



KENO HILL SILVER DISTRICT MINING OPERATIONS

TAILINGS CHARACTERIZATION PLAN, REVISION 8

September 2024

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Prepared for:

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VERSION HISTORY

ISSUE DATE	DESCRIPTION AND REVISIONS MADE
December 2010	Initial plan. Issued to fulfill conditions set out in Clauses 67 and 68 of Water Licence QZ09-092 for development and mine production at the Bellekeno Mine and the operation of the District Mill
January 2013	Revision 1 updated to fulfill conditions set out in Clauses 71 and 72 of Water License QZ12-053-1 (Amendment 1)
January 2014	Revision 1.1 submitted with Water Licence QZ09-092-2 application for the development and operation of the Flame & Moth Mine as exhibit 1.8.3
December 2017	Revision 2 submitted with YESAA project # a2017-0176 application for the development and operation of the New Birmingham Mine as exhibit 2017-0176-038-1
March 2018	Revision 3 updated to include development and mine production from the Flame & Moth Mine and fulfill amended license conditions set out in Clauses 79 and 80 of Water License QZ09-092-2 (Amendment 2).
July 2018	Revision 4 submitted with Water Licence QZ18-044 application as exhibit 1.5.4
November 2019	Revision 5
October 2020	Revision 6 updated to fulfill conditions set out in Clauses 29, 30, 31 and 98 of Water Licence QZ18-044 (renewal of Water Licence QZ09-092)
November 2021	Revision 6 updated to address comments received from EMR 25/06/2021.
October 2023	Revision 7
August 2024	Revision 8 this document. See Document Revision table.

DOCUMENT REVISIONS

SECTION	SUMMARY OF CHANGES
Version History	Table added that lists the previous revisions of the Plan
Document Revisions	Table added to indicate changes made compared to the previous revision of the Plan
Concordance Tables	Tables added to indicate relevant where license conditions, decision document terms and conditions, and the proponent commitments made during the environmental assessment are addressed in the Plan
List of Acronyms and Abbreviations	List added
Section 1	Introduction section reorganized and updated to reflect current management plan template Purpose of plan relocated from Section 4 Section 2 Mine Location and Description relocated to this section, including Figure 2-1
Section 2	Management Approach section added to reflect current management plan template Objectives stated Roles and Responsibilities consolidated and summarized
Section 3	Subheadings added to Previous Tailings Studies section Summary of previous geochemical studies updated 2014 review of physical testing requirements relocated from Section 4.3
Section 4.0	Purpose of plan relocated to Section 1 Roles relocated to Section 2
Section 4.1	Text updated, including sample preservation to include freezing Table of testing requirements relocated from sections 4.2 and 4.3 and edited for readability Frequency of mineralogy tests increased to quarterly



SECTION	SUMMARY OF CHANGES
Section 4.2	Porewater sampling methodology updated (see Subsection 4.2.4) Previous studies moved to Section 3 Link to AMP added
Section 4.3	Text updated and reader referred to the DST OMS for testing details Link to AMP added Physical Property Characterization physical testing requirement review relocated to Section 3
Section 5	Implementation Schedule updated
Section 6	Reporting section revised
Section 7	References added

WATER LICENSE QZ18-044 CONCORDANCE TABLE

Part	Clause	Water Licence Term & Condition	Where Addressed
Part F Plans	30	The updated TCP must include:	Section 4
		a) Testing procedures to be used to confirm the physical, chemical, and mineralogical properties of the tailings which will be deposited at the facility. The procedures must determine the following properties or characteristics of the tailings:	
		i) soil water characteristic curve;	
		ii) tailings gradation;	
		iii) tailings specific gravity;	
		iv) drained and undrained shear strength;	
v) tailings pore water chemistry; and			
vi) tailings mineralogy and acid base accounting.			
		b) Provisions for conducting long-term humidity cell tests and saturated column tests of the Co-mingled Tailings generated through the processing of ore from the Bellekeno, Flame and Moth and Birmingham Mines.	Section 4.2.2
		c) Sampling frequencies for confirming the properties of deposited tailings such that the assumed long term chemical and physical behaviour of the tailings stack can be progressively confirmed during operation of the Keno Hill Silver District Mill, and the rationale to support the recommended frequencies;	Section 3.2 Section 4
		d) Proposed modifying criteria to reduce or increase frequencies identified in sub-clause c) accompanied by a supporting rationale and examples of the application of the rationale to the results of testing; and	Section 4.2 Section 4.3
		e) An analysis of one full suite of the identified properties and characteristics for each ore body brought into production.	Section 4
	31	If a change to the TCP is required, the Licensee must submit the updated version to the Board prior to implementing the change.	This document
	46	With respect to groundwater monitoring:	
		a) the Licensee must install the following:	Section 4.2.4
		i) one groundwater well within the DSTF Phase 2 Expansion area (KV-107) to be installed as part of the DSTF expansion;	Section 5
		b) groundwater monitoring wells must be:	
		iv) sampled and manually monitored monthly for groundwater level and a full suite of field and laboratory parameters for the first 12 months from installation after which time sampling frequency can occur quarterly.	Section 4.2.4
	47	Upon installation of a groundwater monitoring well(s), the Licensee must submit as part of the next monthly report, the geographical coordinates for any newly finalized monitoring stations.	Section 6
	70	<u>Monitoring Program</u> The Licensee must, in accordance with Schedule B3, monitor at the stations listed, for the parameters and at the frequency identified.	Section 4.2.4



Part	Clause	Water Licence Term & Condition	Where Addressed
Part H Monitoring and Surveillance	87	The Licensee must adhere to the groundwater monitoring schedule in Schedule B3 with the exception that: <ul style="list-style-type: none"> a) Sampling of all wells must be completed monthly after installation for the first twelve months where they contain water. Sampling can revert to quarterly as shown in Schedule B3, following the first twelve samples; and b) The Licensee must monitor the water level in all groundwater monitoring wells where water is present at least monthly for the first year. Water level monitoring can be reduced to quarterly after the first twelve monthly readings are completed. 	Section 4.2.4
	98	<u>Co-mingled Tailings Monitoring</u> The Licensee must implement long term humidity cell tests of Co-mingled Tailings to ensure adequate representation of the Co-mingled Tailings deposited in the DSTF as each new ore body is mined, and shall be continued until the make up of the DSTF at the end of operations is known and a steady-state has been established. Results of the long term humidity cell tests must be submitted as part of the annual report	Section 3.2 Section 4.2 Section 6
Part I General Conditions	119	<u>Annual Report</u> Licensee must submit an annual report to the Board for the period of January 1 to December 31 of each year. Annual reports are to be submitted on or before March 31st of the year following the year reported. The annual report must include the information required by the regulation as well as: <ul style="list-style-type: none"> r) Co-mingled Tailings monitoring as required by Clause 98; 	Section 6
		<ul style="list-style-type: none"> x) all data generated as a result of the monitoring requirements of this license, including analysis and interpretation by a qualified individual or firm and a discussion of any variances from baseline conditions or from previous years' data; analysis of predictions versus real data model trajectory; 	Section 6
	121	The Licensee shall provide to the Board one unbound, single-sided, paper copy of all deliverable required by this Licence. All deliverables, with the exception of design drawings, must be reproducible by standard photocopier.	This table
	122	The Licensee must upload electronic copies of all deliverables required by this Licence to the Yukon Water Board's online licensing registry. Electronic copies must be submitted in one of the following formats: MS Word, MS Excel, or Adobe .pdf format. Water quality results must be in the format outlined in the "Laboratory Data Submission Standards for Water Quality", as amended from time to time and available on the Board website	This table

QUARTZ MINING LICENCE QML-0009 CONCORDANCE TABLE

Part	Clause	Quartz Mining Licence Term & Condition	Where Addressed
Part VI, 13.0 Reporting and Inspections	13.5	The licensee must a) evaluate data gathered as a result of implementation of the monitoring and surveillance plan twice per year;	Section 2.2
		b) develop and implement a program to take immediate steps to address any results from the monitoring and surveillance activities that indicate any change in environmental performance of the Undertaking or non-compliance with the Act, the Regulations, this License or any of the approved plans;	Section 2.1 Section 4.2 Section 4.3
	13.7	On or before March 31 of each year of the term of this License, the Licensee must submit an annual report, in writing, containing the information set out in Schedule D covering the period of January 1 to December 31 of the prior year.	Section 6
Schedule C, Part 1: Authorized Activities	7.0	The Licensee is authorized to deposit tailings from the Bellekeno, Lucky Queen, Onek, Flame and Moth, and Bermingham mines in the Phase I and Phase II (expansion) Dry Stack Tailings Facility.	Table 1-1 Section 1.3
Schedule D Annual Reporting Requirements	1.5	<u>Mine Development and Operations</u> This section must include a summary of all tailings management activities including, but not limited to: a) a summary of long term humidity cell tests of co-mingled tailings results;	Section 6
		g) provide the results and interpretation from all quality assurance and quality control programs related to tailings storage and management activities.	Section 6
	6	<u>Environmental Monitoring and Management</u> This section must provide a summary of all activities relating to environmental protection, monitoring, surveillance and management of the Undertaking, including: a) a summary of the programs undertaken for environmental protection, monitoring, surveillance and environmental management as outlined by the License, including an analysis of these data and any action taken or adaptive management strategies implemented to monitor or address any changes in environmental performance;	Section 6
		b) include a summary of any changes to monitoring instrumentation, methodologies or frequencies;	Section 6
		d) a summary and interpretation of geochemical tests undertaken on mine waste materials and ore, including humidity cells and kinetic tests, including the assumptions and conclusions of the geochemical predictions and the effectiveness of existing mitigation measures;	Section 6
		e) the results of any long-term column tests to study the geochemistry of mine waste materials, ore or water treatment residuals, and implications on the physical stability of facilities prone to geochemical weathering of such materials;	Section 6
		l) provide the results and interpretation from all quality assurance and quality control programs related to environmental protection, monitoring, surveillance and management of the Undertaking;	Section 6



YESAA DECISION DOCUMENT CONCORDANCE TABLE

TERM	DECISION DOCUMENT	TERM & CONDITION	WHERE ADDRESSED
6	2017-0176	Kinetic testing on tailings produced from the Bermingham deposit shall be completed. This should include testing of tailings produced from bench scale testing before production begins. Kinetic tests should include testing of tailings produced from milling of Bermingham ore, as described in the Tailings Characterization Plan.	This document

YESAA PROPONENT COMMITMENT CONCORDANCE TABLE

YESAB ONLINE REGISTRY (YOR)	PROPONENT COMMITMENTS	WHERE ADDRESSED
YOR 2009-0030-124-1	An environmental monitoring plan will be implemented to monitor effectiveness of mitigation measures.	Section 4
YOR 2017-0176-036-1	Additional static and kinetic geochemical testing will be initiated with blended tailings when suitable tailings material is available from future metallurgical work or tailings produced from the District Mill.	Section 4



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LIST OF ACRONYMS AND ABBREVIATIONS

ABA	Acid Base Accounting
AKHM	Alexco Keno Hill Mining Corp.
ARD/ML	Acid Rock Drainage and/or Metal Leaching
ASTM	American Society for Testing Materials
COPC	Constituents of Potential Concern
DSTF	Dry Stack Tailings Facility
HCl	Hydrochloric acid
ERDC	Elsa Reclamation and Development Company
FNNND	First Nation of Na-Cho Nyak Dun
ICP-AES/MS	Inductively Coupled Plasma - Atomic Emission Spectroscopy / Mass Spectrometry
KHSD	Keno Hill Silver District
NP	Neutralization Potential
SFE	Shake Flask Extraction
WL	Water Licence
XRD	X-ray diffraction
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental and Socio-economic Assessment Board
YOR	YESAB Online Registry

1. INTRODUCTION

1.1 PURPOSE OF PLAN

This Tailings Characterization Plan describes how tailings sourced from ores within the Keno Hill Silver District (KHSD), including Flame & Moth and New Birmingham mines will be characterized.

This Plan has been developed for tailings being deposited in Phase 1 and Phase 2 of the Dry Stack Tailings Facility (DSTF) and it outlines the methodology followed for material characterization to comply with water licence and quartz mining license requirements. The tailings characterization program described in this Plan will inform tailings management as described in the Tailings Management Plan and the Dry Stack Tailings Facility (DSTF) Operations, Maintenance and Surveillance (OMS) Manual, and the Underground Tailings Management Plan.

1.2 OVERVIEW OF OPERATIONS

The site is located in central Yukon Territory, 354 km (by air) due north of Whitehorse. Alexco Keno Hill Mining Corp (AKHM) owns and operates of a series of small underground silver/lead/zinc mines with a centralized mill as described in Table 1-1. The locations of the mines and the mill described in the Plan are shown on Figure 1-1. Alexco Resource Corp. (doing business as Hecla Yukon), the parent company of AKHM, was acquired by Hecla Mining Company in September 2022.

Table 1-1: Keno Hill Silver District Mining Operations Overview

MINES / ORE DEPOSITS	Bellekeno (Production 2010 – 2013, suspended 2013 – 2020, production 2020, temporary closure 2021) Flame & Moth (Development 2018, suspended 2018 – 2020, development and production 2020 - present) New Birmingham (Advanced exploration 2017 – 2018, development and production 2020 - present) Lucky Queen, Onek 990 (Advanced exploration 2013, not active)
MILL	District Mill location at Flame & Moth Mine area (Constructed 2010) Conventional floatation process, producing separate lead/silver concentrate and zinc concentrate Tailings placed in Dry Stack Tailings Facility (Established 2010) or underground as backfill
WORK FORCE	~ Camp capacity of 250 employees and contractors during active mine and reclamation operations (as per <i>Yukon Environmental and Socio-economic Assessment Act (YESAA)</i> file # 2018-0169 Decision Document)
AIRSTRIP	Village of Mayo, YT
CAMP FACILITIES	Flat Creek camp facilities include a trailer camp, kitchen facility, welcoming center and fitness facility Four refurbished houses and a bunkhouse located nearby in the townsite of Elsa
POWER	Hydro grid power Yukon Energy, diesel power backup
WATER SUPPLY AND USE	Fresh water supply from Flat Creek and adjacent well Water treatment plants at Bellekeno 625, Flame & Moth, and New Birmingham for mine effluent Process water is recycled from the Mill Pond to the District Mill
FIRST NATIONS	First Nation of Na-Cho Nyak Dun (FNNND)

The Keno Hill mining camp has a long mining history and is a brownfields site. AKHM develops the mineral resources, operates the KHSD mines and undertakes receiving environment monitoring and treatment of mine discharge waters. Hecla Yukon’s wholly owned subsidiary Elsa Reclamation and Development Company Ltd. (ERDC) undertakes care and maintenance, environmental monitoring and water treatment of historic adit

drainages, district-wide closure planning, studies, and remediation of the historic environmental liabilities. ERDC activities are outside the scope of this Plan.

