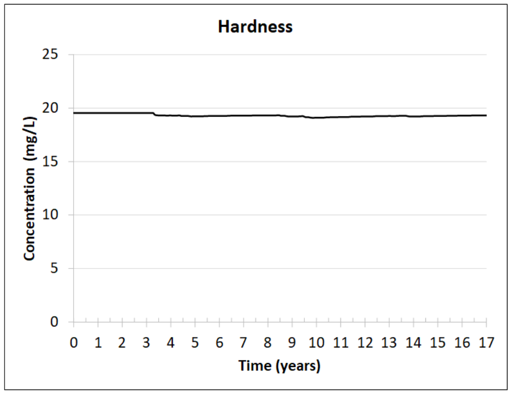
Modelled Concentration Plots 4/5

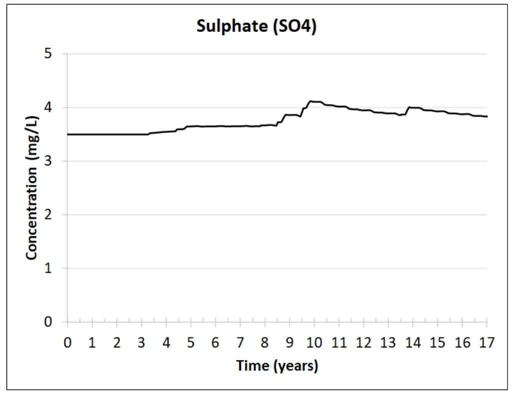
End of Operations: Year 17 (2037)

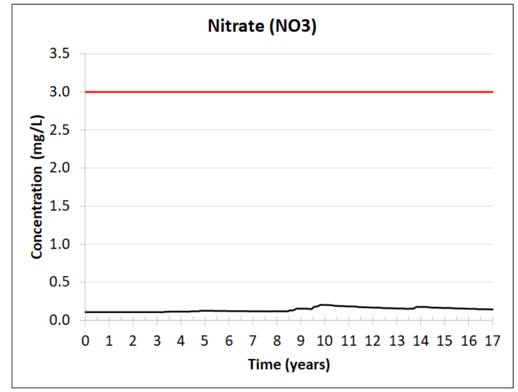
Predicted Concentration

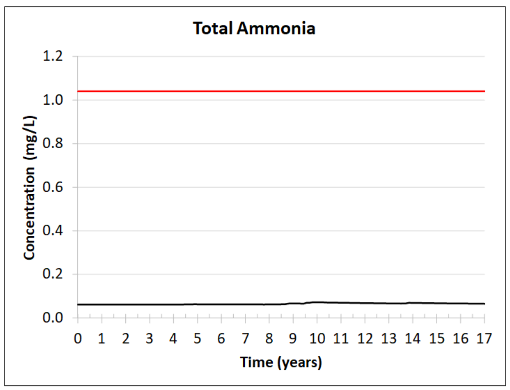
Benchmark Concentration

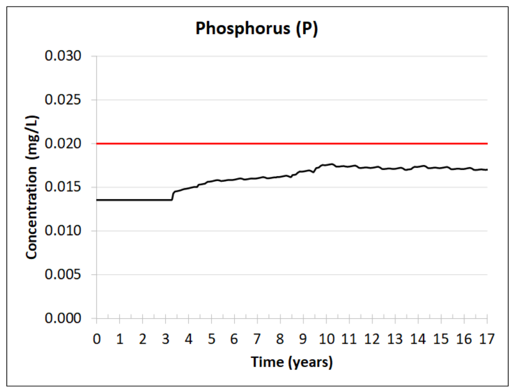
Modelled Water Quality in Hare Lake











Modelled Concentration Plots 5/5

End of Operations: Year 17 (2037)

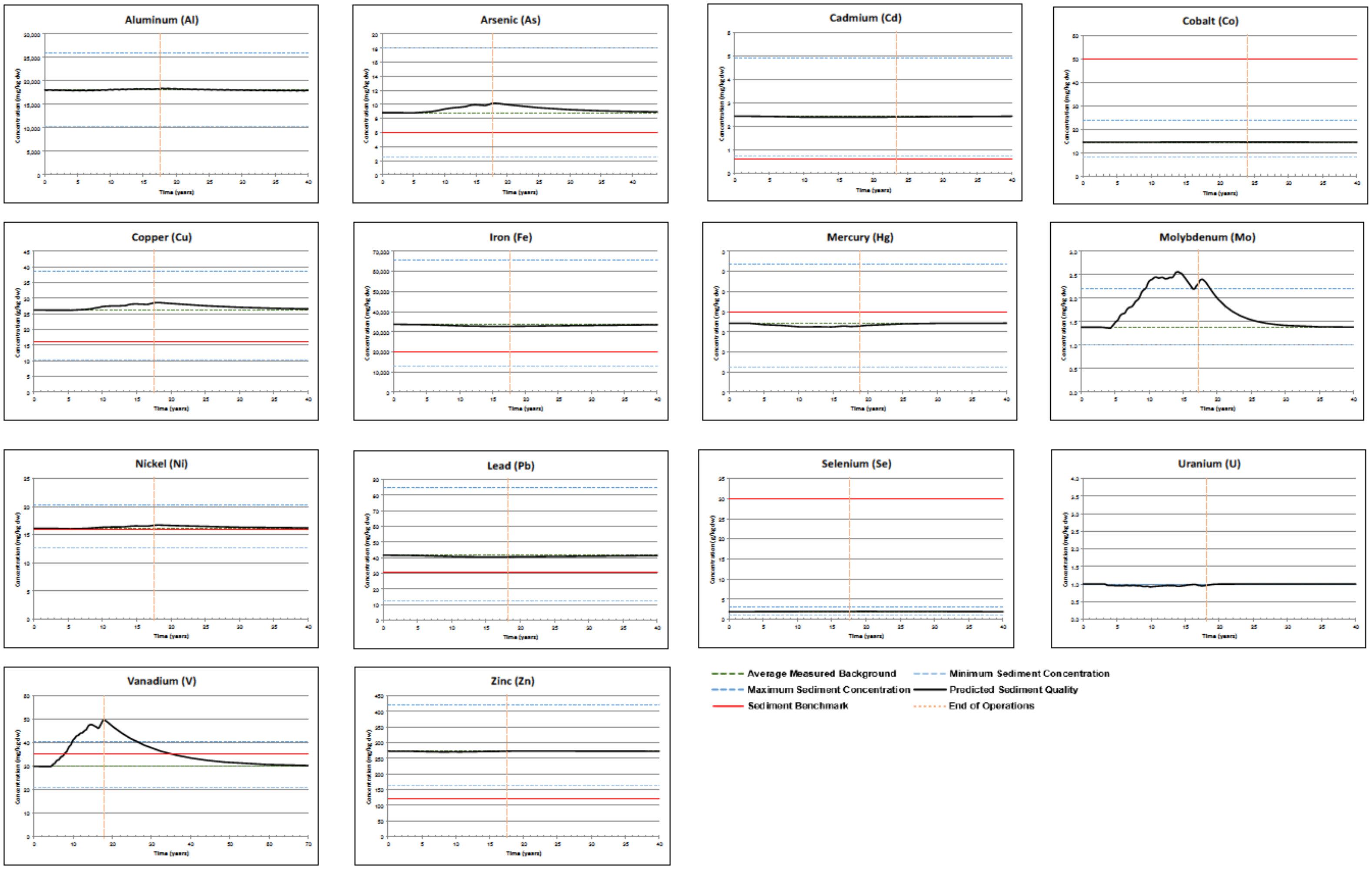
Predicted Concentration

Benchmark Concentration

Appendix C Sediment Quality in Hare Lake during Operations – Supporting Information

The following graphs show temporal trends in Hare Lake sediment quality over time highlighting changes during operations. The time period shown includes predischarge conditions, the operations phase and post-discharge conditions.

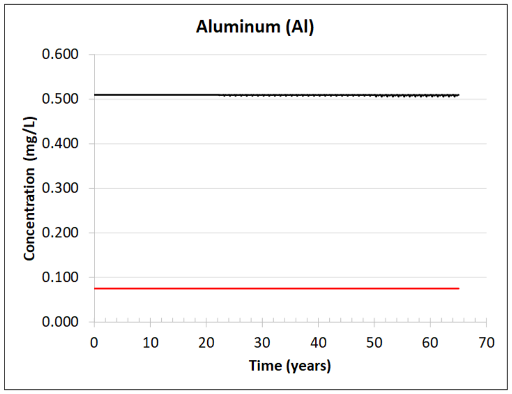
Modelled Sediment Concentration Hare Lake During Mine Operations

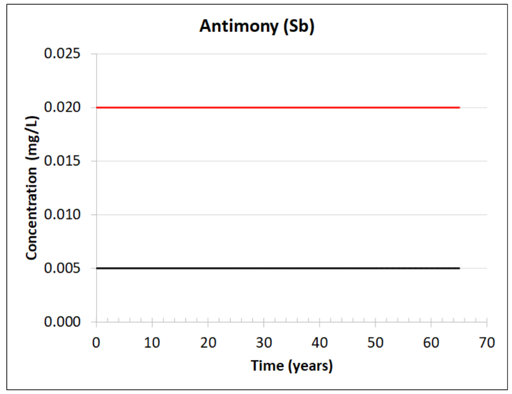


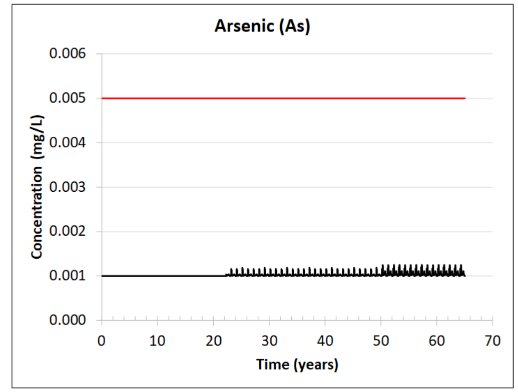
Appendix D Water Quality in the Pic River over the life of mine

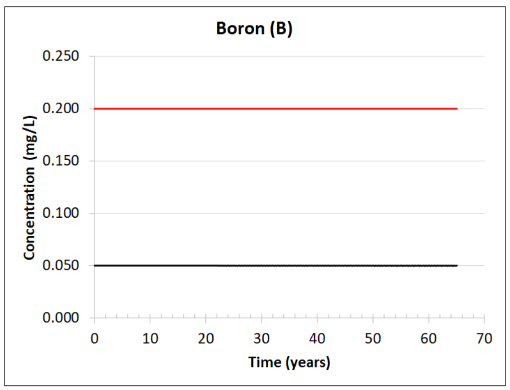
The following graphs show temporal trends (predictions) in Pic River water quality over time, including all mien phases and extending well into closure capturing the period when pre-mining drainage patterns have been restored and the open pit complex has filled and water is released to the environment.

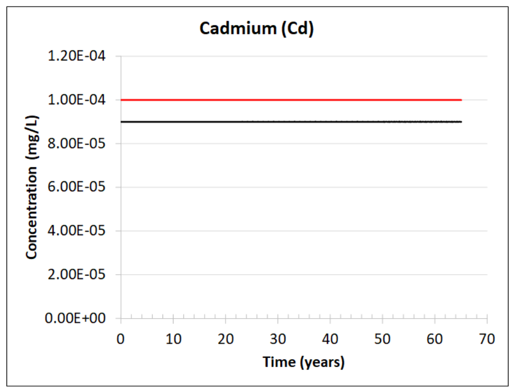
Modelled Water Quality in Pic River











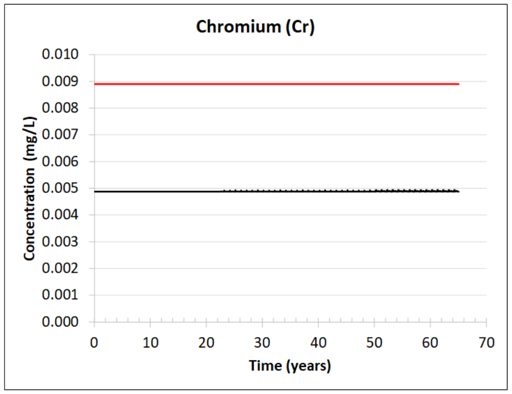
Modelled Concentration Plots 1/5

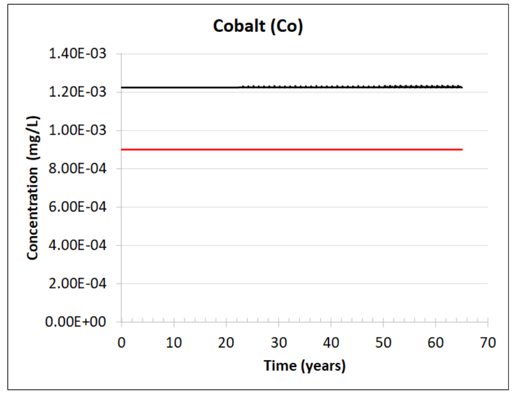
End of Operations: Year 17 (2037)

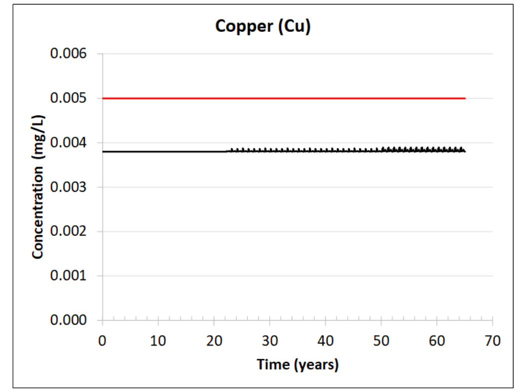
Predicted Concentration

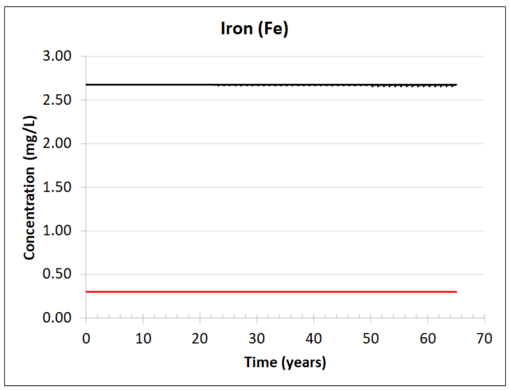
Benchmark Concentration

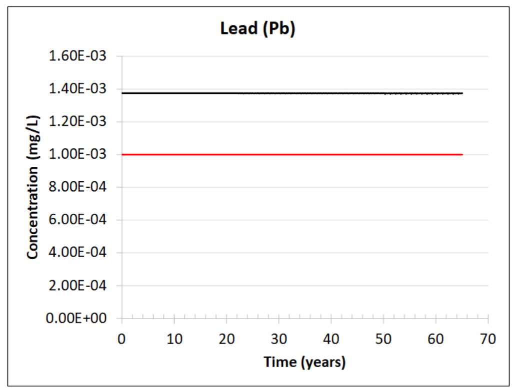
Modelled Water Quality in Pic River











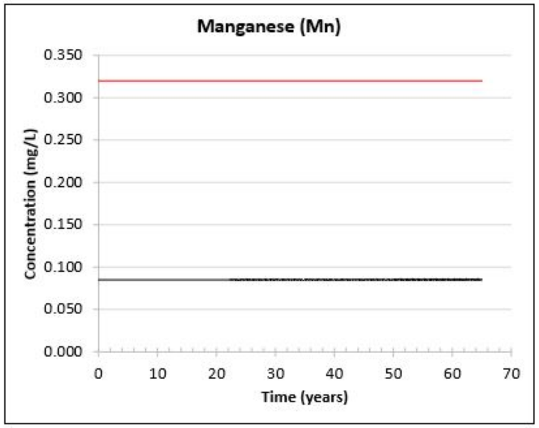
Modelled Concentration Plots 2/5

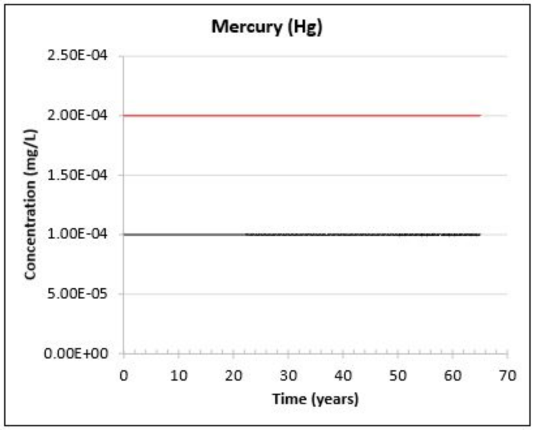
End of Operations: Year 17 (2037)

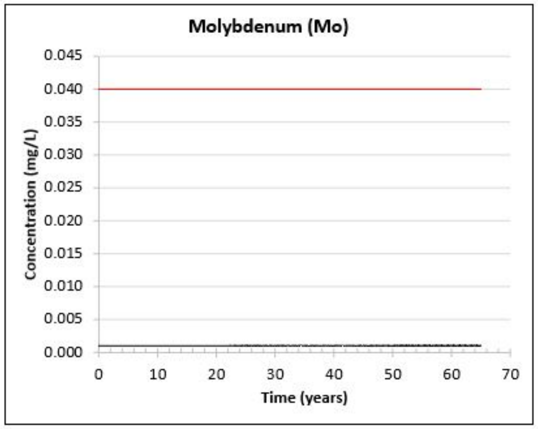
Predicted Concentration

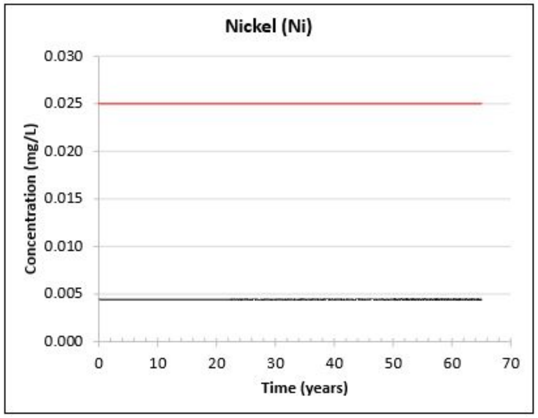
Benchmark Concentration

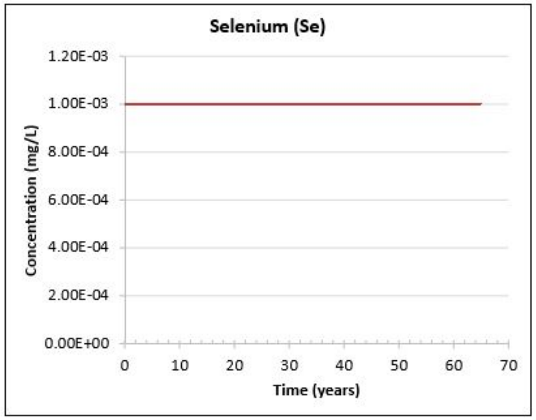
Modelled Water Quality in Pic River











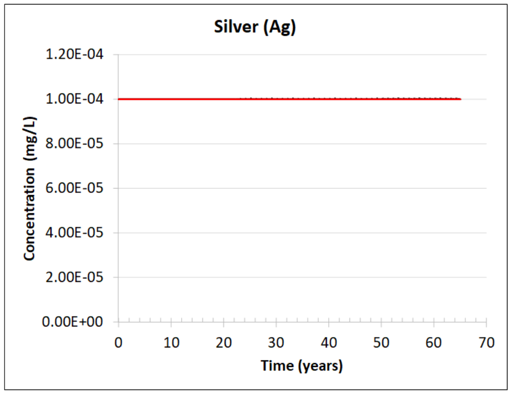
Modelled Concentration Plots 3/5

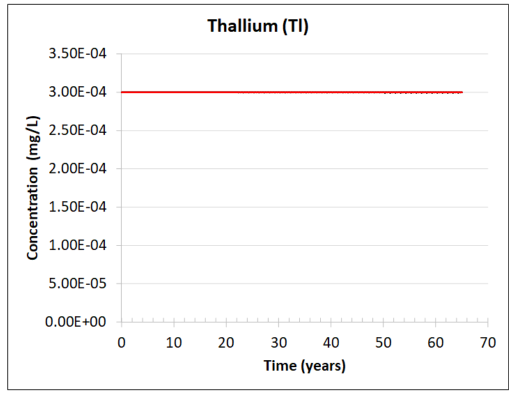
End of Operations: Year 17 (2037)