1.3 REGULATORY CONTEXT

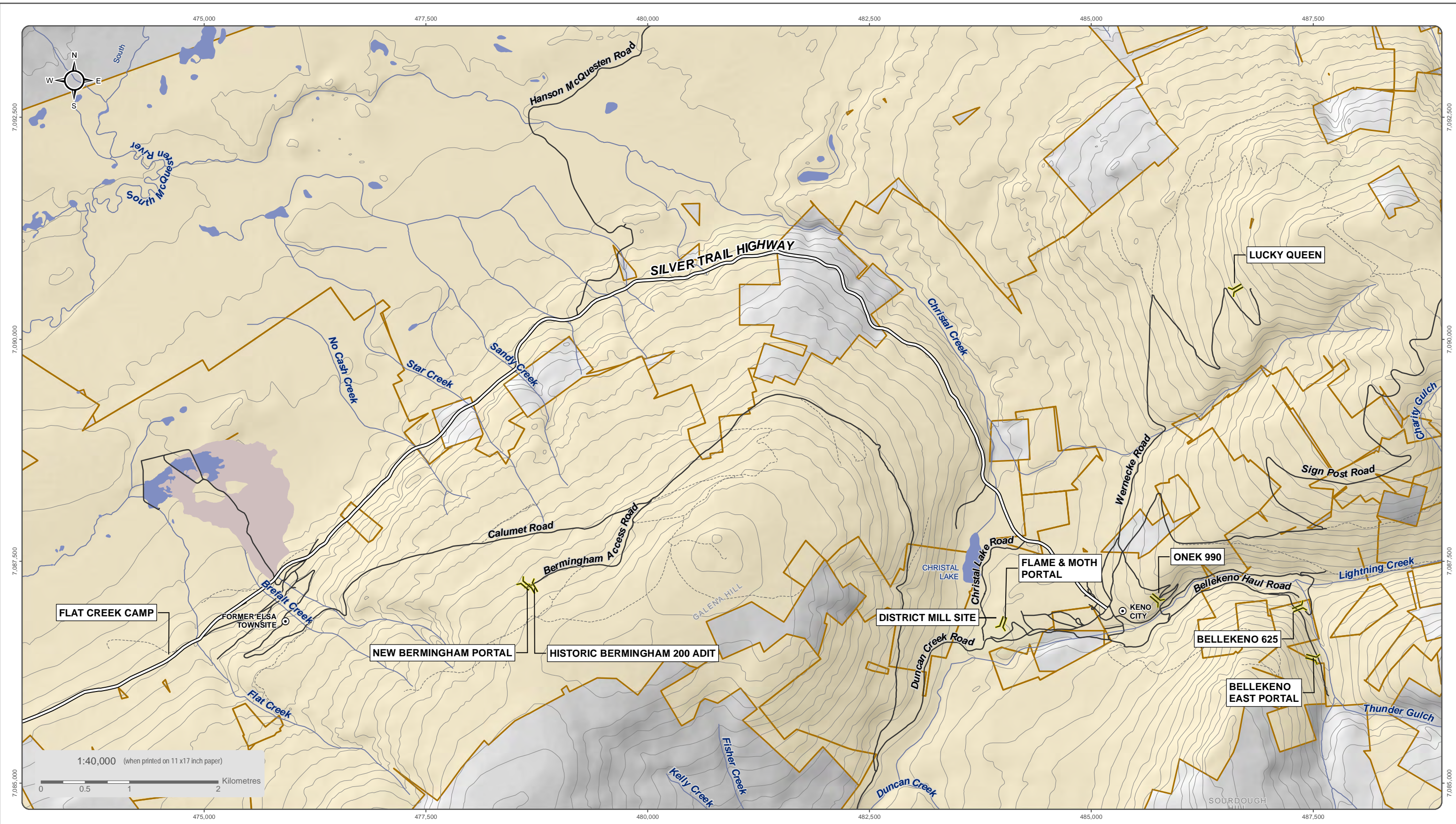
AKHM has all permits and authorizations in place for development and production of KHSD mines Bellekeno, Flame & Moth, and New Birmingham and operations of the District Mill. The existing assessments, approvals and operational management plans for mining and milling activities are summarized in Table 1-2. The operational management plans used to guide activities and monitoring associated with tailings characterization. This plan should be read in conjunction with these documents.

Table 1-2: Related Approvals, Permits, Licenses and Operational Management Plans

YESSA Approvals	Decision Documents and Evaluation Reports for projects #2009-0030, #2011-0315, #2013-0161 and #2017-0176
Quartz Mining License	Quartz Mining License (QML-0009, updated December 2021, expires 2037)
Water Licence	Type A Water Licence (QZ18-044 expires 2037)
Management Plans	<ul style="list-style-type: none"> • Management Health and Safety Program / Emergency Response Plan • Mill Development and Operations Plan • Mine Development and Operations Plans • Adaptive Management Plan • Dust Abatement and Monitoring Plan • Dry Stack Tailings Facility Operation, Maintenance, and Surveillance Manual • Environmental Monitoring, Surveillance and Reporting Plan • Groundwater Monitoring Plan • Hazardous Materials Management Plan • Physical Inspection and Reporting Plan • Reclamation and Closure Plan • Site Characterization Report • Sludge Management Plan • Spill Contingency Plan • Tailings Management Plans • Waste Rock Management Plan

Note: Management plans listed are not required by all the authorizations listed in this table.

Terms and conditions listed assessments and regulatory approvals are addressed in this plan as listed in the concordance tables. All references to documents on the Yukon Environmental and Socio-economic Assessment Board (YESAB) Online Registry can be found by searching for the Project and document number on the YOR.



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Datum: NAD 83; Map Projection: UTM Zone 8N

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Adit
 AKHM/ERDC Quartz Claims

Silver Trail Highway
 Other Road
 Limited-Use Road

Tailings Area
 Waterbody
 Watercourse
 Contours (100 ft intervals)



KENO HILL SILVER DISTRICT MINING OPERATIONS

**FIGURE 1-1
KENO HILL SILVER DISTRICT MINING OPERATIONS OVERVIEW**

MARCH 2024

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 (Last edited by: amaharokas.3225@ncr.nrc.ca)

2. MANAGEMENT APPROACH

2.1 OBJECTIVES

The objectives of the Tailings Characterization Plan are to:

- 1) provide methodology to characterize the physical, chemical and mineralogical properties of tailings,
- 2) specify indicators to be monitored and assessed to enable the implementation of adaptive management if certain conditions or thresholds are met,
- 3) outline studies which have informed the tailings characterization program, and
- 4) obtained appropriate information to assist in closure planning.

This Plan is intended to be an operational document and will be updated as modifications and improvements are made to mill operations, as mill feeds from additional deposits are added, and as tailings disposal methods evolve.

2.2 ROLES AND RESPONSIBILITIES

2.2.1 MILL METALLURGIST

The Mill Metallurgist is responsible for preparing representative monthly composites for testing (Section 4.1).

2.2.2 MILL MANAGER

The Mill Manager is responsible for ensuring there are appropriate and sufficient supplies, staff and equipment on site to support compliant tailings management.

2.2.3 ENVIRONMENTAL STAFF

Environmental staff support the tailings characterization process. Specifically, these responsibilities include:

- submit tailings samples for geochemical analysis as described in Section 4.2,
- obtain reports by qualified professionals on the geochemical analyses,
- report on tailings characterization results in AKHM's annual reports under the water licence and quartz mining license as described in Section 6, and
- prepare updates to the Plan as needed to ensure alignment with mill operations, tailings deposition methodology, and amendments to licence and permit terms and conditions.

2.2.4 ENGINEERING STAFF

Engineering staff are responsible for submitting samples for geotechnical analysis as described in Section 4.3. A comprehensive outline of the roles and responsibilities of engineering staff with respect to tailings management (including physical property monitoring and characterization) is provided in the DSTF OMS Manual.

2.2.5 QUALIFIED PROFESSIONALS

The analysis and interpretation of the geochemical characterization data as described in Section 4.2 and Section 6 is undertaken by geochemical professionals. They are responsible for comparing the results with the geochemical dataset upon receipt of results and determining if there is a marked change in the geochemical characteristics of the static monthly data.

The results of physical property testing as described in Section 4.3 are accessed by the Engineer of Record. They are responsible determining if there is a marked change in geotechnical characteristics that necessitate additional evaluation as described in the DSTF OMS Manual.

3. PREVIOUS TAILINGS STUDIES

The original version of the Plan was based on tailings produced from mill feed from the Bellekeno Mine. Since that time, studies on tailings that would be produced from processing mill feed from the Onek and Lucky Queen, Flame & Moth and New Birmingham deposits have been conducted as outlined below.

3.1 GEOCHEMICAL CHARACTERIZATION

3.1.1 BELLEKENO MILL FEED

Static testing, including particle size distribution, acid base accounting (ABA), metal analysis, shake flask extraction (SFE), x-ray diffraction (XRD), of actual tailings generated from Bellekeno mill feed commenced in January 2011. Composite samples were submitted weekly for ABA and quarterly XRD mineralogy when the mine was in production. A humidity cell for geochemical characterization of the tailings was initiated in August 2011 and was operated for 208 weeks. The humidity cell was a composite comprised of at least 10 splits collected from representative monthly composites during the first 16 months of operations. Results from the initial 47 weeks of humidity cell operation, a comparison 2011 and 2012 filter press filtrate with predicted quality from metallurgical testing, and XRD mineralogy analysis for Q3 2011 are presented in Appendix 1.

Appendix 1 also presents ABA, and SFE results for Onek and Lucky Queen tailings generated from metallurgical testing of drill core.

3.1.2 FLAME & MOTH MILL FEED

A humidity cell containing Flame & Moth tailings generated from metallurgical testing was conducted (operated for 113 weeks) as part of the geochemical characterization work for the Flame & Moth project. The results of the static and kinetic testing on tailings produced from metallurgical testing of the Flame & Moth ore samples in comparison to the Bellekeno tailings are presented in Appendix 2.

3.1.3 NEW BIRMINGHAM MILL FEED

A humidity cell composed of tailings produced from metallurgical testing of New Birmingham ore samples was initiated in 2018 and terminated after 103 weeks of operation. The results of the static and kinetic testing of the Birmingham tailings in comparison with actual Bellekeno tailings and the laboratory generated Flame & Moth, Onek and Lucky Queen tailings are presented in Appendix 3

3.1.4 CO-MINGLED MILL FEED

The comparison of the results of geochemical testing of New Birmingham, Flame & Moth, Onek, Lucky Queen laboratory generated tailings and actual Bellekeno tailings indicates that the tailings will share similar geochemical characteristics with respect to acid rock drainage and metal leaching (ARD/ML). The results show that the low fast reactive carbonate content (e.g., low readily available neutralization potential [NP]) in the New Birmingham mill feed will be compensated by NP from calcian siderite and by NP from other tailings with high NP during co-disposal or blending (Appendix 3).

Static testing results of actual co-mingled tailings generated by combining mill feed from Bellekeno, Flame & Moth and New Birmingham commenced in 2022 and are reported in the annual water license and quartz mining license reports.

3.2 PHYSICAL PROPERTY CHARACTERIZATION

Tetra Tech Inc (formerly EBA Engineering) was retained to undertake an assessment of the properties and suitability of incorporating tailings resulting from the milling of ores from Onek and Lucky Queen into the DSTF, which at that time consisted of ore from Bellekeno only. The review concluded that due to the consistency of the geology across the KHSD, as well as processing the ore from each in the same mill, with the same metallurgical flowsheet, that ore from the Onek and Lucky Queen deposits would produce a nearly identical particle size distribution (EBA, 2012). Production from the Onek and Lucky Queen deposits however are not included in the Water Licence QZ18-044.

Tetra Tech Inc. undertook a review of the suite of physical property testing completed on tailings generated at the District Mill and provide recommendations for ongoing testing requirements in 2013. The review concluded that results from the full suite of physical property testing of tailings produced at the District Mill since 2011, including gradation, moisture (soil-water characteristic curve), weight (specific gravity), and shear strength remained consistent. The review included discussion and rationale for recommending a reduction in the routine physical testing parameters and identified conditions that would trigger for additional physical property testing beyond the routine testing (Tetra Tech, 2014).

Details of the design criteria and slope stability analysis utilized for the operation Phase 1 of the DSTF are presented in the 2011 EBA report *Detailed Design Dry-Stacked Tailings Facility, Keno Hill District Mill Site, Yukon*.

Characterization of physical properties is further described in the DSTF OMS Manual.

4. TAILINGS CHARACTERIZATION PROGRAM

4.1 TAILINGS SAMPLE COLLECTION

The standard testing program includes the geochemical and physical testing monthly. Table 4-1 summarizes the testing requirements, schedule, and approximate sample masses required for each routine test.

Tailings samples will be collected on a weekly basis to prepare a representative monthly composite. Approximately 3 kg should be collected as a grab sample from the tailings pumpbox or filter cake. The sample should be in a sealed container and refrigerated or frozen until it is required to be issued for testing or made into a composite. The monthly composite should be prepared from equally weighted splits of the weekly samples. Similarly, quarterly and annual composites required for mineralogical and kinetic testing, respectively, will be prepared from equally weighted splits of the monthly composites.

Additional grab samples from the tailings pumpbox or filter cake are collected for the physical stability tests as described in the DSTF OMS Manual.

Table 4-1: Routine Tailings Testing Requirements and Frequency

	Analytical Test				
	Tailings Gradation (hydrometer)	Static Geochemistry (ABA, aqua regia metals, SFE)	Mineralogy (XRD)	Humidity Cell	Saturated Column
Approximate (dry) mass required	1 kg	0.5 kg	0.1 kg	1.5 kg	10 kg
Monthly composite	X	X			
Quarterly composite			X		
For new ore bodies or marked change in composition	See Section 4.3 for additional testing requirements	Four consecutive weekly ABA and aqua regia metals	X	X	Required if tailings to be used in underground backfill

4.2 GEOCHEMICAL CHARACTERIZATION

The standard static geochemistry program includes, ABA, metal analysis, SFE, and X-ray diffraction (XRD) and kinetic testing involves humidity cell for tailings going to the DSTF or saturated column for tailings used as underground backfill. Upon receipt, the geochemical data is evaluated, quality checks made, and the data compared to adaptive management thresholds specified in Adaptive Management Initiative #2 of the KHSD Mining Operations Adaptive Management Plan.

4.2.1 GEOCHEMICAL TESTING – STATIC TEST WORK

Geochemical testing to characterize the placed tailings materials will be conducted in accordance with sampling guidance contained in Price (2009):

- A split of the monthly composite will be submitted for ABA (paste pH, Sobek neutralization potential with siderite correction, total inorganic carbon by hydrochloric acid [HCl] leach, total sulphur by Leco, sulphate-sulphur via HCl leach, and sulphide-sulphur by difference), standard 24-hour SFE, and determination of the total metals content using aqua regia digestion and ICP-AES/MS analysis.
- The determination of the neutralization potential for these materials will be conducted using the siderite corrected method due to the elevated presence of this mineral in the tailings.
- If neutralization potential ratios for tailings are less than predicted, frequency of testing may be increased to determine variability.

The geochemical static testing will typically be conducted on a monthly composite. Weekly composite analysis will be conducted if:

- A new mine is brought into production; or
- There is a marked change in the geochemical characteristics of the static monthly data (e.g., the sulphur or metals content of the tailings is significantly higher than usual or the neutralization potential is much lower). The 95th or 5th percentile of the dataset collected to date may be used as the statistic against which such marked increases or decreases can be determined, respectively.

In such cases, weekly splits will be analyzed for ABA and aqua regia metals for at least four consecutive weeks to assess the geochemistry of the new mine or the variability in the parameter(s) that triggered the change in analytical frequency.

4.2.2 GEOCHEMICAL TESTING – KINETIC TEST WORK

Long term humidity cell tests as well as saturated column tests will be initiated from co-mingled tailings sourced from Flame & Moth, and New Bermingham ore. A humidity cell will be started if:

- There is a substantial change in the feed source for the District Mill (e.g., the feed changes from 100% from a single mine to a blend of two or more mines or new ore body); or
- There is a marked change in the geochemical characteristics of the static monthly data (e.g., the sulphur or metals content of the tailings is significantly higher than usual or the neutralization potential is much lower). The 95th or 5th percentile of the dataset collected to date may be used as the statistic against which such marked increases or decreases can be determined, respectively.