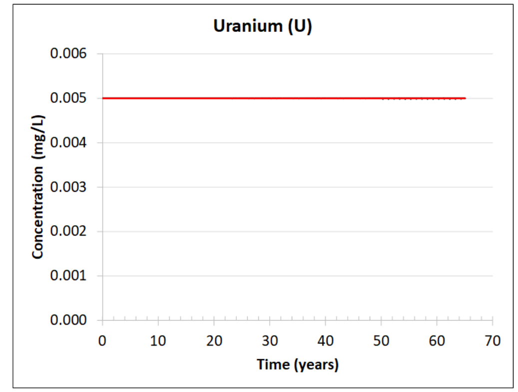
Predicted Concentration

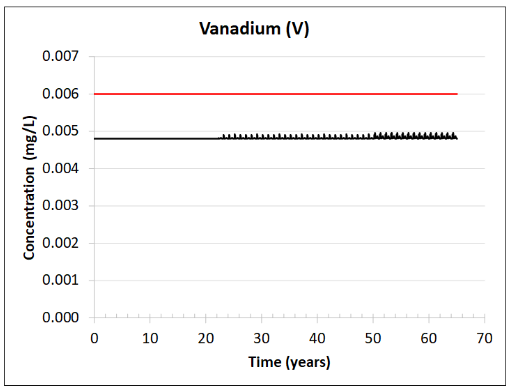
Benchmark Concentration

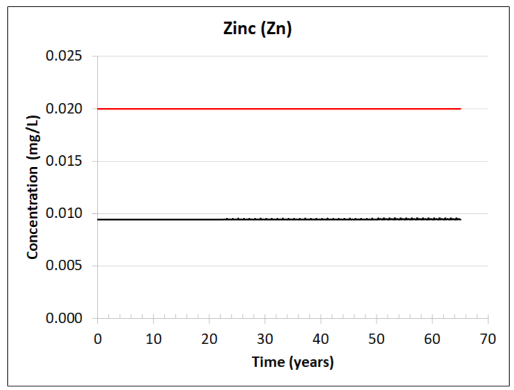
Modelled Water Quality in Pic River











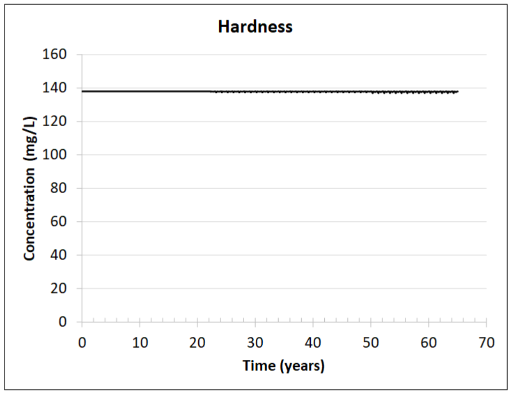
Modelled Concentration Plots 4/5

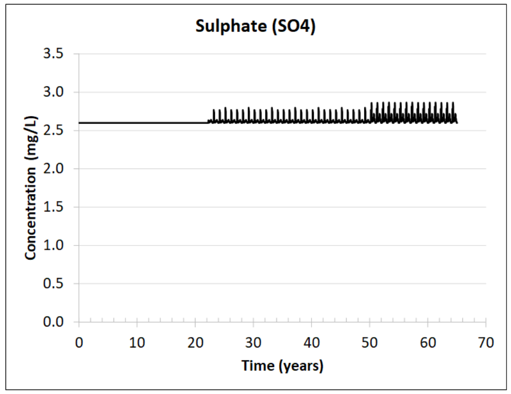
End of Operations: Year 17 (2037)

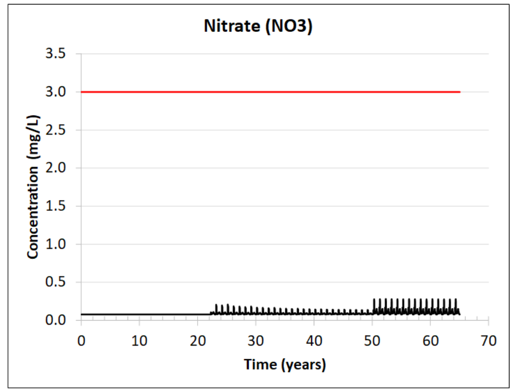
Predicted Concentration

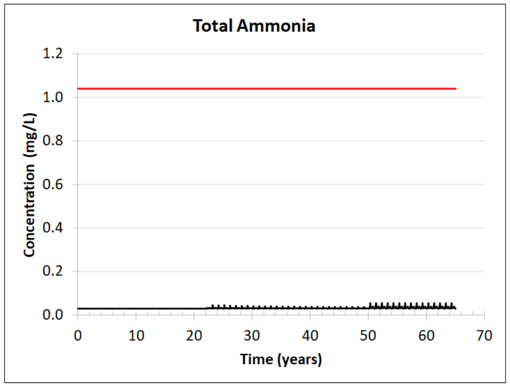
Benchmark Concentration

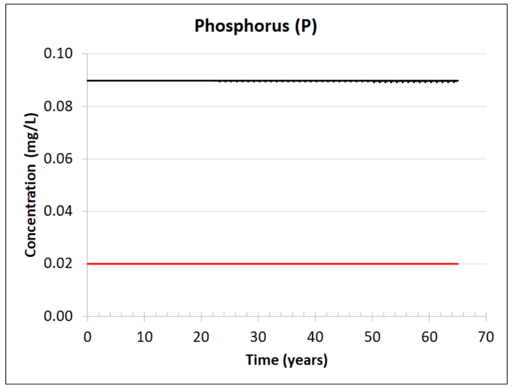
Modelled Water Quality in Pic River











Modelled Concentration Plots 5/5

End of Operations: Year 17 (2037)

Predicted Concentration

Benchmark Concentration

Appendix E Sensitivity Model Scenarios

In accordance with best practice, sensitivity model scenarios were also considered with the water quality model in order to understand the variations in source data and to provide a more conservative estimate of water quality that can be considered both in terms of developing operational management practices and in consideration of monitoring and potential contingency plan frameworks.

One operational sensitivity case was considered and one upper bound loadings case for the closure phase was considered.

Operational Sensitivity Case

The operational sensitivity case evaluated discharge of excess water from the water management pond at a constant rate over the proposed eight-month discharge period at 350 m^3/hour that is on the order of the highest hourly discharge rates observed in the base case scenario. For reference, the basis of the base case scenario was the site balance – that is, treated effluent is discharged to Hare Lake when there are water quantities in the water management system that exceed the needs of the process plant, and that cannot be safely stored. This high, constant rate discharge was run to identify whether there is any seasonal sensitivity in water quality that needs to be considered within the proposed effluent regime.

Predictions of water quality in Hare Lake under the "high" constant effluent discharge scenario are shown in Table E-1. The concentrations shown represent the average and maximum predicted concentrations in Hare Lake over the operations phase of the Project. The predictions reflect whole-lake constituent concentrations following mixing, the physical process whereby the effluent mixes with the lake water. As can be seen, it is predicted that all water quality parameters will be either below their respective water quality benchmarks, or below their respective background concentrations. Overall, this analysis indicates that water quality in Hare Lake can be maintained under a "high" constant effluent discharge case. Accordingly, while it may be desirable for water management purposes to release and/or store water at certain times of the year, the discharge of treated effluent likely does not need to necessarily follow seasonal patterns in flow within the Hare Lake system.

Table E-1: Maximum predicted constituent concentrations in Hare Lake during the operations phase – operational sensitivity case

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Ops)	Max. Conc. Prediction (Ops)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.17	0.17	0.17
Antimony	0.02	-	0.005	0.005	0.005
Arsenic	0.005	0.005	0.001	0.001	0.001
Boron	0.2	1.5	0.05	0.05	0.05
Cadmium	0.0001	0.00005	0.00009	0.00009	0.00009
Chromium	0.0089	0.0089	0.0005	0.0005	0.0005
Cobalt	0.0009	-	0.0005	0.0005	0.0005
Copper	0.005	0.002	0.001	0.001	0.001

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Ops)	Max. Conc. Prediction (Ops)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)	(mg/L)
Iron	0.3	0.3	0.9	0.9	0.9
Lead	0.001	0.001	0.001	0.001	0.001
Manganese	-	0.32	0.08	0.09	0.16
Mercury (filtered)	0.0002	0.000026	0.000005	0.000005	0.000005
Molybdenum	0.04	0.073	0.001	0.002	0.002
Nickel	0.025	0.025	0.002	0.002	0.002
Selenium	0.1	0.001	0.001	0.001	0.001
Silver	0.0001	0.00025	0.0001	0.0001	0.0001
Thallium	0.0003	0.0008	0.0003	0.0003	0.0003
Uranium	0.005	0.005	0.005	0.005	0.005
Vanadium	0.006	-	0.001	0.002	0.002
Zinc	0.02	0.008	0.006	0.006	0.007
Hardness	-	-	20	20	20
Sulphate	-	-	3.5	4.4	5.1
Nitrate (N)	-	3.0	0.11	0.26	0.41
Total Ammonia (N)	-	1.04	0.06	0.08	0.09
Phosphorous	0.02	0.01 to 0.02	0.01	0.02	0.02

<u>Upper Bound Loadings Case for Closure Phase</u>

The closure phase sensitivity case evaluated the influence of upper bound source loadings from the PSMF on water quality over the long term in Hare Lake and in subwatershed 106. The upper bound source loadings considered oxidation reactions in the uppermost 1m of the process solids that would affect seepage quality (i.e., increased constituent concentrations) reporting into these receivers. The following are noted with respect to the model scenarios: the model has been developed based on mass loadings and does not consider chemical and physical attenuation processes; and, the source terms associated with long term seepage for the process solids are derived from laboratory test results that are heavily influenced (overestimated) by results for a variety of constituents (Cd, Co, Cu, Fe, Ni, Pb, V, Zn, Sb, B, P, Ag, Tl). In addition, no attempt has been made to sub-divide the seepage related loadings between Hare Lake and subwatershed 106 based on perceived drainage area boundaries; rather, 100% of the loadings have been apportioned to each area.

Predictions of water quality in Hare Lake under the upper bound source loadings scenario are shown in Table E-2. The concentrations shown represent the average predicted long term concentrations in Hare Lake post closure. The predictions reflect whole-lake constituent concentrations following mixing, the physical process whereby the effluent mixes with the lake water. The predictions indicate that all water quality parameters will be either below their respective water quality benchmarks, or in the case selected constituents below their respective background concentrations. Overall, this analysis indicates that water quality Hare Lake is not affected by the upper bound source loadings.