The humidity cell will be composed of the first monthly composite containing either the change in feed source or the anomalous geochemical characteristics defined above. In this way, a humidity cell test will be initiated as required to ensure adequate representation of the co-mingled tailings deposited in the DSTF as each new ore body is mined. All humidity cells will be continued until the makeup of the DSTF at the end operations is known or a steady state has been established.

Tailings generated will either be placed in the DSTF or used as backfill in the operating mines. The saturated column testing will be conducted on tailings to assess the acid and metal leaching from the tailings that will be deposited below the flood elevation at the underground mines. Saturated column tests will be initiated for cemented tailings generated from milling Bellekeno, Flame & Moth, and New Bermingham ores. Tailings samples that will be tested for the saturated columns will be the sub samples from the material used for tailings

humidity cell testing and prepared as for backfilling (e.g. cement addition). The water sampling testing frequency will parallel that of the humidity cell testing (e.g. weekly samples).

The humidity cells will operate for a minimum of 40 weeks (Price, 2009). They will be terminated when the concentrations of constituents of potential concern (COPC) (e.g., sulphate, arsenic, antimony, cadmium, copper, lead, nickel, selenium, silver, zinc) have stabilized or are declining and lower than those observed in previous humidity cell testing. Saturated column tests will operate for a minimum of 20 weeks and will be terminated when COPC concentrations or weekly loading rates have stabilized.

4.2.3 MINERALOGICAL TESTING

Mineralogical testing of the tailings will be conducted quarterly. A quarterly composite will be submitted for quantitative Rietveld-XRD to determine the major mineral constituents of the tailings. Also, samples for XRD will be collected from tailings derived from metallurgical tests or processing of new ore bodies. The additional XRF testing is to confirm consistency of the new ore with the predicted characteristics, to meet design.

4.2.4 POREWATER TESTING

Tailings porewater chemistry will be monitored by collecting water from liner drains, monitoring wells installed in the tailings, and or with other instruments (e.g., standpipe piezometers) installed in the tailings. The DSTF Phase 2 design allows for separate water samples to be collected from above and below liner drains.

Well BH-39 is a monitoring well within DSTF Phase 1, which is screened within tailings to identify if porewater is present. Well BH-39 will be replaced by well BH-39N in 2024. Well KV-107 will be installed in DSTF Phase 2 as explained in the DSTF OMS Manual. Sampling will be carried out as described in the Groundwater Management Plan. The new wells will be monitored and sampled monthly (if water is present) for the first 12 months after installation, and then quarterly thereafter. The parameters to be analyzed are listed in Table 4-2. The water level data generated will be compared to adaptive management thresholds specified in Adaptive Management Initiative #6 of the KHSD Mining Operations Adaptive Management Plan.

Table 4-2: Porewater Testing Requirements

	level	temp- erature	pH, conductivity	dissolved metals ¹	total suspended solids	hardness	dissolved organic carbon	alkalinity, anions ²	nutrients ³
In-situ Measurements	X	X	X						
External Laboratory Analysis			X	X	X	X	X	X	X

Notes:

1. Dissolved metals by ICP
2. Anions include phosphorous, sulphate
3. Nutrients include Ammonia-N, Nitrite-N

4.3 PHYSICAL PROPERTY CHARACTERIZATION

4.3.1 PHYSICAL PROPERTY TESTING

The physical parameters of the placed tailings will be verified through a combination of physical monitoring results and laboratory testing programs and modified as necessary to ensure adequate physical characterization of the tailings.

Tailings gradations testing will be performed monthly to confirm that tailings placed in the DSTF conform to the grain size distribution limits specified in the DSTF OMS Manual. Specific gravity will also routinely be tested. The physical property testing methods and frequency are described in the DSTF OMS Manual. Additional laboratory testing considered in the DSTF OMS Manual include soil water characteristic curves, drained and undrained shear strength, and standard proctor maximum dry density compaction tests.

4.3.2 TRIGGERS FOR ADDITIONAL PHYSICAL PROPERTY TESTING

When a new mine comes into production, the first monthly composite will be tested to characterize the gradation, soil-water characteristic curve, and specific gravity; shear strength will be conducted on a quarterly basis. The data generated will be reviewed by the Engineer of Record to confirm consistency with design basis and previous tailings.

Modifications to the program resulting from an interpretation of the results of the physical property testing are described further in the DSTF OMS Manual. The Adaptive Management Plan provides additional guidance for responses to unforeseen or contingency events respecting physical conditions of the DSTF.



5. IMPLEMENTATION SCHEDULE

The assembly of monthly composites of tailings produced from mill feed from the Bellekeno Mine commenced at the start of commercial production in Q1 2010 until temporary suspension of mining in Q3 2013. Routine physical and geochemical testing resumed in Q4 2020 when commercial production resumed from the Bellekeno Mine. The program continued as mill feed from Flame & Moth and New Birmingham mines were added to the production stream. Mill feed from the Bellekeno Mine ceased in Q4 2022.

New humidity cells conducted using actual tailings from Flame & Moth and New Birmingham were initiated in 2024 and will run for a minimum of 40 weeks (trial will be extended until stable chemistry is observed).

A porewater monitoring well (BH-39N) will be installed in 2024 to replace the damaged well (BH-39) within DSTF Phase 1.

6. REPORTING

Documentation of tailings characterization sampling and analyses, and quality assurance/quality control measures implemented will be compiled and included with the annual reports for Water Licence QZ18-044 and Quartz Mining License QML-0009. Annual reports are due on or before March 31 for the prior year.

A record of the following details is included in the annual reports:

- the relative proportions of tailings from each mine (Co-mingled Tailings) deposited monthly into the DSTF,
- a summary of any changes to methodologies or frequencies of the tailings characterization program,
- results of geochemical data generated, including mineralogical, static and kinetic (long-term humidity cell) tests,
- results of physical property data generated, and
- analysis and interpretation of the characterization data by qualified professionals, including
 - an interpretation the quality assurance and quality control programs,
 - a discussion of any variances from previous years' data.
 - an interpretation including the assumptions and conclusions of the geochemical predictions and the effectiveness of existing mitigation measures, and
 - an evaluation of the implications on the physical stability of facilities prone to geochemical weathering predicted from the results of any long-term column tests, and
- a summary of any activities carried out or adaptive management strategies implemented to monitor or address any changes in environmental performance or variances from earlier geochemical predictions.

7. REFERENCES

- EBA Engineering. 2011. *Detailed Design Dry-Stacked Tailings Facility, Keno Hill District Mill Site, Yukon*. EBA File: W14101178.011. Prepared for Alexco Resource Corp. May 2011.
- EBA Engineering. 2012. *EBA Opinion on Properties of Lucky Queen and Onek Tails: For Use in Existing Dry Stack Tailings Disposal Facility, near Bellekeno Mill, YT*. EBA File: W14101178.011. Prepared for Alexco Keno Hill Mining Corp. March 2, 2012.
- Price, W.A. 2009. *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials*. MEND Report 1.20.1. CANMET – Mining and Mineral Science Laboratories, Smithers, BC.
- Tetra Tech EBA Inc. 2014. *Tailings Characterization Plan Physical Testing Requirements, Keno Hill District Mill, Yukon*. EBA File: W14103144. Issued to Access Consulting Group. January 15, 2014.

APPENDIX 1

GEOCHEMICAL CHARACTERIZATION OF ONEK AND LUCKY QUEEN TAILINGS

Memorandum

To: Brad Thrall, Alexco Resource Corp.

From: Kai Woloshyn

Date: September 5, 2012

Re: Geochemical Characterization of Onek and Lucky Queen Tailings

TAILINGS GENERATION

Ore from the Onek and Lucky Queen deposits will be processed at the existing Keno District Mill Site, currently processing Bellekeno ore. Composite tailings generated from Bellekeno, Lucky Queen and Onek ore processing will be deposited in the previously assessed and licenced Dry Stack Tailings Facility (DSTF) and cement paste backfilled as composite into the Bellekeno, Onek or Lucky Queen underground workings.

The Bellekeno tailings streams have not been segregated, as was contemplated during the Bellekeno licencing process, because high pyrite tailings have not been generated as was anticipated during the Bellekeno mine assessment and licencing process. The tailings management approach has been fully discussed with the First Nation of Nacho Nyak Dun and Yukon Government regulators since mill commissioning commenced. The mill process produces two tailings streams based on the zinc extraction circuit (i.e., the zinc rougher and zinc cleaner flotation circuits produce tailings of slightly different compositions). Table 1 summarizes the metallurgical test work completed on the Onek and Lucky Queen Ore samples.

Table Table 2 presents the pyrite and other mineralogical contents of the tailings streams produced from the Onek and Lucky Queen ores and the mill tailings from July to September 2011. The Lucky Queen and Onek tailings have very low sulphide concentrations (less than 0.2%); the Bellekeno tailings also have relatively low sulphide content (~2.6%).

Metallurgical Testing of Onek and Lucky Queen Ore

Process Research Associates Ltd. was commissioned by Alexco to undertake a precious and base metal recovery study on samples originating from the Onek and Lucky Queen deposits during surface drilling programs completed in 2010. The purpose of this testing was to determine the recovery of silver (Ag), lead (Pb) and zinc (Zn) in the flotation circuits in the existing mill, and to evaluate the environmental parameters of the residual tailings. Representative samples from drill core were used to produce a composite sample of Onek and Lucky Queen for metallurgical testing.

The results of the metallurgical testwork indicate that Onek and Lucky Queen ore samples respond well to the current metallurgical flowsheet operating at the mill. There is a direct relationship between metal recovery, head grade and adequate base metals galena and sphalerite (PbS and ZnS) in the feed to maximize silver recovery. Therefore balancing the mill feed grade through the concurrent mining of Lucky Queen, Onek and Bellekeno will assist and be important in optimizing metallurgical performance from the Lucky Queen and Onek deposits. The metallurgical results shown in Tables 1 are not from locked cycle tests but demonstrate the importance of adequate base metal concentrations in the feed grade, most notably sufficient galena to optimize overall lead and silver recovery. Additional optimization testwork will be required for final reagent addition optimization through locked cycle testwork.

The four samples in Tables 1, 2, 3 and 4 represent *composites* of individual samples taken from all portions of the mineralized zone of each deposit. The whole rock analytical analysis including iron (Fe) of each of the four composite samples was presented in Table 3Table . The initial metallurgical testing for the Lucky Queen and Onek projects was based on typical laboratory scale ore sample composites and yielded small volumes of tailings. The scale of the metallurgical testing did not allow for collection of supernatant samples. In addition there was insufficient volume of tailings generated by the testing to allow for the establishment of humidity cells. Additional metallurgical testing and associated ABA testing of Lucky Queen and Onek samples will be ongoing.

The level and detail of metallurgical testwork completed for Onek and Lucky Queen is sufficient to determine that the current mill operations will adequately process ore from these deposits as well as determine that the final mill tailings product is geochemically similar to Bellekeno so that it can be stored in the currently permitted DSTF. Additional metallurgical testing and reagent optimization is a secondary requirement for mill operations performance solely for operational requirements and not for determining the environmental performance and assessment of the tailings. Locked cycle tests were completed on Bellekeno samples to determine the design of the process flowsheet while open cycle tests on Lucky Queen and Onek can be used to determine the compatibility of these ores with the current mill flowsheet. Additional metallurgical testwork will be completed as part of normal mill operations and planning but is not necessary for assessment of environmental performance determination.

Onek and Lucky Queen Tailings Characterization

Following metallurgical testing of Onek and Lucky Queen samples, the modified ABA protocol was used to calculate NP values. Alexco has since instituted a siderite ABA correction package for all tailings and near vein sampling where significant siderite is likely. Subsequent ABA testing in mineralized and near vein material for Lucky Queen and Onek will also use the siderite correction method.

The results shown in Table 2 are for the bulk tailings produced from the metallurgical flowsheet tested. As the results indicate, the tailings from Onek and Lucky Queen are well above a standard neutralization potential (NP) ratio (3:1) and potential acid generation is not expected. One of the primary reasons for the high NP ratio is the significantly less acid potential due to lower total sulphur and base metals (i.e. PbS) in Onek and Lucky Queen as compared to Bellekeno.

Carbonate species present in Onek and Lucky Queen tailings in approximate order of abundance include siderite, calcite, ankerite and possibly dolomite/ferroan dolomite.

Table 1 Metallurgical Testwork Summary of Onek and Lucky Queen Ore

Test ID	Sample ID	Products	Mass (%)	Grade			Recovery		
				Ag (g/t)	Pb (%)	Zn (%)	Ag (%)	Pb (%)	Zn (%)
F7	Onek	Head Grade		92.3	0.21	25.17			
		Pb Cl concentrate	0.6	6899.4	32.23	11.35	48.4	74.0	0.3
		Zn Cl concentrate	37.3	45.9	0.04	53.29	21.7	6.2	85.3
		Final Tailings	44.4	2.2	0.01	0.23	1.2	0.4	0.4
F8	Onek	Head Grade		333.8	3.59	12.03			
		Pb Cl concentrate	2.8	5196.5	70.97	3.10	46.5	56.7	0.7
		Zn Cl concentrate	16.2	127.0	0.24	48.44	6.7	1.1	68.1
		Final Tailings	65.0	11.0	0.08	1.76	2.3	1.5	9.9
F9	Lucky Queen	Head Grade		2251.8	4.49	3.15			
		Pb Cl concentrate	6.6	33084.2	65.86	2.97	93.3	95.1	5.7
		Zn Cl concentrate	4.3	214.7	0.16	58.79	0.4	0.2	73.6
		Final Tailings	80.3	8.3	0.06	0.10	0.3	1.1	2.4
F10	Lucky Queen	Head Grade		4527.7	10.40	4.58			
		Pb Cl concentrate	12.1	34837.3	70.47	1.88	84.6	87.3	4.8
		Zn Cl concentrate	5.9	301.2	0.74	58.94	0.4	0.4	72.5
		Final Tailings	67.7	20.9	0.09	0.06	0.3	0.6	0.9

Table 2 Onek and Lucky Queen Tailings ABA Summary

Item	SampleID	$S_{(T)}$	$S_{(SO_4)}$	Paste	Acid	Neutralization Potential (NP)		
		%	%	pH	Potential	Actual	Ratio	Net
1	F7 Final tailing/Onek	0.17	0.03	7.8	4.4	36.8	8.4	32.4
2	F8 Final tailing/Onek	0.15	0.05	7.8	3.1	26.0	8.3	22.9
3	F9 Final tailing/Lucky Queen	0.18	0.04	8.2	4.4	20.4	4.7	16.0
4	F10 Final tailing/Lucky Queen	0.19	0.04	7.5	4.7	17.8	3.8	13.1
DUP	F7 Final tailing/Onek	0.17	0.03	7.8	4.4	37.1	8.5	32.8
Bellekeno Tailings, January to May 2011 Monthly Average		2.61	0.06	8.1	81.62	276.2	3.4	194.6

The final tailings deposited in the DSTF or underground as composite paste backfill at either Bellekeno, Lucky Queen or Onek will be a combination of Onek, Lucky Queen and Bellekeno ores. Given the current performance of the Bellekeno tailings and the ABA testwork completed for Onek and Lucky Queen, bulk tailings stored on the DSTF are not a concern from an acid generating potential perspective. The Onek and Lucky Queen tailings are shown to be geochemically similar or better to Bellekeno in Tables 2 to 4, and therefore the storage of the Onek and Lucky Queen tailings in the DSTF is appropriate.

Metals analysis of the tailings from the Lucky Queen and Onek metallurgical program was completed and the results are shown in Table 3. Shake Flask Extraction (SFE) test results for the Lucky Queen tailing samples F9 and F10 are presented in Table 4. The metal leaching concentrations from the Lucky Queen tailings SFE test are similar or less than those observed in the Bellekeno tailings porewater samples and the Bellekeno humidity cell.