Table E-2: Average long-term predicted constituent concentrations in Hare Lake during the closure phase – upper bound loadings case for closure phase

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Ops)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.17	0.18
Antimony	0.02	-	0.005	0.005
Arsenic	0.005	0.005	0.001	0.001
Boron	0.2	1.5	0.05	0.05
Cadmium	0.0001	0.00005	0.00009	0.00009
Chromium	0.0089	0.0089	0.0005	0.0005
Cobalt	0.0009	-	0.0005	0.0005
Copper	0.005	0.002	0.001	0.001
Iron	0.3	0.3	0.9	0.9
Lead	0.001	0.001	0.001	0.0001
Manganese	-	0.32	0.08	0.16
Mercury (filtered)	0.0002	0.000026	0.000005	0.000005
Molybdenum	0.04	0.073	0.001	0.001
Nickel	0.025	0.025	0.002	0.002
Selenium	0.1	0.001	0.001	0.001
Silver	0.0001	0.00025	0.0001	0.0001
Thallium	0.0003	0.0008	0.0003	0.0003
Uranium	0.005	0.005	0.005	0.005
Vanadium	0.006	-	0.001	0.001
Zinc	0.02	0.008	0.006	0.007
Hardness	-	-	20	20
Sulphate	-	-	3.5	5.3
Nitrate (N)	-	3.0	0.11	0.11
Total Ammonia (N)	-	1.04	0.06	0.06
Phosphorous	0.02	0.01 to 0.02	0.01	0.02

Predictions of water quality in subwatershed 106 under the upper bound source loadings scenario are shown in Table E-3. The concentrations shown represent the average predicted long term concentrations in subwatershed 106 post closure. The upper bound case predictions are higher than those for the expected case, as expected; however, the concentrations of many constituents remain below their respective benchmark values. Concentrations of cobalt, copper, selenium zinc and phosphorous are marginally greater than their respective water quality benchmarks in this conservative scenario. This does not indicate that water quality in subwatershed 106 will exceed relevant benchmarks in the long-term following closure; however, the results do indicate that it would be prudent to monitor the evolution of the chemistry of the PSMF proactively during operations to understand any potential long-term implications.

Table E-3: Average long-term predicted constituent concentrations in subwatershed 106 during the closure phase – upper bound loadings case for closure phase

Constituent	Benchmarks		Background WQ	Avg. Conc. Prediction (Ops)
	PWQO (mg/L)	CCME (mg/L)	(mg/L)	(mg/L)
Aluminum (filtered)	0.075	0.1	0.17	0.17
Antimony	0.02	-	0.005	0.005
Arsenic	0.005	0.005	0.001	0.002
Boron	0.2	1.5	0.05	0.12
Cadmium	0.0001	0.00005	0.00009	0.0001
Chromium	0.0089	0.0089	0.0005	0.001
Cobalt	0.0009	-	0.0005	0.0013
Copper	0.005	0.002	0.001	0.006
Iron	0.3	0.3	0.9	0.9
Lead	0.001	0.001	0.001	0.001
Manganese	-	0.32	0.08	0.13
Mercury (filtered)	0.0002	0.000026	0.000005	0.000005
Molybdenum	0.04	0.073	0.001	0.003
Nickel	0.025	0.025	0.002	0.006
Selenium	0.1	0.001	0.001	0.002
Silver	0.0001	0.00025	0.0001	0.0001
Thallium	0.0003	0.0008	0.0003	0.0003
Uranium	0.005	0.005	0.005	0.005
Vanadium	0.006	-	0.001	0.001
Zinc	0.02	0.008	0.006	0.033
Hardness	-	-	20	20
Sulphate	-	-	3.5	52
Nitrate (N)	-	3.0	0.11	0.13
Total Ammonia (N)	-	1.04	0.06	0.05
Phosphorous	0.03	0.01 to 0.02	0.01	0.04

Appendix F IMPACT™ Model Information

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1.0 Introduction

1.1 Overview of the IMPACT model

The environmental transport and pathways model, IMPACT (Integrated Model for the Probabilistic Assessment of Contaminant Transport), is used to evaluate the transport and effects of constituents of potential concern (CoPCs) on the local environment and valued ecosystem components (VECs), including humans. The model represents a convenient platform and powerful tool to complete systematic evaluations of the risks to ecological and human receptors associated with releases of constituents to water and air from proposed or existing anthropogenic activities. The reader is referred to the IMPACT user manual for further details (Ecometrix, 2009a).

IMPACT is a modelling tool, the current version of which was created, and is maintained and supported by Ecometrix Incorporated (Ecometrix). The IMPACT model was originally developed by BEAK Consultants Ltd. in 1993 as part of research initiative partially funded by the Atomic Energy Control Board (now the Canadian Nuclear Safety Commission). Since the initial development, IMPACT has been continuously updated to improve the interface, to integrate various operating systems, and most importantly, to embody an up-to-date understanding of the fate, transport and toxicity of metals, radionuclides and other constituents released to the environment. The IMPACT 5.5.2 version was tailored to align with the guidance for Derived Release Limits (DRLs) that is referred to in the Canadian Standards Association (CSA, 2014) standard N288.1-14 and supporting documentation (Ecometrix, 2009a).

The IMPACT model is a customizable tool that allows the user to assess the transport and fate of constituents of potential concern (CoPCs) through a user-specified environment. The model is used to estimate concentrations of CoPCs in a range of media. The IMPACT model enables the quantification of potential doses and exposure ratios (ERs) for aquatic and terrestrial ecological receptors as well as humans. The graphical user interface features make it possible to create or modify scenarios quickly and without the need to change the programming code. Thus, users can construct complex models to predict potential environmental effects in a wide variety of natural environments without the need for programming skills or the use of multiple and complex model interfaces.

As discussed in the response to IR12.8 (CIAR# 396), the IMPACT model has been applied to ecological and human health risk assessments at several proposed and operating mines and mills including Cigar Lake (Cameco, 2004), Key Lake (Ecometrix, 2005a, 2008, 2009b, 2013a), Millennium (Ecometrix, 2013b) and McArthur River (Ecometrix, 2005b, 2009c). IMPACT has also been used extensively for ecological and human health risk assessments for the nuclear industry (OPG, 2019, 2020).

1.2 Objective

The objective of this appendix is to present the structure and functioning of the IMPACT model as implemented for the Marathon Palladium Project. This document discusses the inputs and assumptions used in the IMPACT model, including receptor characteristics, exposure pathways, and the derivation and identification of site-specific information that was used in the model.

1.3 Receptors Selected for Inclusion in the IMPACT Model

As part of the Water Quality Baseline Report Update, potential effects of the Marathon Palladium Project were assessed to update the conclusions of the 2013 Report on Impacts of PSMF[1] Discharge to Hare Lake (Ecometrix, 2013c).

The receptors included in this iteration of the IMPACT model for risk analysis were selected to update the conclusions of the 2013 Hare Lake Report. This representative group of organisms were also considered in the context of suggest criteria in CCME's ERA Guidance Document (CCME, 2020). These factors include ecological relevance (i.e., confirmed presence at the site), degree and mechanism of exposure to CoPCs at the site (i.e. receptors with aquatic exposure pathways), relative sensitivity to the CoPCs, availability of ecotoxicological and life history data, and availability of appropriate measurement endpoints.

The selected ecological receptors were either individual species, or generic groups for aquatic plants and invertebrates. The ecological receptors selected for quantitative assessment or as part of the food intake for assessed species are presented in Table 1.1.

Table 1.1: Ecological Receptors for Quantitative Assessment

Receptor Group / Type	Ecological Receptor	Importance in the Quantitative Assessment
Fish	Northern Pike (*Esox Lucius*)	Representative of fish in country foods diet Harvested from Hare Lake Fish tissue data available Exposed to aquatic release through surface water and diet (small fish, aquatic invertebrates)
Large Mammalian Herbivore	Moose (*Alces alces*)	Representative of large game in country foods diet Present in the study area Identified by Indigenous groups to be of dietary/cultural significance Exposed to aquatic releases through water and diet (macrophytes)
Aquatic Vegetation	Macrophytes	Important role in nutrient cycling Food source for other ecological receptors Exposed to aquatic release through uptake from surface water and sediment
Benthic Invertebrate	Benthic Invertebrates	Food source for other ecological receptors Exposed to aquatic release through uptake from surface water and sediment

[1] Process Solids Management Facility

Receptor Group / Type	Ecological Receptor	Importance in the Quantitative Assessment
Riparian Carnivore	American Mink (*Neovison vison*)	Present in study area Surrogate for other furbearers Identified by Indigenous groups to be of dietary/cultural significance Exposed to aquatic releases through water, sediment and diet (fish, invertebrates)
Riparian Herbivore	Muskrat (*Ondatra zibethicus*)	Present in study area Surrogate for other furbearers Identified by Indigenous groups to be of dietary/cultural significance Exposed to aquatic releases through water, sediment and diet (aquatic plants, invertebrates)

Baseline reports and supplemental documents reviewed to develop the list of ecological receptors included:

- 2009 Terrestrial Baseline Assessment (Northern Bioscience, 2009);
- 2020 Terrestrial Updated Baseline (Northern Bioscience, 2020);
- 2012 Bird Studies (Northern Bioscience, 2012);
- 2012 Aquatic Resources Baseline (EcoMetrix, 2012);
- 2020 Updated Aquatic Baseline (Ecometrix, 2020);
- 2013 Report on Impacts of PSMF Discharge to Hare Lake (Ecometrix, 2013); and
- Terrestrial and aquatic species of importance to Indigenous communities.

1.4 Structure

This appendix contains the following sections and content:

Section 2: Describes the model structure for environmental assessment and the generic equations used to calculate the transfer of constituents between environmental media; and

Section 3: Presents the development of input parameters, and describes the approach used for calibration based on monitoring data

References are listed in Section 4.

2.0 The IMPACT Model

The IMPACT model simulates the transport of constituents from sources through various environmental media such as air, water, soil and sediment to receptors. The model estimates the resulting concentration of constituents in environmental media, potential uptake by aquatic and terrestrial vegetation and animals, and potential intake by and dose to animals and humans.