Humidity cells have not been established for any of the geological materials at the Lucky Queen or Onek sites. The Onek and Lucky Queen tailings are low sulphide (<0.2%) (see Table 2); therefore, they are not anticipated to be acid-generating. The following factors are relevant to characterizing the potential effects of deposition of Lucky Queen and Onek tailings:

- tailings placed as backfill into the underground workings will be cemented backfill which includes a cement binder that will effectively reduce the leachability and permeability of the backfilled tailings;
- during the operations phase of the mine, the DSTF seepage is collected and routed to the Mill Pond for use in the processing circuit;
- any discharges from the Mill Pond already require treatment to achieve EQS under QZ09-092;
- at closure the DSTF will have a soil cover installed to reduce infiltration in addition to a bioreactor to provide ongoing long-term water treatment during the post-closure period; and
- humidity cells were not provided or deemed necessary for assessment or licensing of the Bellekeno mine but instead have been commissioned during operations. The information provided for the Lucky Queen and Onek assessment is considered consistent with that approach.

Additional metallurgical testing on the Lucky Queen and Onek ores is currently being advanced by Alexco and the tailings generated by this testing will be utilized for additional geochemical testing programs.

Elevated concentrations of sphalerite (ZnS) in the tailings will result in leachate containing higher concentrations of zinc. Sample F8 from Onek in Tables 1 and 2 had a low zinc recovery; consequently, there is a considerable amount of zinc in the metallurgical analysis of the tailings shown in Table 3. Through metallurgical optimization, zinc recovery will increase; consequently, zinc concentrations in the tailings and leachate will decrease. During operations, leachate from the DSTF will be collected and recycled in the mill processing, or diverted to the mill water treatment plant. At closure, the DSTF will be covered to minimize water infiltration and leachate will be treated with a passive bioreactor system.

Bellekeno Tailings Characterization

Characterization of the actual tailings generated from Bellekeno ores has been ongoing and the results of the humidity cell tests currently in operation on representative tailings from the Bellekeno deposit for the first 47 weeks of humidity cell operation are shown presented in Table 5 and Figures 1 to 3. The ABA and metallurgical monthly averages from January to May 2011 for the Bellekeno tailings are shown in Table 2 and 3, respectively. The humidity cells for Bellekeno have been in operation over 47 weeks and results to date show a decreasing trend in metal concentrations for arsenic, copper, lead and nickel in the cell leachate over time. The exception to the observed trends is zinc and cadmium. Zinc has shown an increasing trend to a concentration of approximately 3 mg/L while cadmium has a current concentration of approximately 0.008 mg/L. The 47 week humidity cell data is presented in Table 5Table . Alexco intends to continue to operate this cell through 2012 and into 2013. At closure the DSTF will be covered. Table 7 presents the XRD mineralogical analysis of the composite Bellekeno tailings samples collected in July, August and September 2011.

Table 3 Onek and Lucky Queen Tailings Metallurgical Analysis

Elements	Units	Sample ID				Bellekeno Tailings
		F7 Cut Tailings/ Onek	F8 Cut Tailings/ Onek	F9 Cut Tailings/ Lucky Queen	F10 Cut Tailings/Lucky Queen	January to May 2011 Monthly Average
C-Inorg	%	0.34	0.06	0.21	0.23	3.91
S(SO4)	%	0.03	0.05	0.04	0.04	0.06
Ag	ppm	3.2	9.6	9.6	23.2	53.08
Al	%	0.36	0.36	0.99	0.49	1.12
As	ppm	344	406	13	22	3526
Ba	ppm	18	30	169	80	180
Bi	ppm	<2	<2	<2	<2	3
Ca	%	0.65	0.28	0.48	0.27	1.55
Cd	ppm	14.4	131.1	4.9	3.0	255
Co	ppm	<1	2	3	<1	14.6
Cr	ppm	168	180	454	77	19
Cu	ppm	384	370	281	226	270
Fe	%	18.38	18.82	5.8	6.99	13.73
K	%	0.07	0.09	0.37	0.18	0.33
La	ppm	15	<10	<10	<10	8.66
Mg	%	0.55	0.39	0.36	0.32	0.40
Mn	ppm	52200	51678	21651	27757	42420
Mo	ppm	<1	<1	2	<1	0.81
Na	%	0.02	0.02	0.03	0.02	0.074
Ni	ppm	52	36	69	33	20
P	ppm	115	165	141	122	178
Pb	ppm	81	744	423	686	3498
Sb	ppm	<5	<5	9.0	<5	60
Sc	ppm	3	2	2	1	4
Sr	ppm	10	12	20	10	42
Ti	%	<0.01	<0.01	0.02	<0.01	0.04
Tl	ppm	15	20	<10	11	0.424
V	ppm	5	6	17	8	22
W	ppm	<10	177	<10	<10	1.46
Zn	ppm	1937	15630	697	416	1749

Table 4 Shake Flask Extraction Results for Lucky Queen Tailings Samples

Mine/Dump Location	Units	Lucky Queen Tailings	
		Lucky Queen Bulk Tails F9	Lucky Queen Bulk Tails F10
Leachable Anions & Nutrients			
Alkalinity, Total (as CaCO ₃)	mg/L	28.2	25.1
Bromide (Br)	mg/L	<0.050	<0.050
Chloride (Cl)	mg/L	1.51	0.89
Conductivity	us/cm	434	352
Fluoride (F)	mg/L	0.078	0.035
Nitrate (as N)	mg/L	0.0259	0.0254
Nitrite (as N)	mg/L	0.0072	0.0053
pH	pH	8.1	8.0
Sulfate (SO ₄)	mg/L	183	140
Hardness (as CaCO ₃)	mg/L	204	158
Leachable Metals			
Aluminum (Al)-Leachable	mg/L	<0.0050	<0.0050
Antimony (Sb)-Leachable	mg/L	0.016	0.0116
Arsenic (As)-Leachable	mg/L	<0.0010	<0.0010
Barium (Ba)-Leachable	mg/L	0.037	0.0459
Beryllium (Be)-Leachable	mg/L	<0.00050	<0.00050
Bismuth (Bi)-Leachable	mg/L	<0.00050	<0.00050
Boron (B)-Leachable	mg/L	0.025	0.014
Cadmium (Cd)-Leachable	mg/L	0.00164	0.00509
Calcium (Ca)-Leachable	mg/L	74.9	59.6
Chromium (Cr)-Leachable	mg/L	<0.00050	<0.00050
Cobalt (Co)-Leachable	mg/L	0.0002	0.00702
Copper (Cu)-Leachable	mg/L	0.0303	0.0503
Iron (Fe)-Leachable	mg/L	<0.030	<0.030
Lead (Pb)-Leachable	mg/L	0.0181	0.112
Lithium (Li)-Leachable	mg/L	<0.0050	<0.0050
Magnesium (Mg)-Leachable	mg/L	3.96	2.27
Manganese (Mn)-Leachable	mg/L	0.765	1.14
Mercury (Hg)-Leachable	mg/L	<0.000050	<0.000050
Molybdenum (Mo)-Leachable	mg/L	0.00318	0.00078
Nickel (Ni)-Leachable	mg/L	0.00067	0.00253
Phosphorus (P)-Leachable	mg/L	<0.30	<0.30
Potassium (K)-Leachable	mg/L	3.93	1.87
Selenium (Se)-Leachable	mg/L	0.00871	0.00463
Silicon (Si)-Leachable	mg/L	1.91	1.11
Silver (Ag)-Leachable	mg/L	0.000144	0.000627
Sodium (Na)-Leachable	mg/L	6.19	4.57
Strontium (Sr)-Leachable	mg/L	0.193	0.141
Thallium (Tl)-Leachable	mg/L	0.00011	<0.00010
Tin (Sn)-Leachable	mg/L	<0.00050	<0.00050
Titanium (Ti)-Leachable	mg/L	<0.010	<0.010
Uranium (U)-Leachable	mg/L	0.000011	<0.000010
Vanadium (V)-Leachable	mg/L	<0.0010	<0.0010
Zinc (Zn)-Leachable	mg/L	0.0189	0.0955

Table 5 Bellekeno Humidity Cell Results up to Week 47

Sample ID	MILL TAILS COMPOSITE-JAN- JUN2011-0	MILL TAILS COMPOSITE-JAN- JUN2011-1	MILL TAILS COMPOSITE-JAN- JUN2011-2	MILL TAILS COMPOSITE-JAN- JUN2011-3	MILL TAILS COMPOSITE-JAN- JUN2011-4	MILL TAILS COMPOSITE-JAN- JUN2011-5	MILL TAILS COMPOSITE-JAN- JUN2011-6	MILL TAILS COMPOSITE-JAN- JUN2011-7	MILL TAILS COMPOSITE-JAN- JUN2011-8	MILL TAILS COMPOSITE-JAN- JUN2011-9	MILL TAILS COMPOSITE-JAN- JUN2011-10	MILL TAILS COMPOSITE-JAN- JUN2011-11
Date Sampled	17-AUG-11	24-AUG-11	31-AUG-11	07-SEP-11	14-SEP-11	21-SEP-11	28-SEP-11	05-OCT-11	12-OCT-11	19-OCT-11	26-OCT-11	02-NOV-11
ALS Sample ID	L1045358-1	L1049390-1	L1051834-1	L1054437-1	L1057740-1	L1060984-1	L1064228-1	L1067341-1	L1070094-1	L1073037-1	L1076479-1	L1079310-1
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Sample Preparation												
Total Volume In	750	500	500	500	500	500	500	500	500	500	500	500
Total Volume Out	550	460	460	450	450	475	435	485	475	450	500	460
Physical Tests												
Conductivity	1950	1050	1050	822	648	553	523	415	463	435	438	428
pH	7.89	7.7	7.86	7.81	7.91	7.81	7.91	7.86	7.84	7.79	7.91	7.83
Anions and Nutrients												
Acidity (as CaCO ₃)	5	4.8	5.8	10.9	5	3.4	5.6	7.1	7.2	6.3	10.4	5.1
Alkalinity, Total (as CaCO ₃)	43	45	68.3	64.5	49.6	62.7	68.4	78.3	73.7	73.9	72.1	75.6
Bromide (Br)	<0.050	<0.50	<0.5	<0.50	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	15.6	7.4	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Fluoride (F)	0.354	0.37	0.34	0.34	0.288	0.27	0.254	0.208	0.183	0.164	0.161	0.179
Nitrate (as N)	10.1	3.36	<0.050	<0.050	0.0148	0.0065	0.0096	0.0052	<0.0050	<0.0050	0.007	0.0066
Nitrite (as N)	0.0845	0.089	0.011	<0.010	0.0064	<0.0010	0.0036	0.0046	<0.0010	0.0016	0.0012	0.0043
Sulfate (SO ₄)	1150	513	595	455	320	248	230	158	189	172	181	184
Dissolved Metals												
Aluminum (Al)-Dissolved	<0.010	<0.010	<0.010	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0219	<0.0050	<0.0050	<0.0050
Antimony (Sb)-Dissolved	0.023	0.0241	0.0222	0.0178	0.0159	0.0166	0.0159	0.016	0.0164	0.0154	0.0155	0.0152
Arsenic (As)-Dissolved	0.00081	0.00195	0.00248	0.0015	0.00139	0.00104	0.00079	0.00091	0.0008	0.0008	0.00083	0.00078
Barium (Ba)-Dissolved	0.0985	0.056	0.0372	0.0359	0.0387	0.0347	0.0371	0.0381	0.0395	0.0368	0.0389	0.0371
Beryllium (Be)-Dissolved	<0.00020	<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	<0.0010	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Boron (B)-Dissolved	0.166	0.157	0.185	0.117	0.075	0.076	0.054	0.037	0.134	0.029	0.025	0.024
Cadmium (Cd)-Dissolved	0.0264	0.0216	0.0339	0.0292	0.0228	0.0263	0.0249	0.0205	0.0294	0.0292	0.0333	0.0328
Calcium (Ca)-Dissolved	439	217	240	192	150	119	121	90.3	101	94.3	100	94.2
Chromium (Cr)-Dissolved	<0.0010	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Cobalt (Co)-Dissolved	0.00155	0.00089	0.00289	0.00318	0.00179	0.00198	0.002	0.0015	0.00223	0.002	0.00223	0.00219
Copper (Cu)-Dissolved	0.0049	<0.0010	<0.0010	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Iron (Fe)-Dissolved	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Lead (Pb)-Dissolved	0.192	0.161	0.137	0.104	0.111	0.128	0.123	0.0971	0.0956	0.107	0.104	0.0985
Lithium (Li)-Dissolved	0.0608	0.0495	0.0488	0.0269	0.0196	0.0162	0.0113	0.00832	0.0074	0.00656	0.00592	0.00589
Magnesium (Mg)-Dissolved	17.3	10.6	10.3	6.94	4.64	3.7	2.89	1.89	2.05	1.71	1.67	1.46
Manganese (Mn)-Dissolved	3.69	1.81	4.07	3.71	2.11	2.13	2.08	1.53	1.81	1.59	1.72	1.6
Mercury (Hg)-Dissolved	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	0.00463	0.00467	0.00422	0.00327	0.00376	0.00393	0.00387	0.00361	0.00333	0.00314	0.00299	0.00319
Nickel (Ni)-Dissolved	0.0037	0.0015	0.0042	0.00415	0.00193	0.00223	0.00209	0.00154	0.00264	0.00217	0.00238	0.00209
Phosphorus (P)-Dissolved	0.61	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Dissolved	27.1	13	8.75	4.78	3.74	2.88	2.23	1.57	1.58	1.3	1.29	1.17
Selenium (Se)-Dissolved	0.00176	0.00109	0.00076	0.00075	0.00054	0.00044	0.00042	0.00028	0.00031	0.00029	0.00028	0.00026
Silicon (Si)-Dissolved	2.48	2.82	4.61	3.76	4.07	4.28	4.42	4.11	3.97	3.98	4.07	4.17
Silver (Ag)-Dissolved	0.00801	0.000588	<0.000020	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Sodium (Na)-Dissolved	67.5	23.3	10.4	3.64	2.14	1.35	0.853	0.562	0.746	0.46	0.477	0.426
Strontium (Sr)-Dissolved	1.33	0.623	0.565	0.382	0.276	0.249	0.245	0.179	0.185	0.166	0.168	0.187
Sulfur (S)-Dissolved	459	249	198	147	111	86.1	78.8	53.1	63.5	58.5	60.9	57.7
Thallium (Tl)-Dissolved	0.000564	0.000455	0.000381	0.000248	0.000147	0.000189	0.000218	0.000232	0.000105	0.000097	0.000099	0.000263
Tin (Sn)-Dissolved	<0.00020	<0.00020	<0.00020	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Dissolved	<0.010	<0.010	<0.010	<0.010	0.016	0.014	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Dissolved	0.000725	0.000413	0.000698	0.000526	0.000315	0.000276	0.000261	0.000179	0.000243	0.000193	0.000212	0.000188
Vanadium (V)-Dissolved	<0.0020	<0.0020	<0.0020	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	0.478	0.587	1.97	2.16	1.16	1.77	1.82	1.56	2.34	2.23	2.71	2.87