Environmental pathways are the series of environmental components and the relationships by which CoPCs travel from sources to receptors. A pathway is formed when there is a point at which CoPC uptake by an ecological or human receptor may occur through a continuous series of environmental components and interactions. If a continuous pathway does not exist between the source of a CoPC and an ecological or human receptor then no exposure is expected to occur.

The links within a pathway represent different processes of constituent transfer which depend on the VECs and environmental conditions. These can include intake, transfer and accumulation of constituents.

2.1 The IMPACT Model Structure

Ecological and human receptors inhabit “polygons” in IMPACT. Polygons represent zones of surface water or land that have similar physical, chemical, biological and/or hydrologic characteristics and are generally uniform in nature. Individual polygons are given specific attributes, such as topography for land polygons and water depth and flow for water polygons, which can be based on site-specific information. Each polygon is given a specific spatial extent that is defined by a centroid point (with X and Y coordinates) and a surface area. Polygons can be connected by water or air pathways. A number of receptors may reside within each polygon and may have connections to other polygons.

The transfer of constituents between environmental media, receptors and polygons is conceptualized by links (arrows indicating direction of transfer). The links represent different transfer processes depending on the context. For example, a link between two waterbodies may represent flow of water and a link between water and sediment may represent sedimentation.

2.2 Water Polygons

Lakes and streams are defined within IMPACT as water polygons, which are distinct from land polygons. Water polygons consist of lakes and streams that can be inhabited by aquatic receptors and provide exposure pathways for terrestrial and human receptors.

The IMPACT model includes flow and mass balance in lakes and streams. Constituents enter the aquatic environment from a source and travel through various waterbodies. As constituents travel through a series of connected waterbodies such as lakes, concentrations in water can decrease as a result of mixing with natural inflows from the surrounding watershed and interactions with lake sediment. The exchange of constituents is estimated using chemical-specific partitioning coefficients. The water and sediment pathways involve the exchange of constituents between surface water and sediment through the following processes:

- sorption and desorption between dissolved and particulate forms in water and sediment;
- settling of particulates from water to sediment;
- diffusive exchange between sediment porewater and the water column; and
- loss to deeper sediments through accumulation and burial.

The model estimates the water and sediment concentrations using the advection dispersion equation, which is essentially a mass conservation equation. The partial differential equations are solved iteratively. The model estimates the change in water and sediment concentrations through each of the downstream waterbodies over time.

If aquatic receptors are included in the model, they reside in aquatic polygons. Terrestrial receptors (such as moose and humans) reside in terrestrial polygons and can be linked to aquatic receptors from aquatic polygons.

2.2.1 Aquatic Receptors

Aquatic plants and animals are assigned to water polygons. As discussed in Section 1.3, the aquatic receptors that were considered in this iteration of the IMPACT model include aquatic plants (macrophytes), benthic invertebrates, and fish.

<u>Macrophytes</u>

Aquatic macrophytes are primary producers that occupy the lowest level in the food chain, and are exposed to constituents in surface water. Macrophytes can potentially uptake metals in their roots and shoots, and are modelled accordingly. Macrophytes provide a pathway for the introduction of bioavailable constituents and their compounds into the food chain through direct consumption by terrestrial herbivores.

<u>Benthic Invertebrates</u>

Benthic invertebrates are considered primary consumers. They are important food sources for aquatic and semi-aquatic animals. Benthic invertebrates are assumed to be exposed to constituents in the aquatic environment directly through contact with water and sediment in the IMPACT model.

<u>Fish</u>

A number of fish species were collected from waterbodies within the Marathon Project area to provide data on CoPC concentrations in whole body for small-bodied fish and muscle and bone tissues for large-bodied fish. Fish species observed and sampled in Hare Lake include Northern Pike (*Esox lucius*) and Spottail Shiner (*Notropis hudsonius*). Northern Pike was selected for

IMPACT modelling purposes to represent a piscivorous top carnivore. Although there may be other fish species in Hare Lake that are not included explicitly in the model, Northern Pike is expected to be representative of other species and provide a conservative assessment of CoPC accumulation from surface water. Protection of this species is expected to be protective of other fish species. Northern Pike is also expected to provide a conservative assessment for receptors that consume fish.

Fish species are used as surrogates for amphibians because the sensitive life stages for amphibians (i.e., egg and tadpole) are aquatic and similar to the sensitive life stages for fish. During the tadpole stage, tadpoles and fish have similar exposure pathways (i.e., gills for breathing, absorption through skin and similar feeding habits). The toxicological data for amphibians are limited but the available data for cadmium, cobalt, copper, lead, nickel and zinc for sensitive life stages indicate that the selected toxicity reference values (TRVs) for fish are protective of amphibians. Therefore, the fish species in the model are expected to provide a reasonably good surrogate for, and protection of, amphibians such as frogs during the sensitive tadpole stage.

2.2.2 Aquatic Pathways

Aquatic pathways include the transfer of constituents between water, sediment, aquatic animals and aquatic plants. Environmental media (i.e., water and sediment) and aquatic receptors (fish) are connected by arrows in the IMPACT model (Figure 2.1). The arrows represent equations listed below. Model outputs include concentrations in environmental media and receptors, and dose and risk values for ecological receptors.

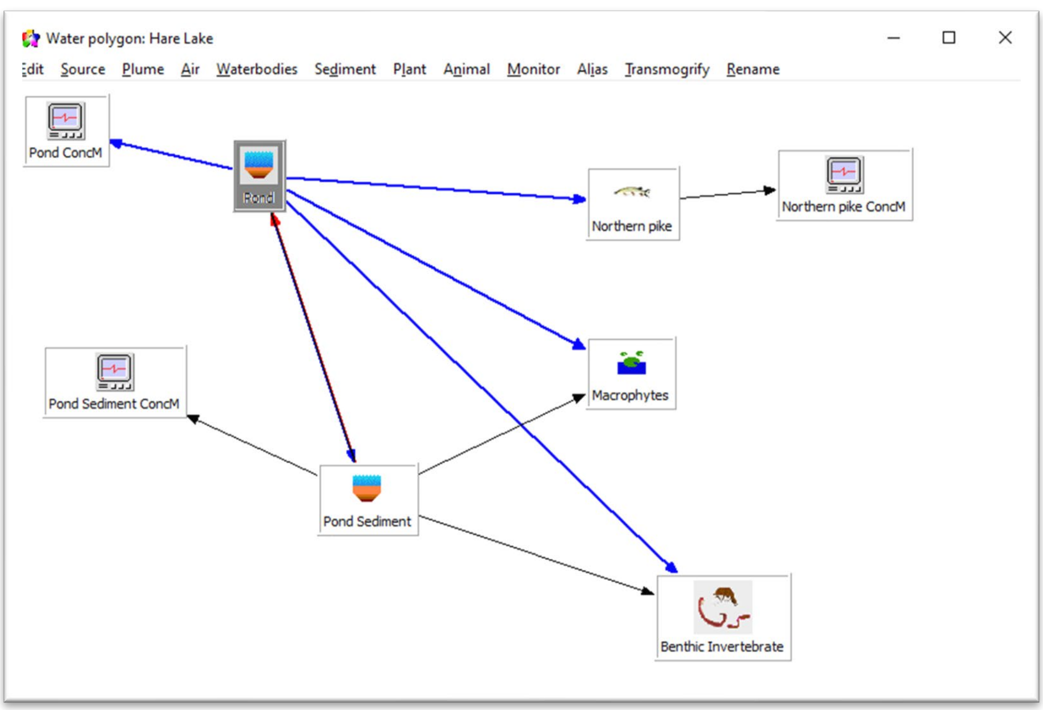

Figure 2.1: Representation of Transfer between Aquatic Media in IMPACT

The equations for water and sediment concentrations are partial differential equations that are solved numerically within IMPACT. Each of these equations is characterized by a series of parameters that describe the physical and biochemical environment of each lake and stream represented by the model. These parameters can be divided into the following general categories to represent the following components and processes:

- physical environment;
- natural background conditions;
- project-related constituent loadings; and
- biochemical exchange processes.

There are four basic equations that describe the concentrations in the aquatic environment for water and sediment.

Water column concentration:

$$\frac{dC_{wc}}{dt} = \frac{W_w + Q_{in} \cdot C_{in} + Q_{gw} \cdot C_{gw}}{V_w} + \lambda_{parent} \cdot C_{parent} - \frac{k_s}{z_w}\left[(1-f_w) \cdot C_{wc} - C_{pw}\right] - C_{wc} \cdot \left[\lambda_T + \frac{g_w \cdot f_w}{z_w} + \frac{Q_{out} + (1-f_w) \cdot Q_{gw\leftrightarrow out}}{V_w}\right]$$

Sediment layer concentration:

$$\frac{dC_s}{dt} = \frac{g_w \cdot f_w \cdot C_{wc}}{z_s} + \lambda_{parent} \cdot C_{parent} + \frac{k_s}{z_s}\left[(1-f_w) \cdot C_{wc} - C_{pw}\right] + \frac{Q_{gw} \cdot C_{gw}}{V_s} - C_s \cdot \left[\lambda_T + \frac{g_b}{z_s} + \frac{(1-f_s) \cdot Q_{gw\leftrightarrow out}}{\varepsilon_s \cdot V_s}\right]$$

Aquatic animal concentration (C_{aa}):

$$C_{aa} = C_{wc} \cdot BAF_{aa} \cdot \alpha \cdot (1 - OF_s) + C_{pw} \cdot BAF_{aa} \cdot \alpha \cdot OF_s$$

Aquatic plant concentration (C_{ap}):

$$C_{ap} = C_{wc} \cdot BAF_{ap}$$

where:

α	=	food web multiplier [unitless]
BAF_{aa}	=	bioaccumulation factor for aquatic animals [L/kg]
BAF_{ap}	=	bioaccumulation factor for aquatic plants [L/kg]
C_{in}	=	concentration of constituent entering water column [mg/L]

C_{gw}	=	concentration of constituent in seepage (input) groundwater [mg/L]
C_{parent}	=	concentration of parent constituent
C_{pw}	=	concentration in the surficial sediment pore water [mg/L]
C_s	=	concentration of constituent in surficial sediments [mg/kg]
C_{wc}	=	concentration of constituent in water column [mg/L]
D^*	=	sediment-water column diffusion coefficient [m^2/s]
ε_s	=	porosity of surficial sediment [unitless]
f_s	=	fraction of a constituent that is particulate in the sediment layer [unitless]
f_w	=	fraction of a constituent that is particulate in the water column [unitless]
g_b	=	burial rate of sediments [m/s]
g_w	=	settling rate of particulates in water column [m/s]
k_s	=	sediment-water transport coefficient [m/s], ($k_s = D^*/z_i$)
λ_{parent}	=	first-order decay constant for parent constituent [s^{-1}]
λ_T	=	total first-order decay constant for constituent [s^{-1}], which is the sum of the universal decay constant and the media-specific decay constant
OF_S	=	sediment occupancy factor [unitless]
Q_{in}	=	inflow rate from upstream surface water (L/s)
Q_{gw}	=	inflow rate from groundwater (L/s)
Q_{out}	=	net outflow rate to downstream surface water [L/s]
$Q_{gw\leftrightarrow out}$	=	outflow rate to groundwater [L/s]
V_s	=	volume of surficial sediment layer [L]
V_w	=	volume of surface waterbody [L]
W_w	=	total effluent emission rate from all sub-sources (mg/s)
z_i	=	sediment-water column diffusion interface thickness [m]
z_s	=	thickness of sediment layer [m]
z_w	=	mean lake depth [m]

Many parameters representing the physical environment were derived from baseline studies including waterbody surface areas and volumes. Information from published literature and from experience with similar environments was used to quantify physical parameters that are conceptual or that were not observed directly (such as sediment interface thickness). A summary of sediment characteristics is presented in Table 2.1.

Table 2.1: Sediment Modelling Parameters

Model Parameter	Value	Unit
Mixing depth	0.03	m
Dry bulk density	0.11	kg(dw)/L
Water content	0.96	unitless
Diffusion Coefficient	3.16E-10	m^2/s
Interface Thickness	0.01	m

The natural background conditions represent the quality of water and sediment within the watershed prior to mining operations. Where possible, field data were used to quantify the natural background conditions (Sections 3.2 and 3.3). Monitoring data indicated that concentrations of some constituents in water were below analytical detection limits.

Concentrations in the sediments from lakes were generally measurable. Water-sediment partitioning coefficients were developed based on the available data, as discussed in Section 3.3.2.

The source loads of constituents from natural and project-related sources represent the boundary conditions of the model. Natural sources are represented by the chemical influx from natural groundwater discharge, overland runoff and stream inflows from the surrounding landscape. These natural loadings were estimated from natural background water quality and inflow rates for site-specific conditions.

2.2.3 Risk to Aquatic Receptors

The exposure ratio (ER) for aquatic animals due to exposure of constituents in water is estimated as:

$$\mathrm{ER} = \frac{1}{\mathrm{RC_{wc}}} \cdot \left[C_{\mathrm{wc}} \cdot (1 - \mathrm{OF}_s) + C_{\mathrm{pw}} \cdot \mathrm{OF}_s\right]$$

where:

C_{pw}	=	concentration in the surficial sediment pore water [mg/L]
C_{wc}	=	concentration of constituent in water column [mg/L]
OF_s	=	sediment occupancy factor [unitless]
RC_{wc}	=	reference toxic concentration – water column [mg/L]

2.3 Terrestrial Polygons

Terrestrial receptors are modelled as residing in land polygons. Terrestrial polygons can be inhabited by terrestrial receptors and provide exposure pathways for terrestrial and human receptors. Land polygons are populated by one or more terrestrial receptors that are expected to occupy the habitat represented by the prevailing vegetation community and physical characteristics of the home polygon.

Terrestrial receptors are divided into ecological receptors or human receptors. Ecological receptors typically are selected to include representative species of terrestrial plants, small and large mammals, invertebrates, birds and riparian animals. Human receptors can be modeled to represent the habits of population groups and ages that are expected to reside in the area of interest.

IMPACT models both terrestrial and aquatic dietary components for terrestrial receptors. Terrestrial pathways include the transfer of constituents between air, soil, terrestrial plants, and terrestrial animals. In this iteration of the model, only the aquatic pathways are represented.

2.3.1 Terrestrial Receptors and Pathways

As discussed in Section 1.3, the terrestrial receptors considered representative for consumption of aquatic components in this iteration of the IMPACT model are moose, muskrat and mink.

<u>Moose</u>

Moose are large ungulates. The herbivorous diet of the moose consists primarily of woody matter including shrubs, twigs and branches; approximately one-fifth of their diet consists of aquatic vegetation (FCSAP, 2012). Moose have distinct summer and winter ranges with linkages to aquatic environments during the summer period when aquatic plants are consumed.

<u>Muskrat</u>

Muskrat is a rodent that relies primarily on the aquatic environment for its diet. Muskrats are rather small, weighing approximately one kilogram (kg), and are prey for terrestrial predators. Their main food source is aquatic plants, although a small proportion of their diet comes from aquatic invertebrates (FCSAP, 2012).

<u>Mink</u>

Terrestrial predators at the top level of the food chain are represented by mink (*Mustela vison*). Mink has a direct linkage to the aquatic environment through the consumption of fish and aquatic invertebrates. Aquatic prey represents approximately one-third of the mink's diet (FCSAP, 2012).

2.3.2 Exposure Assumptions for Terrestrial Receptors

Terrestrial receptors may be exposed to CoPCs released from the Marathon Palladium Project through aquatic pathways, including ingestion of water and food, and incidental ingestion of sediment from Hare Lake. To model these exposure pathways, it is necessary to define rates of water, food and sediment ingestion. The characteristics and intake rates of all terrestrial receptors that were considered in this iteration of the model are presented in Table 2.2.

Table 2.2: Aquatic Dietary Components and Characteristics of Terrestrial Receptors

Receptor	Body Weight	Total Feed Intake		Aquatic Dietary Components	Feed Type Fraction		Feed Intake Rate		Basis of the Soil and Sediment Intake Value	Total Soil/ Sediment Intake Rate[2]	Water Intake Rate[3]
	kg	kg dw/d[1]	kg fw/d[1]		fw	dw	kg dw/d	kg fw/d		kg dw/d	L/d
Moose	400	8.0	32	Macrophytes	0.2	0.2	1.6	6.4	Moose	0.16	21.8
Muskrat	1	0.1	0.3	Benthic Invertebrates	0.2	0.2	0.014	0.1	Mallard	0.0023	0.099
				Macrophytes	0.8	0.8	0.056	0.2			
Mink	0.82	0.029	0.115	Fish (Northern Pike)	0.4	0.393	0.011	0.046	Average of mallard and red fox	0.00089	0.083
				Benthic Invertebrates	0.25	0.246	0.007	0.029			

[1] Calculated based on body weight and food ingestion rate from (FCSAP, 2012)

[2] (Beyer et al., 1994)

[3] (US EPA, 1993)

2.3.3 Risk to Terrestrial Receptors

While terrestrial pathways can include the transfer of constituents between air, soil, terrestrial plants and terrestrial animals as well as uptake from aquatic polygons, the current version of the model focuses on the interaction of aquatic components with terrestrial receptors. The pathways for exposure of terrestrial receptors to the aquatic environment include ingestion of water, sediment, aquatic plants and aquatic animals. The exposure ratio (ER) for terrestrial animals due to ingestion of constituents through aquatic pathways is estimated as:

$$\mathrm{ER} = \frac{1}{\mathrm{RD} \cdot \mathrm{BM}} \cdot \begin{bmatrix} I_w \cdot \sum (C_{\mathrm{wc}} \cdot k_w) + I_s \cdot \sum (C_s \cdot k_{\mathrm{sed}}) + \\ I_{\mathrm{ap}} \cdot \sum (C_{\mathrm{ap}} \cdot k_{\mathrm{ap}}) + I_{\mathrm{aa}} \cdot \sum (C_{\mathrm{aa}} \cdot k_{\mathrm{aa}}) \end{bmatrix}$$

Where:

BM	=	body mass [kg]
C_{aa}	=	concentration in ingested aquatic animals [mg/kg]
C_{ap}	=	concentration in ingested aquatic plants [mg/kg]
C_s	=	concentration of constituent in surficial sediments [mg/kg]
C_{wc}	=	concentration of constituent in water column [mg/L]
I_{aa}	=	aquatic animal ingestion rate [kg/d]
I_{ap}	=	aquatic plant ingestion rate [kg/d]
I_s	=	sediment ingestion rate [kg/d]
I_w	=	water ingestion rate [L/d]
k_{aa}	=	fraction of aquatic animal intake from contaminated source [unitless]
k_{ap}	=	fraction of aquatic plant intake from contaminated source [unitless]
k_{sed}	=	fraction of sediment intake from contaminated source [unitless]
k_w	=	fraction of water intake from contaminated source [unitless]
RD	=	reference toxic dose [mg/kg/d]

3.0 Development of Model Parameters

A baseline sampling program is fundamental to the development and application of an ecological model for environmental assessment. In addition to data on environmental media, many other parameters are required to quantify the transport and fate of constituents in the environment. Many of those parameters are not typically measured and are therefore estimated in the modelling process.

The site falls within the Lake Superior watershed with a watershed divide separating the site along the north-south axis. Treated effluent will be discharged to Hare Lake in the Stream 105 subwatershed during operations. Bamoos Lake, located upstream of Hare Lake, was included in the IMPACT model for completeness, however only Hare Lake water, sediment and biota quality were evaluated.

3.1 Ambient Hydrology

3.1.1 Lake Characteristics

Hare Lake will receive treated effluent from the Marathon Palladium Project. It has a maximum depth of 29 m and average depth of 15 m (Ecometrix, 2013c). Hare Lake bathymetry was obtained from an OMNR survey undertaken in August 1975 (OMNR, 1975). Waterbody characteristics are summarized in Table 3.1.

Table 3.1: Physical Characteristics of Hare Lake

Lake Area m^2	Average Depth m	Maximum Depth m	Catchment Area km^2
567,300	15	29	44.1

3.1.2 Surface Water Flows and Yield

Monthly surface water flows for Hare Lake were estimated using a catchment area of 44.1 km^2 and the mean monthly flow regression equations from Table 6.8 of the updated baseline hydrology report (Stantec, 2020). Monthly and annual average flows, as well as average yield, for Hare Lake are presented in Table 3.2.