Sample ID	MILL TAILS COMPOSITE-JAN-JUN2011-12	MILL TAILS COMPOSITE-JAN-JUN2011-13	MILL TAILS COMPOSITE-JAN-JUN2011-14	MILL TAILS COMPOSITE-JAN-JUN2011-15	MILL TAILS COMPOSITE-JAN-JUN2011-16	MILL TAILS COMPOSITE-JAN-JUN2011-17	MILL TAILS COMPOSITE-JAN-JUN2011-18	MILL TAILS COMPOSITE-JAN-JUN2011-19	MILL TAILS COMPOSITE-JAN-JUN2011-20	MILL TAILS COMPOSITE-JAN-JUN2011-21	MILL TAILS COMPOSITE-JAN-JUN2011-22	MILL TAILS COMPOSITE-JAN-JUN2011-23
Date Sampled	09-NOV-11	16-NOV-11	23-NOV-11	30-NOV-11	07-DEC-11	14-DEC-11	21-DEC-11	28-DEC-11	04-JAN-12	11-JAN-12	18-JAN-12	25-JAN-12
ALS Sample ID	L1082246-1	L1084760-1	L1087901-1	L1090459-1	L1092271-1	L1095037-1	L1097547-1	L1099484-1	L1100871-1	L1102681-1	L1104828-1	L1106888-1
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Sample Preparation												
Total Volume In	500	500	500	500	500	500	500	500	500	500	500	500
Total Volume Out	460	480	450	475	470	450	460	410	445	425	420	490
Physical Tests												
Conductivity	359	408	362	374	362	341	397	512	525	505	472	435
pH	7.85	7.91	7.87	7.95	7.90	7.8	7.9	7.95	7.88	7.84	7.8	7.9
Anions and Nutrients												
Acidity (as CaCO ₃)	6.2	7.5	5.8	7.7	4.8	5.7	7.8	6.2	7.1	6.2	6.2	8.8
Alkalinity, Total (as CaCO ₃)	71.3	71.7	72.3	72.4	72.7	71.2	64.9	58.2	48.7	62.8	66.3	66.1
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Fluoride (F)	0.138	0.125	0.124	0.113	0.111	0.174	0.097	0.106	0.111	0.108	0.098	0.101
Nitrate (as N)	0.0064	0.0062	0.0141	0.0061	<0.0050	0.0101	0.0137	<0.0050	0.0061	0.01	0.0096	0.0076
Nitrite (as N)	0.0046	0.0052	0.0056	0.0046	0.004	0.0069	0.0054	0.0049	0.0026	0.0056	0.0045	0.0025
Sulfate (SO ₄)	128	159	129	138	130	119	129	194	206	193	175	148
Dissolved Metals												
Aluminum (Al)-Dissolved	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Antimony (Sb)-Dissolved	0.0141	0.0146	0.0145	0.0142	0.013	0.0129	0.013	0.0124	0.0107	0.0099	0.00986	0.0103
Arsenic (As)-Dissolved	0.00075	0.00087	0.00076	0.00084	0.00083	0.00082	0.00089	0.00092	0.00076	0.00084	0.00098	0.00145
Barium (Ba)-Dissolved	0.0397	0.0441	0.0397	0.0417	0.0415	0.04	0.04	0.0465	0.045	0.0431	0.04	0.05
Beryllium (Be)-Dissolved	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Boron (B)-Dissolved	0.019	0.018	0.015	0.017	0.015	0.01	0.01	0.013	0.011	0.01	0.01	<0.010
Cadmium (Cd)-Dissolved	0.0272	0.0329	0.0318	0.0342	0.0351	0.03	0.04	0.0391	0.0465	0.0485	0.05	0.05
Calcium (Ca)-Dissolved	79.2	94.6	79.7	80.6	80.6	79.50	76.70	102	103	104	97.40	85.30
Chromium (Cr)-Dissolved	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Cobalt (Co)-Dissolved	0.00164	0.00213	0.00183	0.00194	0.00188	0.00	0.00	0.00184	0.00188	0.00201	0.00	0.00
Copper (Cu)-Dissolved	<0.00050	0.0005	0.00062	0.00074	0.00078	0.00	0.00	<0.00050	<0.00050	0.00059	0.00	0.00
Iron (Fe)-Dissolved	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Lead (Pb)-Dissolved	0.0893	0.0894	0.0927	0.0918	0.0886	0.09	0.08	0.0794	0.0943	0.0898	0.10	0.09
Lithium (Li)-Dissolved	0.00417	0.00426	0.00365	0.00339	0.00291	0.00	0.00	0.00297	0.00282	0.00284	0.00	0.00
Magnesium (Mg)-Dissolved	1.09	1.28	1.04	1.09	1	0.90	0.97	1.28	1.39	1.45	1.28	1.28
Manganese (Mn)-Dissolved	1.18	1.5	1.22	1.47	1.27	1.15	1.15	1.13	1.2	1.23	1.30	1.36
Mercury (Hg)-Dissolved	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Molybdenum (Mo)-Dissolved	0.00295	0.00277	0.00268	0.00265	0.00259	0.00	0.00	0.00268	0.00266	0.00231	0.00	0.00
Nickel (Ni)-Dissolved	0.00158	0.002	0.00161	0.00175	0.00163	0.00	0.00	0.00157	0.00125	0.00143	0.00	0.00
Phosphorus (P)-Dissolved	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Dissolved	0.846	0.923	0.807	0.794	0.727	0.64	0.65	0.715	0.702	0.618	0.58	0.63
Selenium (Se)-Dissolved	0.0002	0.00022	0.00017	0.0002	0.00019	0.00	0.00	0.00022	0.0002	0.00017	0.00	0.00
Silicon (Si)-Dissolved	3.67	3.71	3.73	3.51	3.62	3.36	3.21	3.01	2.95	2.98	2.94	3.25
Silver (Ag)-Dissolved	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Sodium (Na)-Dissolved	0.35	0.352	0.295	0.305	0.289	0.26	0.29	0.338	0.322	0.315	0.28	0.31
Strontium (Sr)-Dissolved	0.129	0.148	0.147	0.144	0.134	0.12	0.11	0.147	0.174	0.146	0.14	0.12
Sulfur (S)-Dissolved	43.4	54.1	44.3	46.7	43.5	40.50	44.40	65.8	70.6	65.8	59.30	50.50
Thallium (Tl)-Dissolved	0.000076	0.000079	0.000243	0.000267	0.000222	0.00	0.00	0.000078	0.000238	0.000091	0.00	0.00
Tin (Sn)-Dissolved	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Dissolved	<0.010	0.01	0.011	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	<0.010	<0.010	<0.010
Uranium (U)-Dissolved	0.000127	0.000184	0.000124	0.000147	0.000129	0.00	0.00	0.0002	0.000178	0.000153	0.00	0.00
Vanadium (V)-Dissolved	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Dissolved	2.14	2.69	2.55	2.71	2.76	2.64	2.72	2.18	2.69	2.98	2.91	3.47

Sample ID	MILL TAILS COMPOSITE- JAN-JUN2011-24	MILL TAILS COMPOSITE-JAN- JUN2011-29	MILL TAILS COMPOSITE-JAN- JUN2011-30	MILL TAILS COMPOSITE-JAN- JUN2011-31	MILL TAILS COMPOSITE-JAN- JUN2011-32	MILL TAILS COMPOSITE-JAN- JUN2011-33	MILL TAILS COMPOSITE-JAN- JUN2011-34	MILL TAILS COMPOSITE-JAN- JUN2011-35	MILL TAILS COMPOSITE-JAN- JUN2011-36	MILL TAILS COMPOSITE-JAN- JUN2011-37	MILL TAILS COMPOSITE-JAN- JUN2011-38	MILL TAILS COMPOSITE-JAN- JUN2011-39
Date Sampled	01-FEB-12	07-MAR-12	14-MAR-12	21-MAR-12	28-MAR-12	04-APR-12	11-APR-12	18-APR-12	25-APR-12	02-MAY-12	09-MAY-12	16-MAY-12
ALS Sample ID	L1109203-1	L1121471-1	L1123018-1	L1125306-1	L1127559-1	L1130834-1	L1133140-1	L1135454-1	L1138358-1	L1141290-1	L1143994-1	L1147310-1
Matrix	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Sample Preparation												
Total Volume In	500	500	500	500	500	500	500	500	500	500	500	500
Total Volume Out	425	460	475	500	470	425	480	455	475	475	500	455
Physical Tests												
Conductivity	409	382	344	351	369	383	322	341	332	309	294	330
pH	7.97	7.91	7.85	7.9	7.9	7.93	7.79	7.92	7.9	7.9	7.85	7.88
Anions and Nutrients												
Acidity (as CaCO ₃)	4.1	5.4	7.4	8.3	9	11.5	6.9	10.3	15	12.8	8	6.2
Alkalinity, Total (as CaCO ₃)	58.2	65.5	64.8	59.8	54.9	57.1	49	61.2	58.8	49.2	55.3	49.3
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Fluoride (F)	0.092	0.08	0.08	0.073	0.071	0.071	0.059	0.068	0.067	0.059	0.05	0.058
Nitrate (as N)	0.0104	0.0063	0.0074	0.0085	0.0095	0.0056	0.0057	<0.0050	0.0069	<0.0050	0.0194	0.0061
Nitrite (as N)	0.0052	0.0015	0.0019	0.0014	0.0017	0.0019	0.0018	0.001	0.0014	0.0012	<0.0010	<0.0010
Sulfate (SO ₄)	141	124	109	112	122	131	102	112	106	94.3	88.7	108
Dissolved Metals												
Aluminum (Al)-Dissolved	<0.0050		<0.0050		<0.0050		<0.0050		<0.0050		<0.0050	
Antimony (Sb)-Dissolved	0.00943		0.00812		0.00817		0.00804		0.00749		0.00858	
Arsenic (As)-Dissolved	0.0011		0.00155		0.00129		0.00168		0.00145		0.00154	
Barium (Ba)-Dissolved	0.0407		0.0393		0.04		0.0388		0.04		0.0408	
Beryllium (Be)-Dissolved	<0.00010		<0.00010		<0.00010		<0.00010		<0.00010		<0.00010	
Bismuth (Bi)-Dissolved	<0.00050		<0.00050		<0.00050		<0.00050		<0.00050		<0.00050	
Boron (B)-Dissolved	<0.010		<0.010		<0.010		<0.010		<0.010		<0.010	
Cadmium (Cd)-Dissolved	0.0433		0.0491		0.05	0.0498	0.0538	0.0604	0.05	0.06	0.0525	0.0505
Calcium (Ca)-Dissolved	83.5		62.1		67.00		58.2		67.90		55.3	
Chromium (Cr)-Dissolved	<0.00050		<0.00050		<0.00050		<0.00050		<0.00050		<0.00050	
Cobalt (Co)-Dissolved	0.00195		0.00256		0.00		0.00277		0.00		0.00307	
Copper (Cu)-Dissolved	0.00082		0.00192		0.00		0.00225		0.00		0.00261	
Iron (Fe)-Dissolved	<0.030		<0.030		<0.030		<0.030		<0.030		<0.030	
Lead (Pb)-Dissolved	0.0809		0.0779		0.08		0.0834		0.09		0.0926	
Lithium (Li)-Dissolved	0.00238		0.00172		0.00		0.00099		0.00		0.00148	
Magnesium (Mg)-Dissolved	1.07		0.862		0.99		0.939		1.12		1.02	
Manganese (Mn)-Dissolved	1.04		1.09		0.96		1.03		0.98		1.01	
Mercury (Hg)-Dissolved	<0.000010		<0.000010		<0.000010		<0.000010		<0.000010		<0.000010	
Molybdenum (Mo)-Dissolved	0.00223		0.00178		0.00		0.00158		0.00		0.00162	
Nickel (Ni)-Dissolved	0.00145		0.00188		0.00		0.00204		0.00		0.00234	
Phosphorus (P)-Dissolved	<0.30		<0.30		<0.30		<0.30		<0.30		<0.30	
Potassium (K)-Dissolved	0.497		0.385		0.37		0.331		0.35		0.317	
Selenium (Se)-Dissolved	0.00017		0.00014		0.00		0.00012		0.00		0.00013	
Silicon (Si)-Dissolved	2.87		2.72		2.43		2.41		2.58		2.45	
Silver (Ag)-Dissolved	<0.000010		<0.000010		<0.000010		<0.000010		<0.000010		<0.000010	
Sodium (Na)-Dissolved	0.241		0.209		0.20		0.184		0.20		0.172	
Strontium (Sr)-Dissolved	0.119		0.104		0.11		0.101		0.10		0.103	
Sulfur (S)-Dissolved	50.7		36.7		39.40		34.7		36.70		29.6	
Thallium (Tl)-Dissolved	0.000058		0.000038		0.00		0.000039		0.00		0.000041	
Tin (Sn)-Dissolved	<0.00010		<0.00010		<0.00010		<0.00010		<0.00010		<0.00010	
Titanium (Ti)-Dissolved	<0.010		<0.010		<0.010		<0.010		<0.010		<0.010	
Uranium (U)-Dissolved	0.000099		0.000049		0.00		0.000042		0.00		0.000037	
Vanadium (V)-Dissolved	<0.0010		<0.0010		<0.0010		<0.0010		<0.0010		<0.0010	
Zinc (Zn)-Dissolved	2.76	4.25	3.72	3.14	3.11	3.35	3.48	4.28	3.01	3.87	3.29	2.6

Sample ID	MILL TAILS COMPOSITE- JAN-JUN2011-40	MILL TAILS COMPOSITE-JAN- JUN2011-41	MILL TAILS COMPOSITE-JAN- JUN2011-42	MILL TAILS COMPOSITE-JAN- JUN2011-43	MILL TAILS COMPOSITE-JAN- JUN2011-44	MILL TAILS COMPOSITE-JAN- JUN2011-45	MILL TAILS COMPOSITE-JAN- JUN2011-46	MILL TAILS COMPOSITE-JAN- JUN2011-47
Date Sampled	23-MAY-12	30-MAY-12	06-JUN-12	13-JUN-12	20-JUN-12	27-JUN-12	04-JUL-12	11-JUL-12
ALS Sample ID	L1150106-1	L1153466-1	L1156963-1	L1160871-1	L1164482-1	L1167961-1	L1171477-1	L1174741-1
Matrix	Water	Water	Water	Water	Water	Water	Water	Water
Sample Preparation								
Total Volume In	500	500	500	500	500	500	500	500
Total Volume Out	485	495	490	475	475	475	470	475
Physical Tests								
Conductivity	299	299	292	281	277	274	271	270
pH	7.80	7.9	7.8	7.91	7.9	7.93	7.9	7.9
Anions and Nutrients								
Acidity (as CaCO ₃)	8.8	14.9	14.3	8.7	7.7	12.9	5.3	6.8
Alkalinity, Total (as CaCO ₃)	57.9	55.5	62.8	58.8	48.5	47.4	49.1	56.2
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Fluoride (F)	0.052	0.05	0.048	0.044	0.041	0.037	0.038	0.04
Nitrate (as N)	0.0054	0.0067	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.015
Nitrite (as N)	<0.0010	<0.0010	0.0019	0.0018	<0.0010	0.0013	0.0019	0.0012
Sulfate (SO ₄)	92.9	90.9	87.4	81.8	82.7	82.3	79.9	78
Dissolved Metals								
Aluminum (Al)-Dissolved	<0.0050		<0.0050		<0.0050		<0.0050	FIELD
Antimony (Sb)-Dissolved	0.0077		0.008		0.00729		0.00719	
Arsenic (As)-Dissolved	0.0016		0.00168		0.00137		0.00141	
Barium (Ba)-Dissolved	0.0446		0.05		0.0468		0.05	
Beryllium (Be)-Dissolved	<0.00010		<0.00010		<0.00010		<0.00010	
Bismuth (Bi)-Dissolved	<0.00050		<0.00050		<0.00050		<0.00050	
Boron (B)-Dissolved	<0.010		<0.010		<0.010		<0.010	
Cadmium (Cd)-Dissolved	0.0596	0.06	0.06	0.0614	0.0481	0.0493	0.05	0.06
Calcium (Ca)-Dissolved	53.9		56.60		52.8		51.20	
Chromium (Cr)-Dissolved	<0.00050		<0.00050		<0.00050		<0.00050	
Cobalt (Co)-Dissolved	0.0035		0.00		0.0036		0.00	
Copper (Cu)-Dissolved	0.00241		0.00		0.00261		0.00	
Iron (Fe)-Dissolved	<0.030		<0.030		<0.030		<0.030	
Lead (Pb)-Dissolved	0.0831		0.09		0.0875		0.09	
Lithium (Li)-Dissolved	0.00207		0.00		0.00165		0.00	
Magnesium (Mg)-Dissolved	1.32		1.43		1.46		1.54	
Manganese (Mn)-Dissolved	1.14		1.20		1.06		1.20	
Mercury (Hg)-Dissolved	<0.000010		<0.000010		<0.000010		<0.000010	
Molybdenum (Mo)-Dissolved	0.00139		0.00		0.00138		0.00	
Nickel (Ni)-Dissolved	0.00278		0.00		0.00282		0.00	
Phosphorus (P)-Dissolved	<0.30		<0.30		<0.30		<0.30	
Potassium (K)-Dissolved	0.329		0.32		0.311		0.31	
Selenium (Se)-Dissolved	0.00015		0.00		0.00015		0.00	
Silicon (Si)-Dissolved	2.57		2.62		2.48		2.49	
Silver (Ag)-Dissolved	<0.000010		<0.000010		<0.000010		<0.000010	
Sodium (Na)-Dissolved	0.183		0.18		0.159		0.16	
Strontium (Sr)-Dissolved	0.0966		0.09		0.0919		0.09	
Sulfur (S)-Dissolved	31.1		29.30		27.4		27.00	
Thallium (Tl)-Dissolved	0.000039		0.00		0.000037		0.00	
Tin (Sn)-Dissolved	<0.00010		<0.00010		<0.00010		<0.00010	
Titanium (Ti)-Dissolved	<0.010		<0.010		<0.010		<0.010	
Uranium (U)-Dissolved	0.000035		0.00		0.00003		0.00	
Vanadium (V)-Dissolved	<0.0010		<0.0010		<0.0010		<0.0010	
Zinc (Zn)-Dissolved	3.86	3.65	3.61	4.07	2.63	2.89	2.96	3.96

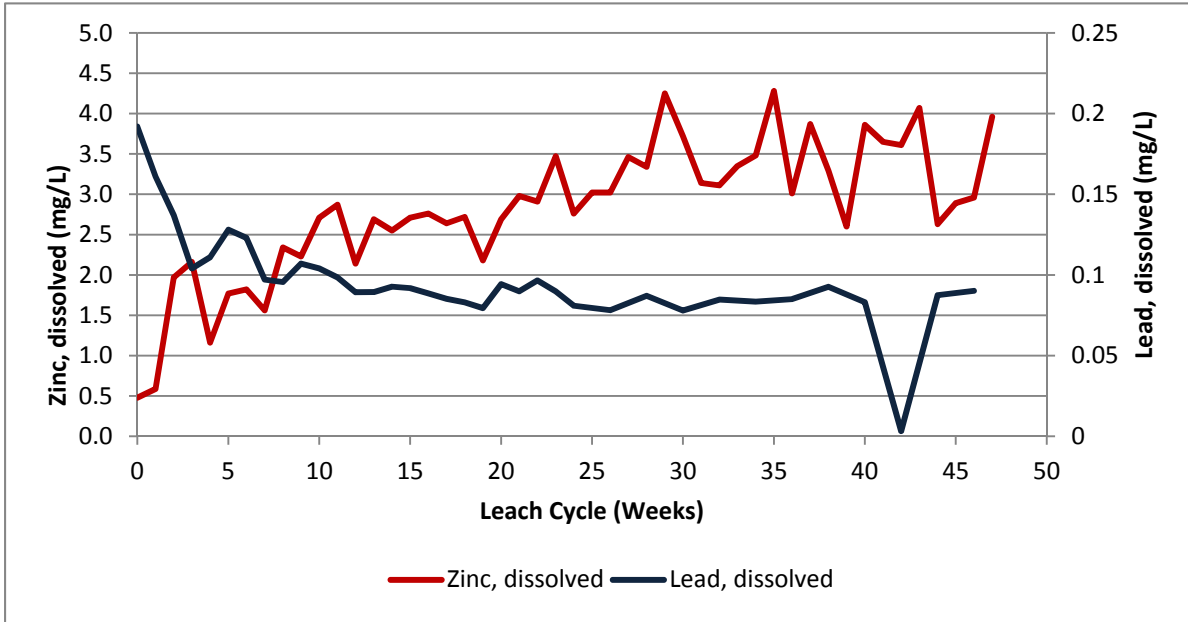


Figure 1 Bellekeno Tailings Humidity Cell Dissolved Zinc and Lead

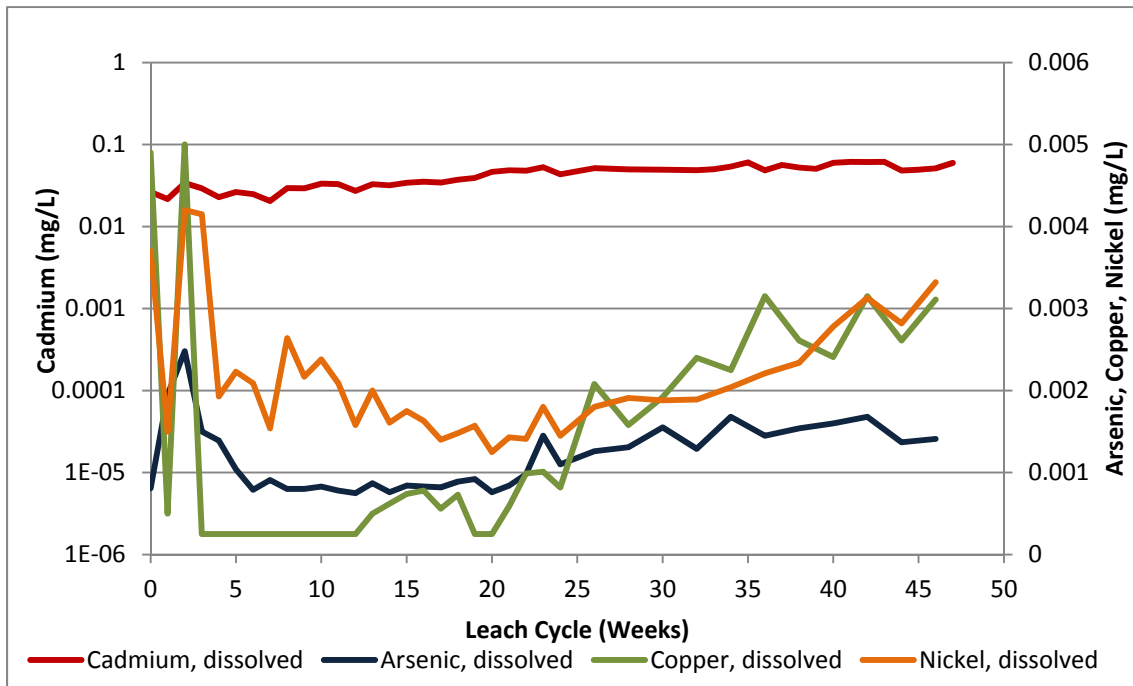


Figure 2 Bellekeno Tailings Humidity Cell Dissolved As, Cd, Cu and Ni

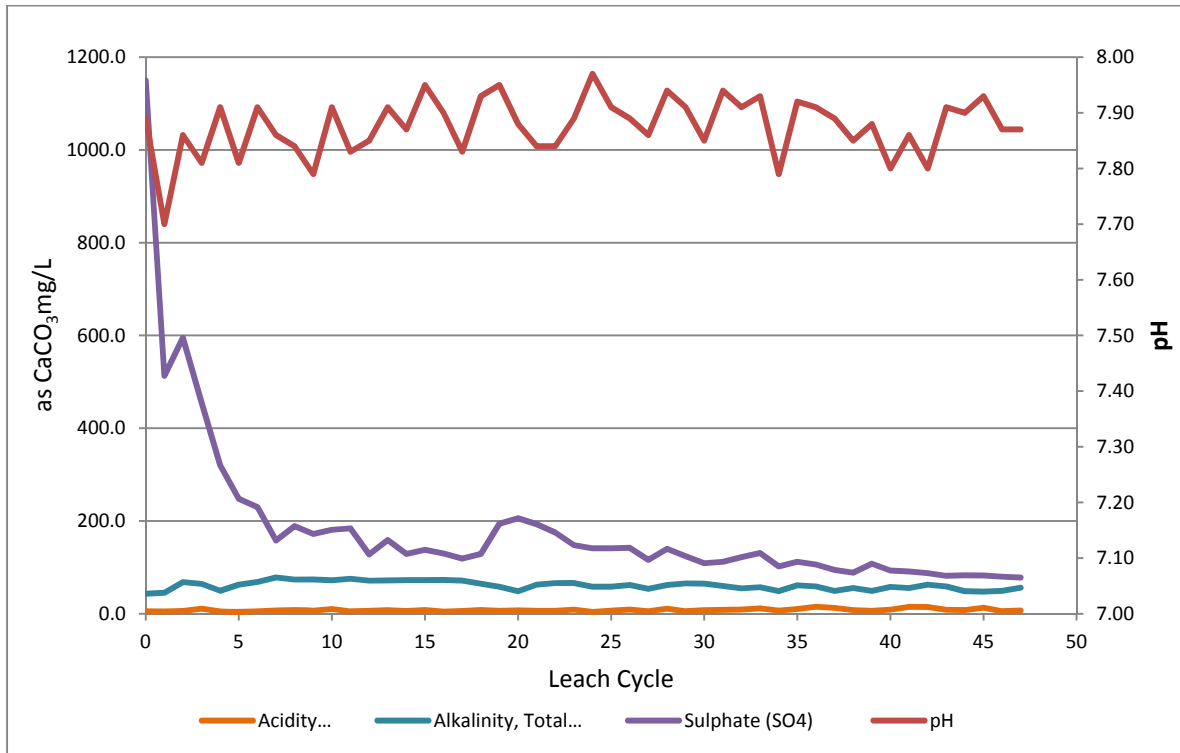


Figure 3 Bellekeno Tailings Humidity Cell Alkalinity, Acidity, pH and Sulphate

Laboratory test results were used previously to assess and predict the pore water quality of the filtered tailings from Bellekeno. This filter press filtrate quality was used to predict environmental effects from storage of tailings in the Dry Stack Tailings Facility. Table 6 compares the actual filter press filtrate of tailings from Bellekeno against the prediction of filter press filtrate quality obtained from laboratory testing on Bellekeno. The comparison demonstrates that the actual filter press filtrate is significantly better than predicted from the testwork.

Table 6 Bellekeno Tailings Filter Press Filtrate Data

Elements	Units	Bellekeno Filter press filtrate From Testwork	Actual Tailings Filter press filtrate Chemistry (Average 2011)	Actual Tailings Filter press filtrate Chemistry (Average 2012)
Sb	mg/L	<0.1	0.0516	0.0498
As	mg/L	<0.2	0.00647	0.00375
Cd	mg/L	0.12	0.00425	0.00465
Ca	mg/L	145	772	768
Cr	mg/L	<0.01	0.00025	0.0019
Cu	mg/L	0.64	0.403	0.281
Fe	mg/L	4.77	0.212	0.133
Pb	mg/L	0.45	0.0990	0.133
Ag	mg/L	<0.02	0.0236	0.0446
Zn	mg/L	20.31	0.0280	0.0627

Of most significance is the significantly lower zinc concentration in the filter press filtrate as compared to the testwork. The estimate of 20 mg/L zinc was used as the basis for potential environmental effects on groundwater from the DSTF and the comparison demonstrates that the initial estimate was highly conservative and actual water quality is significantly improved. In addition, a geosynthetic clay liner (GCL) layer was added to the DSTF design and has been installed below the DSTF footprint as a requirement under MMER to capture and measure any seepage from the tailings. The liner feature below the DSTF was not considered during the original assessment of the Bellekeno mine or a condition of the QML, but rather an outcome during the water licensing phase. The combination of the substantially high ABA ratio (3.8 to 8.4 : 1) due to the lower sulphur content of the Onek and Lucky Queen ores, preliminary results of the Bellekeno humidity cell tests, similarity of the Onek and Lucky Queen geochemical characteristics, consideration of the actual performance of the Bellekeno tailings and porewater chemistry compared to previously assessed testwork, and the addition of a GCL layer to the DSTF design give considerable confidence and justification for depositing filtered tailings from Onek and Lucky Queen into the currently authorized DSTF.

Alexco notes that during operations, any DSTF seepage is collected and routed to the Mill Pond for use in the processing circuit. Any discharges from the Mill Pond require treatment to achieve Effluent Quality Standards under QZ09-092. There has been no mill discharge to date since the mill was commissioned in late 2010. At closure the DSTF will have a soil cover installed to reduce infiltration, in addition to a bioreactor to provide ongoing long-term water treatment during the post-closure period.

Table 7 Results of XRD-Rietveld Mineralogical Analysis (weight %) of Bellekeno Composite Tailings

Minerals	Zn Rougher Tailings	Zn Cleaner Tailings	Final Mill Tailings	Minerals	Zn Rougher Tailings	Zn Cleaner Tailings	Final Mill Tailings	Minerals	Zn Rougher Tailings	Zn Cleaner Tailings	Final Mill Tailings	Final Mill Tailings
	July 2011 Composite	July 2011 Composite	July 2011 Composite		August 2011 Composite	August 2011 Composite	August 2011 Composite		September 2011 Composite	September 2011 Composite	September 2011 Composite	February 2012 Composite
Quartz	53.44	47.07	51.27	Quartz	53.36	45.38	54.29	Quartz	51.14	46.86	48.75	47.2
Siderite	32.16	26.08	34.31	Siderite	30.37	22.27	31.33	Siderite	31.66	25.05	32.79	35.1
Muscovite	5.53	10.76	4.62	Muscovite	6.33	12.92	5.68	Muscovite	6.39	10.69	6.19	7.3
Calcite	2.23	5.17	2.92	Calcite	2.77	4.88	2.70	Calcite	3.27	4.42	2.68	2.8
Sphalerite	1.75	5.17	3.27	Sphalerite	0.94	3.40	1.83	Sphalerite	1.52	2.81	2.76	2.8
Pyrite	1.96	1.91	2.35	Pyrite	2.10	2.24	2.21	Pyrite	2.56	1.65	2.77	3.1
Galena	0.18	1.31	0.38	Galena	0.11	1.04	0.27	Galena	0.15	0.71	0.51	0.6
Plagioclase	2.36	0	0.00	Plagioclase	2.29	2.05	0	Plagioclase	2.54	2.72	0.00	0
Ankerite	0	1.02	0.66	Ankerite	1.73	0	0.58	Ankerite	0	0.52	0.99	1.1
Gahnite	0	0	0.23	Gypsum	0	1.20	0	Gypsum	0	1.22	0	0
Chalcopyrite	0.27	0	0	Rutile	0	0.67	0	Arsenopyrite	0	0	0.33	0
Clinochlore	0	0.86	0	Clinochlore	0	1.79	0	Clinochlore	0.78	1.26	0.97	0
Rutile	0	0.65	0	Clinozoisite	0	2.17	0	Clinozoisite	0	2.11	0.00	0
Wurtzite	0.12	0	0	K-feldspar	0	0	1.13	K-feldspar	0	0	1.26	0
Total	100.0	100.0	100.0	Total	100.0	100.0	100.0	Total	100.0	100.0	100.0	100.0

APPENDIX 2

SUMMARY OF GEOCHEMICAL CHARACTERIZATION OF FLAME & MOTH TAILINGS



Memorandum

To: Kai Woloshyn, Alexco Resource Corp.