Table 3.2: Average Monthly Flow (m^3/s) in Hare Lake

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average m^3/s	Average Yield $m^3/s/km^2$
0.15	0.11	0.24	1.28	2.01	0.67	0.39	0.23	0.45	0.94	0.74	0.33	0.63	0.015

3.2 Water Quality

To characterize background water quality, updated baseline water quality data from the water quality baseline report update were used (Ecometrix, 2020). The water sampling stations included in the characterization of baseline water quality for sub-watersheds 105 and 106 are S10, S11, S12, S13, S14, S15, S30, S31, S41, LHare, Bamoos1 and Bamoos2.

3.2.1 Background Water Quality

Most parameters in water remained below the analytical detection limits for most water samples, and therefore do not provide a definitive estimate of the ambient or background water quality for modelling purposes. The water quality values used to characterize background in the model were based on the 75th percentile of observed concentrations if values were above detection limits. If levels were below detection limits, the detection limit was used (See Table 6-1 within the Water Quality Assessment Update). A comparison of measured and modelled baseline water concentrations is shown in Figure 3.1.

3.3 Sediment Quality

3.3.1 Background Sediment Chemistry

The characterization of background sediment quality was based on baseline sampling performed in Hare Lake in 2009 (Ecometrix, 2012). Five littoral and five profundal locations in Hare Lake were sampled using a petite Ponar. The sediment quality values used to characterize background in the model were based on the average concentrations for the profundal and littoral samples collected.

3.3.2 Water to Sediment Partitioning Coefficients

The water-to-sediment partitioning coefficients (K_d) are derived from sediment and water characteristics, preferably where detectable concentrations exist for contemporaneous water and sediment concentrations. The K_d values are used to estimate the fraction of a constituent that is associated with the particulate fraction in the shallow sediment layer (f_s). The fraction of CoPC in the solid phase is estimated using the following equation:

$$f_s = \frac{K_d \cdot \frac{\rho_s}{\varepsilon_s}}{1 + K_d \cdot \frac{\rho_s}{\varepsilon_s}}$$

where:

K_d	=	distribution coefficient between water and sediment [L/kg]
ε_s	=	porosity of surficial sediment [unitless]
ρ_s	=	bulk density of surficial sediment [kg/L]

The average of littoral and profundal sample concentrations was used to develop the site-specific Kd values presented in Table 3.3.

Table 3.3: Distribution Coefficients Calibrated for Hare Lake

CoPC	K_d
Al	147000
As	8950
Cd	28500
Co	30450
Cu	25000
Fe	37200
Hg	1705
Mo	1375
Ni	8200
Pb	45300
Se	1850
U	192
V	31700
Zn	45850

3.4 Transfer of Constituents to Aquatic Receptors

A fundamental premise of pathways analysis is that chemical uptake by receptors is related to their level of exposure. A linear relationship is usually assumed, and is represented by a bioaccumulation factor (BAF). For aquatic receptors, the BAF is the concentration in the organism divided by the concentration in water. The BAF may be estimated from organism and water data by using a regression that generally is assumed to pass through the origin, such as "C_{fish} = Slope · C_{water}". The slope of the regression line is the BAF. If the data show an adequate relationship between organism and water then the slope can be used to represent bioaccumulation. In cases where there is not a clear relationship, it is conservative to assume that there is, as over-predictions tend to occur at exposure concentrations rather than at background concentrations.

As a result of physiological control, intracellular storage and different excretion mechanisms, biota have an ability to actively regulate the body burden of many metals including selenium, and maintain homeostatic control over a range of exposures (Chapman et al., 1996; Hamilton and Mehrle, 1986; Wood and Port, 2000). These homeostatic controls can produce non-linear relationships between the steady-state tissue concentrations and the environmental exposure concentrations (Newman and Unger, 2002). However, these complicating issues do not diminish the importance of or negate the practical application of BAFs in the assessment of environmental hazards associated with CoPCs.

Bioaccumulation factors reflect the correlation between a CoPC present in environmental media and the concentration in the tissue of an ecological receptor. The IMPACT model represents a simplification of the more complex multi-media system. The BAF model in aquatic systems is used to estimate the concentration of CoPCs in the tissues of animals based on equilibrium principles. If animals and their prey are in equilibrium with the CoPC in the environment, their concentrations can be estimated using an overall BAF between water and the organisms (Thomann and Mueller, 1987).

Since BAF values cited in the literature vary over a considerable range, BAF values based on site-specific data are preferred. The values of BAFs are often based on low background concentrations and are used as a predictive tool over a range of environmental conditions. Site-specific BAF values developed from monitoring data for northern pike were used in the IMPACT model.

The BAFs for northern pike were based on the relationship between tissue concentration values and water concentrations as discussed below. The BAFs used in the model are presented in Table 3.4 for northern pike, benthic invertebrates and macrophytes. Section 3.4.1 describes the development of BAFs for northern pike based on site-specific data. The BAFs for other aquatic animals and plants relevant in the food chain were based on literature values in the absence of measured concentrations.

3.4.1 Bioaccumulation Factors

The following equation was used to estimate BAF values from field data for fish tissue and water concentration.

$$\text{BAF (L/kg wet weight)} = \frac{\text{Concentration in Fish (mg/kg wet weight)}}{\text{Concentration in Water (mg/L)}}$$

The BAFs cited in the literature vary over a considerable range. Where fish tissue and water concentration data were available at detectable levels, the BAF was estimated from the above relationship. In the case of no measured fish concentrations over the detection limit (cobalt), the BAF was calibrated to the detection limit in fish tissue which can be considered conservative.

As discussed above, the water-based BAF values were based on an assumed linear relationship through the origin for fish because all potential sources of CoPCs for the fish were assumed to be driven by water. In the IMPACT model, fish are linked to surface water only but the BAF accounts for all exposure pathways, including food ingestion, dermal contact and uptake across the gills.

Both the assumption of a linear relationship between water and tissue concentrations and the relatively small sample sizes in the data set represent areas of uncertainty. Nonetheless, the use of the transfer relationships based on site-specific data remains as a practical approach to estimating CoPC transfer to organisms and through the food chain.

Table 3.4: Bioaccumulation Factors for Northern Pike, Benthic Invertebrates and Macrophytes

CoPC	BAF L/kg (fw)		
	Northern Pike[1]	Benthic Invertebrates[2]	Macrophytes[3]
As	236	120	0.75
Co	200	110	790
Cu	175	42	3000
Mo	22	3.6	240
Ni	66	100	52
Pb	20	22	1900
Se	882	240	110
V	152	390	40
Zn	570	1800	1400

[1] Calibrated from Measurements
[2] As, Co, Mo, Ni, Se, Zn BAFs from CSA N288.1, Table A.25e (CSA, 2014); Cu, Pb and V BAFs from IAEA TRS, Table 56 (IAEA, 2010)
[3] As, Co, Mo, Ni, Se, Zn BAFs from CSA N288.1, Table A.25f (CSA, 2014); Cu, Pb and V BAFs from IAEA TRS, Table 55 (IAEA, 2010)

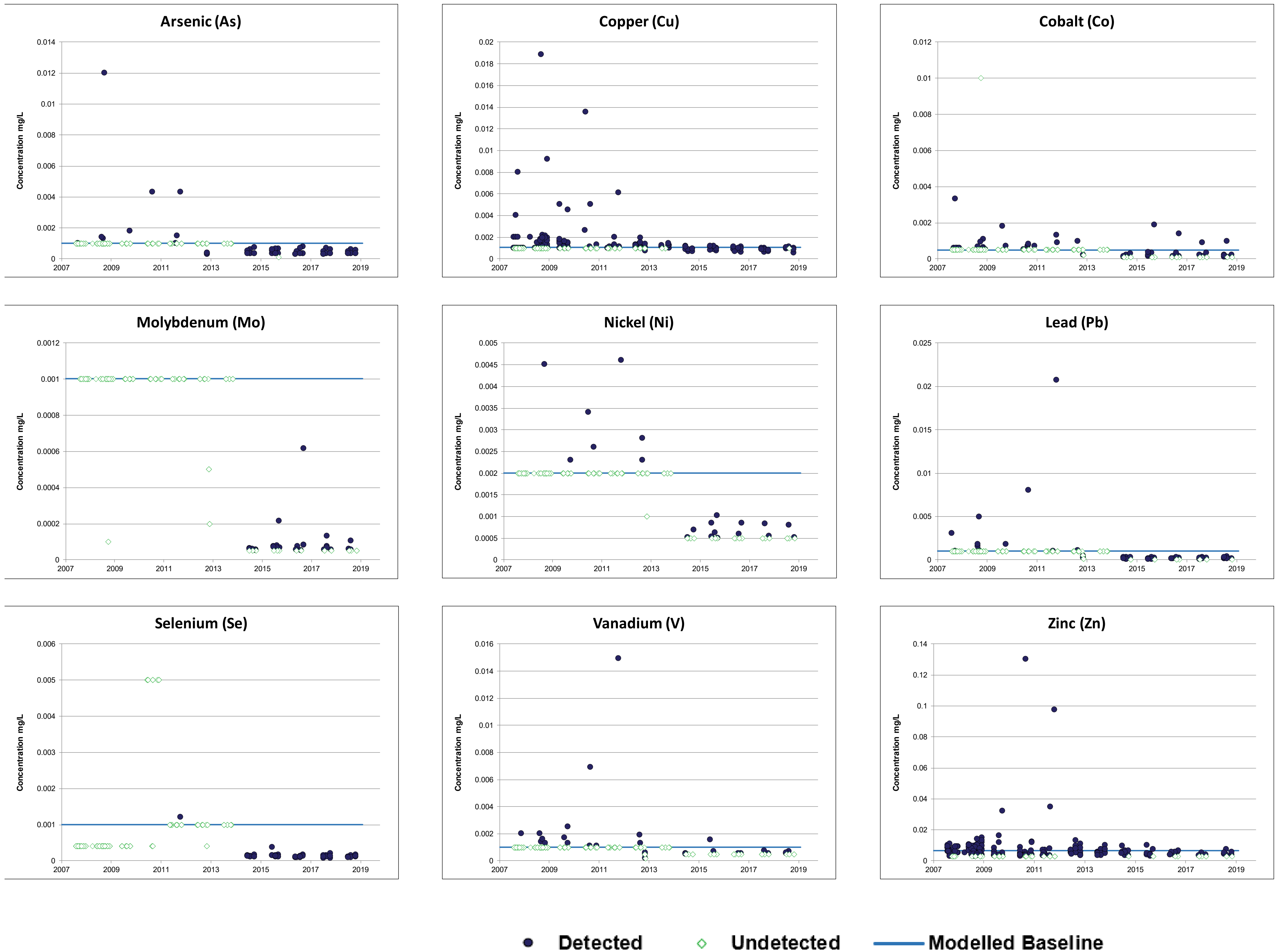

Figure 3.1: Comparison of Measured and Modelled Water Concentrations for Baseline Conditions in Hare Lake