From: Andrew Gault, Alexco Environmental Group

Date: August 6, 2015

Re: Summary of Geochemical Characterization of Flame & Moth Tailings

1 INTRODUCTION

Ore from the Flame & Moth deposit will be processed at the existing Keno District Mill Site, currently licenced for processing ore from the Bellekeno, Lucky Queen and Onek mines. Tailings generated from Flame & Moth ore processing will be deposited in one of the following locations:

1. Areas of the previously assessed and licenced Dry Stack Tailings Facility (DSTF);
2. Expansion areas of the DSTF (described in section C of the Application); and
3. Cement paste backfilled as composite into the Bellekeno, Onek, Lucky Queen, or Flame & Moth underground workings.

Past metallurgical and geochemical testing of the composite tailings produced from processing of ore from the unmined Onek and Lucky Queen deposits has indicated they are geochemically similar to those produced from the Bellekeno mine and are suitable for co-disposal (Access, 2012). This memorandum summarizes the geochemical testing data collected from composite tailings produced from Flame & Moth ore, particularly with respect to metal leaching and/or acid rock generation (ML/ARD), and places it in the context of the Bellekeno tailings geochemistry.

2 FLAME & MOTH GEOCHEMICAL TESTING

The tailings produced from the metallurgical testing that showed optimal metal recovery (tests F4 and F5) were used for geochemical characterization since these represented the material that would remain following the most likely metal recovery process employed at the District Mill. These tailings were combined into a composite sample (F4+F5) and submitted to ALS Chemex Labs for static and kinetic testing. Acid base

accounting (ABA) testing was conducted using the Sobek method with siderite correction. Aqua regia digestion followed by ICP-MS and ICP-AES analysis was used to determine the metals content of the tailings composite, whereas the mineralogical makeup of the sample was determined by Rietveld X-ray diffraction (XRD) (latter work performed at the Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia). A standard 24 hour shake flask extraction (SFE) test was also performed using a 3:1 liquid to solid ratio using deionized water as the extracting fluid according to the procedure described in Price (2009). Kinetic testing was also performed on this composite sample; a humidity cell of the F4&F5 composite was established in July, 2013 and is still in operation at the time of writing.

3 RESULTS

3.1 METALS CONTENT

The ICP metals composition of the Flame & Moth F4+F5 composite tailings is shown in Table 3-1, alongside the average of monthly ICP analyses of composite tailings samples produced from Bellekeno ore between July 2012 and August 2013 (when Bellekeno mining and milling operations were suspended). The concentration of a number of minor and trace metals and metalloids of main geoenvironmental interest (arsenic, lead, cadmium, zinc, and selenium) were lower in the Flame & Moth F4+F5 tailings composite sample than the Bellekeno monthly tailings composite average (Table 3-1). Other parameters that were higher in the Flame & Moth composite included chromium, copper, iron, manganese, nickel, and molybdenum.

Table 3-1: Elemental composition of Flame & Moth and Bellekeno composite tailings

Element	Unit	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite Jul 12 - Aug 13
Aluminum (Al)	%	0.2	0.2
Antimony (Sb)	ppm	41	120.6
Arsenic (As)	ppm	699	2147
Barium (Ba)	ppm	11.5	16.4
Beryllium (Be)	ppm	0.14	<0.2
Bismuth (Bi)	ppm	6.59	2.1
Cadmium (Cd)	ppm	7.19	165.8
Calcium (Ca)	%	0.59	1.52
Chromium (Cr)	ppm	185.5	5.5
Cobalt (Co)	ppm	2.7	9.9
Copper (Cu)	ppm	565	242.4
Iron (Fe)	%	16.25	10.09
Lead (Pb)	ppm	789	6359
Lithium (Li)	ppm	1.2	<5.0
Magnesium (Mg)	%	0.31	0.31
Manganese (Mn)	%	4.28	3.22
Mercury (Hg)	ppm	0.055	0.191
Molybdenum (Mo)	ppm	3.74	1.16
Nickel (Ni)	ppm	86.6	19.5
Phosphorus (P)	%	0.01	0.02
Potassium (K)	%	0.03	0.04
Selenium (Se)	ppm	0.1	0.52
Silver (Ag)	ppm	12.35	50.1
Sodium (Na)	%	0.006	0.014
Strontium (Sr)	ppm	4.81	24.0
Thallium (Tl)	ppm	0.652	0.129
Tin (Sn)	ppm	32.9	17.6
Titanium (Ti)	%	0.001	0.002
Uranium (U)	ppm	0.406	1.052
Vanadium (V)	ppm	9.4	5.18
Zinc (Zn)	ppm	1265	12623

3.2 ABA

The ABA characteristics of the Flame & Moth F4+F5 composite tailings are displayed in Table 3-2 alongside the average of monthly ABA analyses of Bellekeno tailings between January 2011 and July 2013. Both the Flame & Moth and Bellekeno tailings exhibited a slightly alkaline paste pH and high carbonate and bulk neutralization potential (NP). The carbonate-NP was significantly higher than the bulk NP in both samples due to the presence of a large proportion of siderite (FeCO_3), which does not contribute to acid neutralization under oxidizing conditions.

Sulphide-sulphur comprised the bulk of total sulphur in both tailings; the Flame & Moth composite sample had a much lower sulphur content than the Bellekeno tailings (Table 3-2). Indeed, although the Flame & Moth tailings had a lower bulk NP, its neutralization potential ratio (NPR; 7.1), derived by dividing the bulk NP by the acid potential (AP), was much higher than that of the Bellekeno tailings (1.9). The lower sulphide-sulphur (and hence low AP, which is calculated from the sulphide-sulphur concentration) accounts for the higher NPR for the Flame & Moth sample. An $\text{NPR} > 2$ typically indicates that acid generation is not expected (Price, 2009), suggesting that the Flame & Moth tailings will not give rise to acid generation following disposal.

Table 3-2: ABA characteristics of Flame & Moth and Bellekeno tailings

Sample	Fizz Rating	pH	S _{total}	S _{sulphide}	S _{SO4}	C	CO ₂	CO ₃ -NP	Bulk NP	AP	NNP	NPR
Unit	Unity	Unity	%	%	%	%	%	kg CaCO ₃ /t			Unity	
Flame & Moth F4+F5 Composite Tailings	3	8	0.45	0.43	0.02	4.66	17.1	389	100	14.1	86	7.1
Bellekeno Tailings, Jan 11- July 13 Monthly Avg.	3	8.1	2.30	2.21	0.02	3.30	12.0	273	132	71.7	61	1.9

3.3 MINERALOGY

XRD analysis of the Flame & Moth tailings composite indicated it was dominated by equal parts of quartz (SiO_2 ; 45 wt. %) and siderite (FeCO_3 ; 45 wt. %) (Table 3-3). Both these phases also dominated the mineralogy of the Bellekeno tailings (53 wt. % quartz, 30 wt. % siderite). Notably, the main base metal sulphides in both ores, sphalerite (ZnS) and galena (PbS), were below the limit of detection for the Flame & Moth sample, but present in the Bellekeno composite tailings at 2.4 wt. % and 0.6 wt. % abundance, respectively (Table 3-3). Pyrite (FeS_2) was also present at a higher concentration in the Bellekeno tailings (2.3 wt. %) than in the Flame & Moth tailings composite (0.7 wt. %). Conversely, the calcite (CaCO_3) content of the Bellekeno tailings (3.2 wt. %) was higher than that of the Flame & Moth tailings composite (1.2 wt. %).

The XRD data corroborate the ABA and ICP metals results, showing that within the Flame & Moth composite, the lower bulk NP is due to lower calcite content, the lower AP is due to lower pyrite content, and the lower base metals (Pb and Zn) are due to lower galena and sphalerite content. The overall balance of contained minerals is primarily due to higher siderite content in the Flame & Moth composite, which is reflected in the higher manganese shown in the ICP metals results; manganese often substitutes for iron in siderite.

Table 3-3: Mineralogy of Flame & Moth and Bellekeno composite tailings as determined by XRD

Mineral	Flame & Moth F4 + F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13
Quartz	45.20	52.62
Siderite	45.30	29.81
Muscovite	2.50	6.56
Calcite	1.20	3.20
Sphalerite	0	2.42
Pyrite	0.70	2.27
Galena	0	0.58
Plagioclase	0	0.81
Ankerite	0	0.41
Gahnite	0	0.17
Chalcopyrite	0	0.08
Clinocllore	1.30	0.35
Rutile	0	0.31
Wurtzite	0	0.16
K-Feldspar	0	0.26
Dravite	3.2	0
Cassiterite	0.5	0
Total	100	100

3.4 SFE

SFE provides a measure of the soluble metals in the sample that may be mobilized upon flushing. SFE data for both the Flame & Moth tailings composite and the Bellekeno tailings composite are shown in Table 3-4. Many metals of geoenvironmental interest were leachable in the Flame & Moth composite sample at similar or lower concentrations than the Bellekeno composite, including arsenic, cadmium, lead, selenium, and zinc. Similar to the contained trace metal content measured by ICP, several elements showed higher leachable concentrations

in the Flame & Moth composite compared with the Bellekeno monthly composite, including copper, manganese, and nickel. Elements with elevated ICP contained metal concentrations were generally reflected in the element's leachability, although the relationship was not necessarily directly proportional. For example, although ICP contained zinc in the Bellekeno composite was an order of magnitude higher than the Flame & Moth composite, SFE leachable zinc was higher in the Flame & Moth SFE leachate.

Table 3-4: SFE leachable metals from Flame & Moth and Bellekeno tailings composites

Leachable Metals	Unit	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13
Aluminum (Al)-Leachable	mg/L	0.0109	0.0282
Antimony (Sb)-Leachable	mg/L	0.0217	0.0387
Arsenic (As)-Leachable	mg/L	0.0061	0.0072
Barium (Ba)-Leachable	mg/L	0.0253	0.0234
Beryllium (Be)-Leachable	mg/L	<0.00050	<0.00050
Bismuth (Bi)-Leachable	mg/L	<0.00050	<0.00050
Boron (B)-Leachable	mg/L	0.0710	0.0942
Cadmium (Cd)-Leachable	mg/L	0.0024	0.00318
Calcium (Ca)-Leachable	mg/L	105	138
Chromium (Cr)-Leachable	mg/L	<0.00050	<0.00050
Cobalt (Co)-Leachable	mg/L	0.0004	0.00031
Copper (Cu)-Leachable	mg/L	0.0271	0.0096
Iron (Fe)-Leachable	mg/L	<0.030	<0.030
Lead (Pb)-Leachable	mg/L	0.0144	0.0593
Lithium (Li)-Leachable	mg/L	0.0071	0.0339
Magnesium (Mg)-Leachable	mg/L	6.9000	6.01
Manganese (Mn)-Leachable	mg/L	1.9500	0.797
Mercury (Hg)-Leachable	mg/L	0.0001	<0.000050
Molybdenum (Mo)-Leachable	mg/L	0.0024	0.0108
Nickel (Ni)-Leachable	mg/L	0.0012	0.0009
Phosphorus (P)-Leachable	mg/L	<0.30	<0.30
Potassium (K)-Leachable	mg/L	2.0400	10.6
Selenium (Se)-Leachable	mg/L	0.0009	0.00106
Silicon (Si)-Leachable	mg/L	1.5500	3.4
Silver (Ag)-Leachable	mg/L	0.0009	0.0018

Sodium (Na)-Leachable	mg/L	2.3600	24.1
Strontium (Sr)-Leachable	mg/L	0.3800	0.515
Thallium (Tl)-Leachable	mg/L	0.0001	0.0002
Tin (Sn)-Leachable	mg/L	<0.00050	<0.00050
Titanium (Ti)-Leachable	mg/L	0.0100	0.012
Uranium (U)-Leachable	mg/L	0.0000	0.00162
Vanadium (V)-Leachable	mg/L	<0.0010	<0.0010
Zinc (Zn)-Leachable	mg/L	0.1560	0.051

3.5 HUMIDITY CELL

At the time of writing, 100 weeks of data were available for the Flame & Moth F4+F5 tailings composite humidity cell. The Bellekeno tailings humidity cell is also ongoing, with 200 weeks of data available. Data from both humidity cells over the first 100 weeks of their operation is plotted for comparison in Figure 3-1 to Figure 3-3. Where appropriate, the QZ09-092 water licence effluent quality standard (EQS) and Canadian Council of Ministers of the Environment Freshwater Aquatic Life (CCME-FAL) thresholds are also shown for context.

Both the Flame & Moth and Bellekeno tailings humidity cell leachates have shared similar stable pH, alkalinity and acidity levels (Figure 3-1). The Bellekeno tailings showed higher dissolved sulphate levels over the first 100 weeks of operation, likely due to the higher sulphide content of these tailings. Both dissolved zinc and cadmium concentrations were approximately an order of magnitude higher in the Bellekeno humidity cell leachate. Indeed, following the initial flush of soluble material in the first few weeks of operation of the Flame & Moth humidity cell, the concentration of both zinc and cadmium remained below their respective EQS (Figure 3-1). Similar behaviour was observed for copper, nickel, lead, and silver with all four of these elements remaining below their EQS for both of the composite tailings samples (Figure 3-2). Arsenic and antimony concentrations were highest in the Flame & Moth humidity cell effluent for the first 60 weeks of operation, before they declined to similar levels as those measured in the Bellekeno tailings humidity cell leachate (Figure 3-3). The leachate from both humidity cells was always well below the arsenic EQS, and after 60 weeks, below CCME-FAL. Indeed, sub-CCME-FAL concentrations were observed for the longer term (>60 weeks) Flame & Moth humidity cell leachate samples for lead, nickel, silver, arsenic, antimony (Ontario provincial water quality objective used in absence of CCME-FAL guideline), and selenium (Figure 3-2 and Figure 3-3).