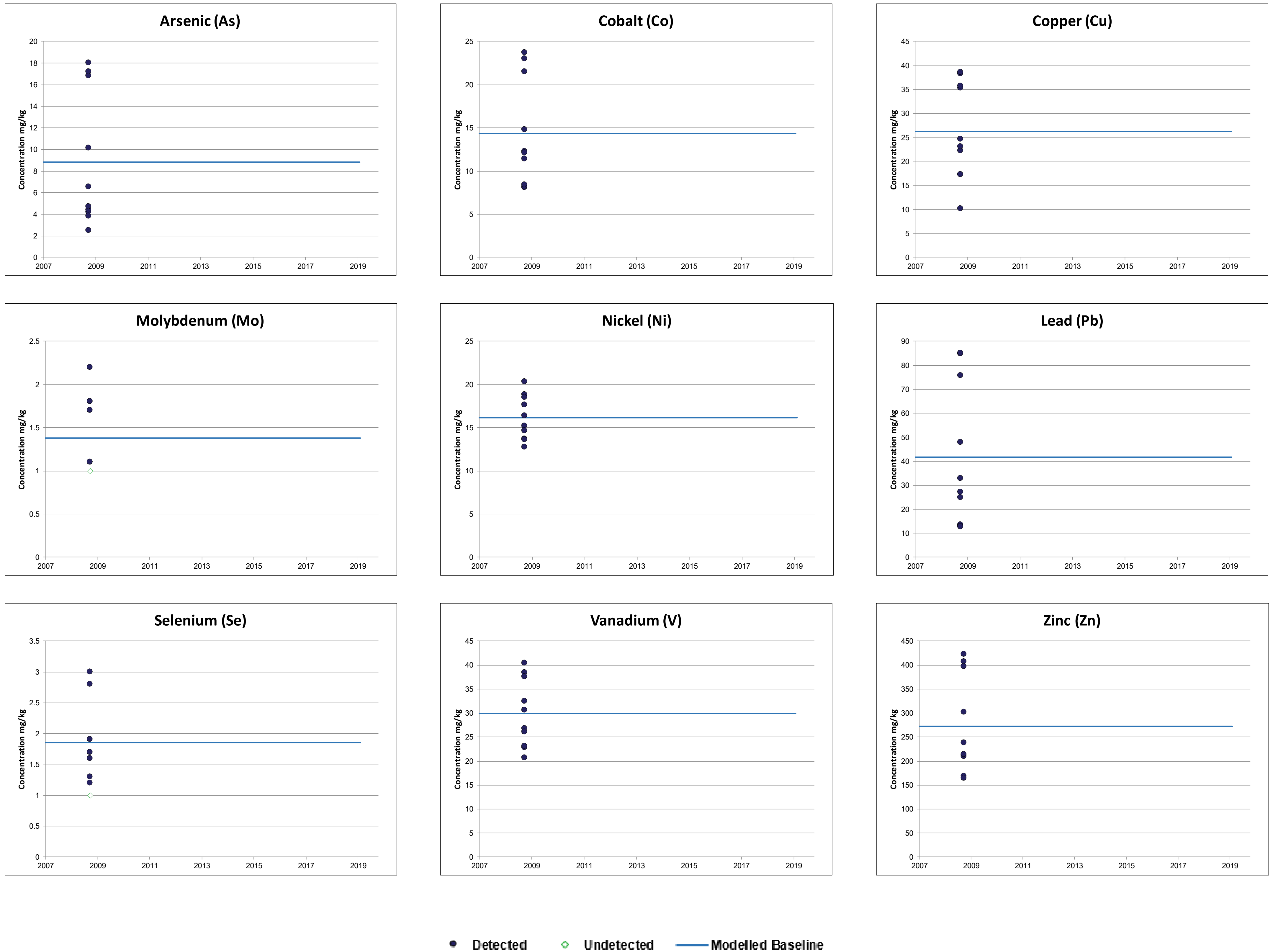

Figure 3.2: Comparison of Measured and Modelled Sediment Concentrations for Baseline Conditions in Hare Lake

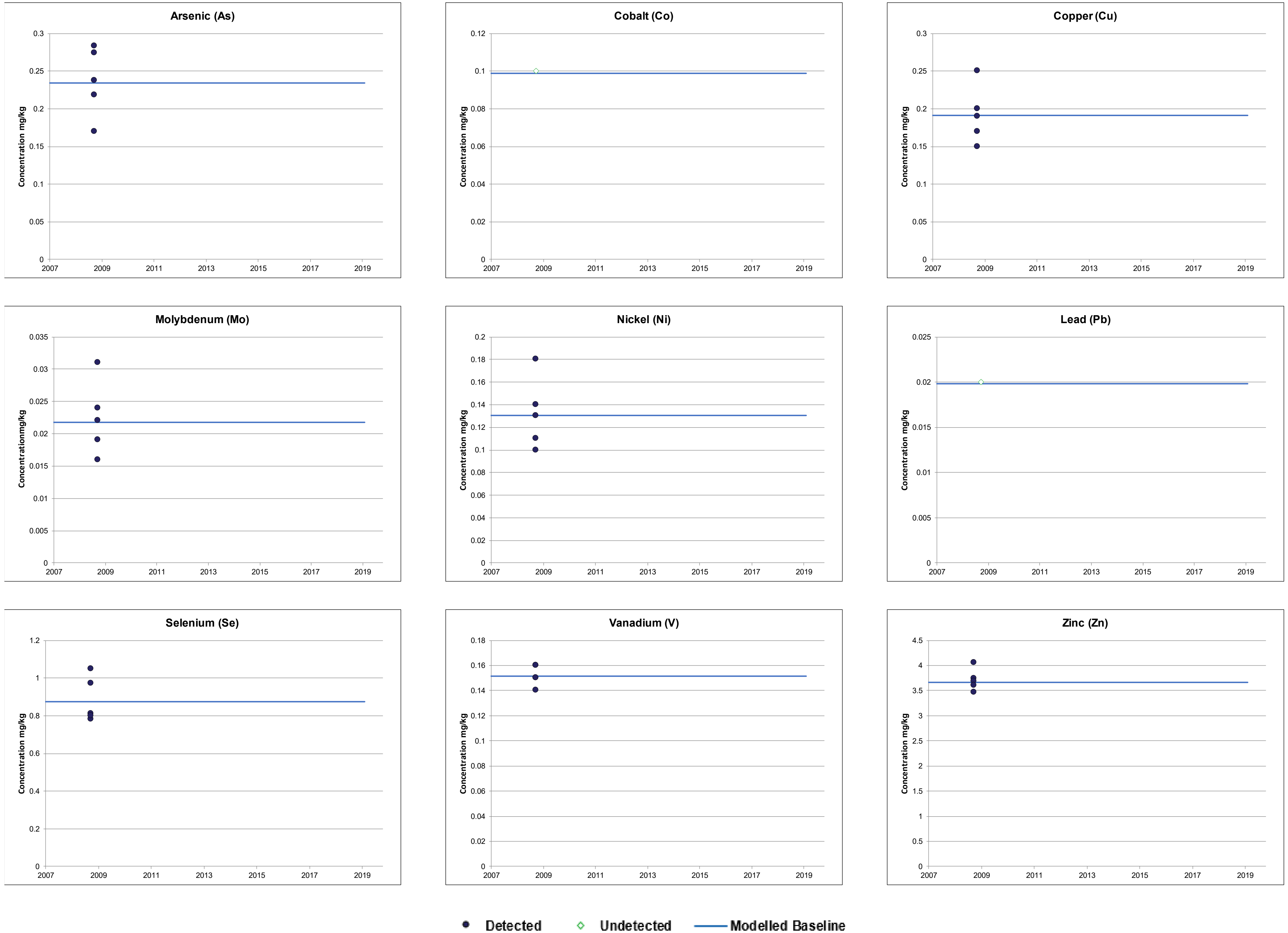

Figure 3.3: Comparison of Measured and Modelled Northern Pike Concentrations for Baseline Conditions in Hare Lake

3.5 Toxicity Reference Values

Exposure ratios were calculated in IMPACT following the methodology presented in Sections 2.2.3 and 2.3.3. The toxicity reference values (TRVs) and sources used for these calculations are presented in Table 3.5.

Where available, literature based TRVs were selected for each of the VECs under consideration to evaluate potential effects that may result from the estimated exposure to each of the CoPCs. The selected TRVs are concentrations or weight normalized daily dietary doses of CoPCs below which ecologically relevant effects on growth, reproduction or survival are not expected to occur.

Table 3.5: Toxicity Reference Values for Aquatic and Terrestrial Receptors

CoPC	Northern Pike		Moose		Mink		Muskrat	
	mg/L	Basis	mg/kg/day	Basis	mg/kg/day	Basis	mg/kg/day	Basis
As	0.55	a	0.548	h	5.62	h	0.548	h
Co	0.29	b	8.76	h	8.76	h	8.76	h
Cu	0.0032	c	5.51	h	6.79	h	5.78	h
Pb	0.12	d	0.569	h	0.569	h	0.569	h
Mo	43.2	e	2.6	f	2.6	f	2.6	f
Ni	0.035	i	0.62	h	83	g	309	h
Se	0.002	c	0.296	h	0.13	h	0.13	h
V	0.08	b	1.88	h	1.88	h	1.88	h
Zn	0.135	d	10	g	8.71	h	8.71	h

a CCME Water Quality Guidelines (CCME, 1999)
b (Suter and Tsao, 1996)
c BC MOECCS Water Quality Guidelines (BC MOE, 2014; BC MOECCS, 2019)
d Ontario MOE Rationale for the Establishment of Ontario's Provincial Water Quality Objectives (OMOE, 1979)
e (De Schamphelaere et al, 2010)
f Ontario MECP TRVs for mammals and birds (MOE, 2011)
g CCME Scientific Criteria Documents (CCME, 2015, 2018)
h US EPA Region 9 recommended mammalian TRVs (US EPA, 2002)
i (CCME, 1987; Nebeker et al., 1985) for water hardness of less than 50mg/L

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