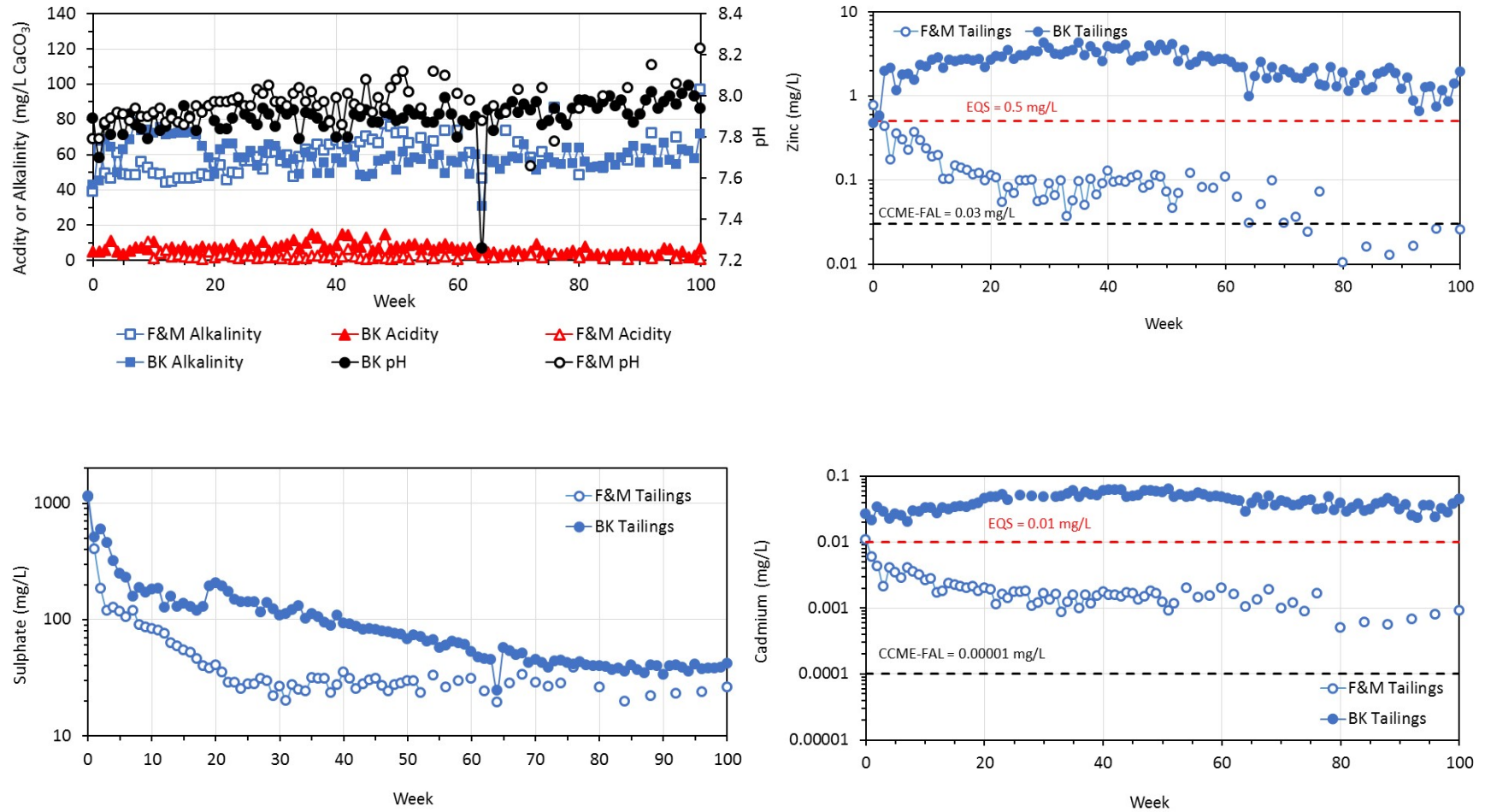


Figure 3-1: Change in pH, alkalinity, acidity (top left), sulphate (bottom left), zinc (top right), and cadmium (bottom right) in humidity cell leachate from Flame & Moth and Bellekeno tailings. Note log scale.

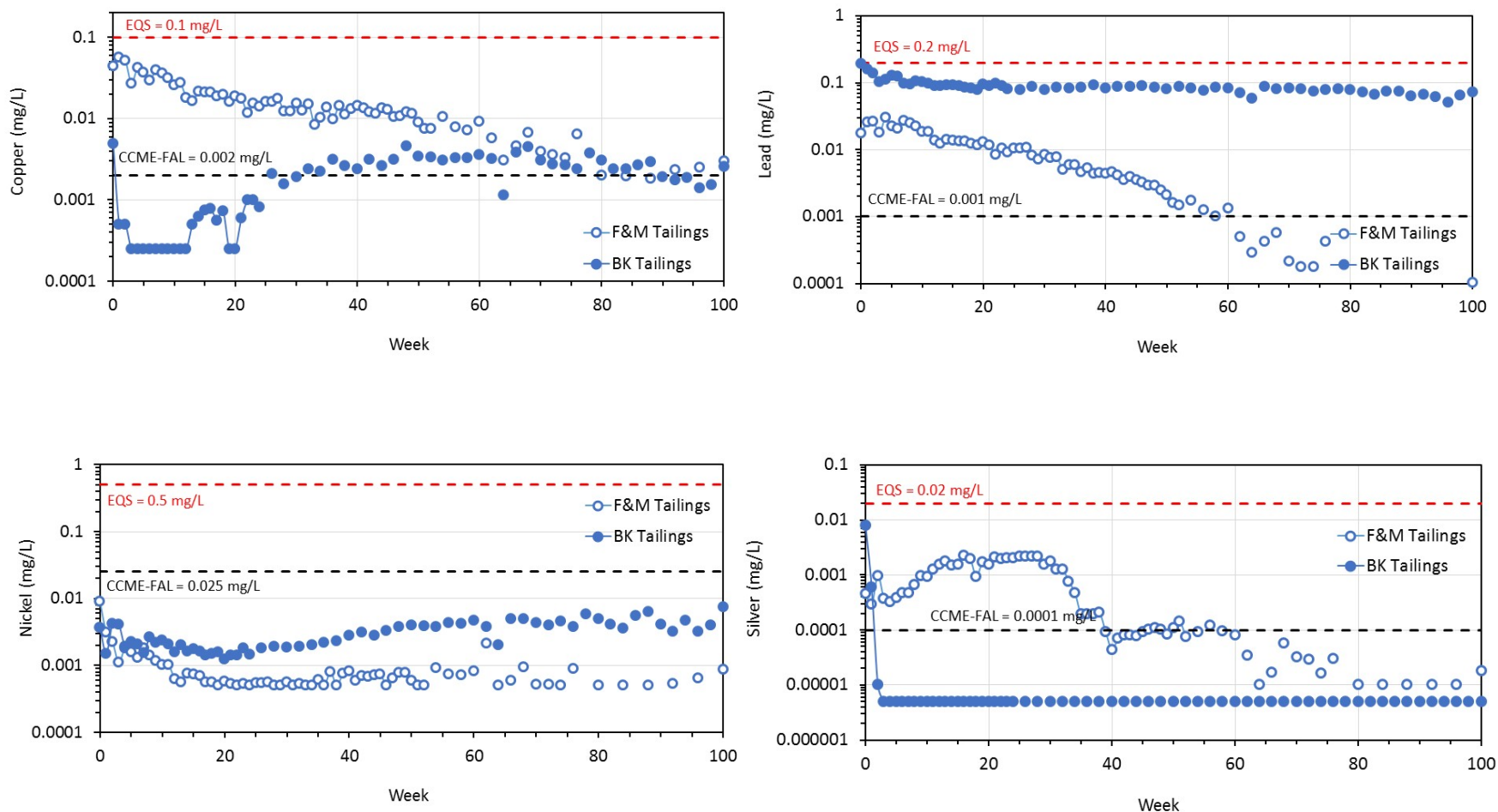


Figure 3-2: Change in copper (top left), nickel (bottom left), lead (top right), and silver (bottom right) in humidity cell leachate from Flame & Moth and Bellekeno tailings. Note log scale.

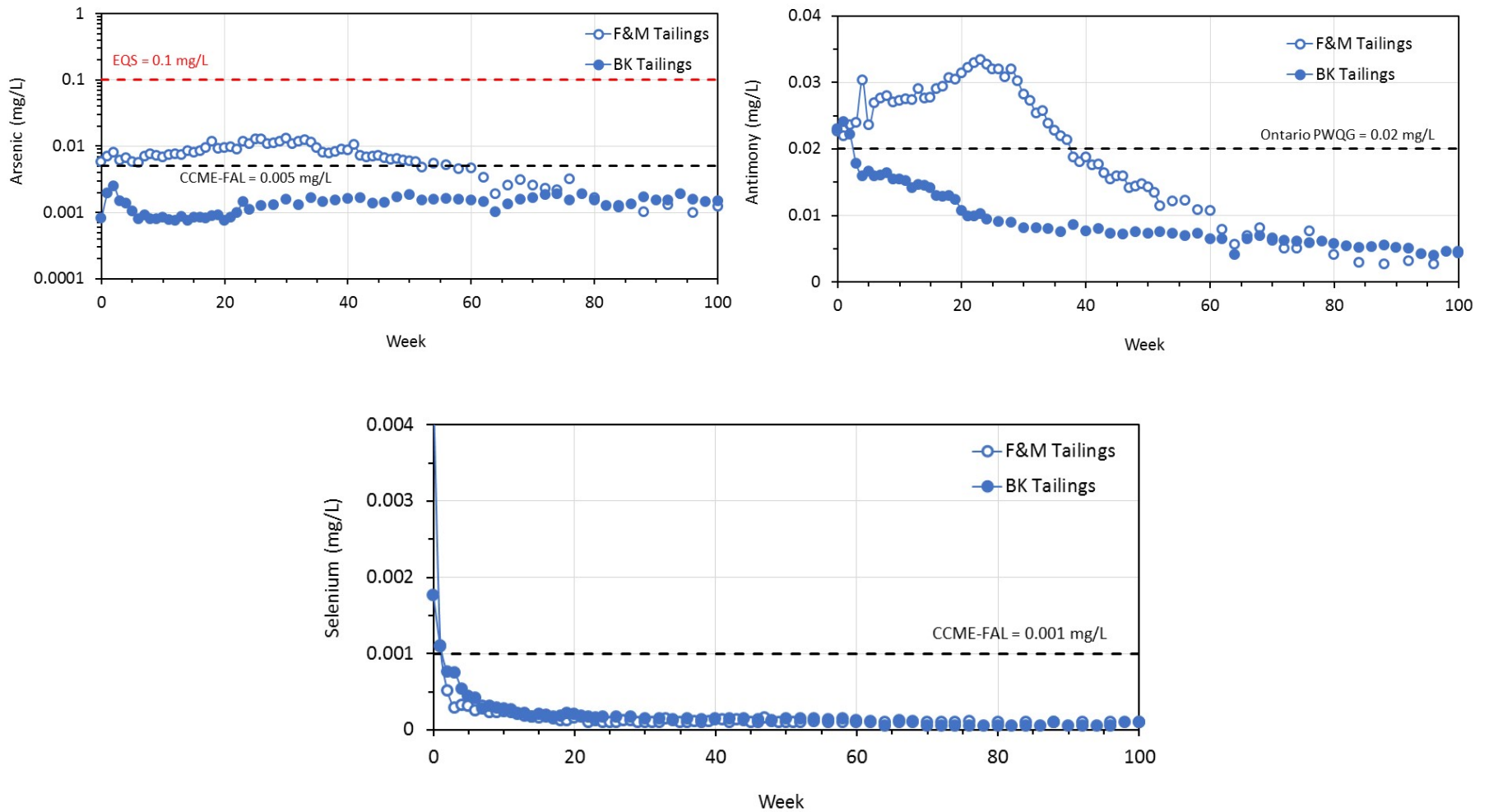


Figure 3-3: Change in arsenic (top left), antimony (top right), and selenium (bottom) in humidity cell leachate from Flame & Moth and Bellekeno tailings. Note log scale for arsenic.

4 SUMMARY

Comparative testing of the Flame & Moth F4+F5 composite tailings and those produced by the District Mill from Bellekeno ore indicates that both share similar geochemistry, with the Flame & Moth tailings showing slightly more favourable ML/ARD characteristics in the form of lower sulphide content, higher NPR (indicative of non-acid generating status), and lower leaching of cadmium and zinc, which are the primary constituents of concern in surface waters of the District (Minnow, 2015). Given the similar and/or more favourable geochemical characteristics of the Flame & Moth tailings, they are suitable for co-disposal with Bellekeno, Lucky Queen and Onek tailings in the existing DSTF and its proposed extension.

5 REFERENCES

- Access Consulting Group. (2012) *Memorandum: Geochemical Characterization of the Onek and Lucky Queen Tailings*. September 5, 2012.
- Minnow Environmental Inc. (2015) *Draft Memorandum: Proposed Water Quality Goals for United Keno Hill Complex Watersheds*. February 23, 2015.
- Price, W.A. (2009) *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials*. MEND Report 1.20.1. CANMET – Mining and Mineral Science Laboratories, Smithers, BC.

APPENDIX 3

GEOCHEMICAL CHARACTERIZATION OF BIRMINGHAM LOCKED CYCLE TAILINGS

Memorandum

To: Alexco Keno Hill Mining Corp.

From: Cheibany Ould Elemine, P.Geo., Ensero Solutions Canada, Inc.

Date: September 9, 2020

Re: Geochemical Characterization of Birmingham Locked Cycle Tailings

1 INTRODUCTION

The Birmingham Mine Development and Production Project has received Water Licence QZ18-044 and amended Quartz Mining License QML-0009 authorizing the development and production of the deposit in addition to the Flame and Moth and Bellekeno deposits. This memorandum has been updated to satisfy the requirements of the Water Licence and Quartz Mining License.

The scope of the Birmingham Project includes the development of underground workings and ventilation/escape raise, construction of surface and underground infrastructure, underground definition drilling, development of ore accesses, mining and processing ore through the Keno District Mill, deposition of waste rock on surface, treatment and release of water and deposition of tailings in the licenced Dry Stack Tailings Facility (DSTF).

To characterize the acid rock drainage and metal leaching (ARD/ML) potential related to the tailings when exposed to oxidizing surface conditions, two large tailings samples were collected from the locked cycle (LC) metallurgical testing of Birmingham ore, and tested for their geochemical composition and properties. This technical memorandum summarizes the results of the geochemical static and kinetic tests conducted on these tailings material and provide a comparison with the tailings from Flame and Moth, Bellekeno, Lucky Queen, and Onek deposits in the Keno Hill District (KHSD).

2 TAILINGS SAMPLE PREPARATION

Two representative 5.5 kg tailings samples (Berm LCT1 and LCT2) were obtained from the LC metallurgical testing and sent to Maxxam Analytics, Burnaby, British Columbia for static and kinetic testing. Each tailings sample was homogenized without any further crushing prior to shake flask extraction analysis and kinetic testing. Two subsamples of the tailings were crushed further to 85% passing 200 mesh (75 µm) for acid base accounting, elemental, and X-ray diffraction analyses.

3 LABORATORY GEOCHEMICAL TESTING

The acid base accounting (ABA) test included: paste pH, total inorganic carbon, bulk neutralization potential by the siderite-corrected method, and sulphur speciation with the sulphide sulphur determined by difference between total sulphur (Leco) and sulphate sulphur (HCl extraction). A sequential net acid generation (NAG) test was done as a cross-check on the ABA test work. The metal content of the tailings samples was determined by *aqua regia* digestion followed by inductively coupled plasma mass spectrometry (ICP-MS) analysis, and the mineralogical composition determined by X-ray diffraction (XRD) with Rietveld refinement. A standard shake flask extraction (MEND SFE) test was also performed using a 3:1 liquid to solid ratio using deionized water as leaching fluid. Kinetic testing using the standard humidity cell (HC) was also performed using the LCT2 sample. The HC analysis was started in July 2018 and terminated on June 23, 2020 after operating for 103 weeks. The cell was terminated as per standard closedown procedure and its residue subjected to ABA, bulk elemental, and XRD analyses similar to the head sample. Detailed descriptions of each of the above analytical methods can be found in Price (2009).

4 RESULTS

4.1 ACID BASE ACCOUNTING

The results of the Birmingham ABA testing are presented Table 4-1 alongside those of the Onek F7+F8 tailings, Lucky Queen F9+F10 tailings, Flame & Moth F4+F5 composite tailings and the average of monthly ABA analyses of composite tailings samples produced from Bellekeno ore between January 2011 and July 2013 (ACG, 2015). These results show that the Birmingham LC tailings have a slightly alkaline paste pH (7.6-8.15), a very high carbonate neutralization potential (carbonate-NP; 184-204 kg CaCO₃/t) and relatively low bulk neutralization potential (bulk NP; 50.5-56 kg CaCO₃/t). The carbonate-NP was significantly (3.6 times) higher than the bulk NP due to the anticipated presence of a large proportion of iron and/or manganese carbonates such as siderite and ankerite that do not contribute to the net acid neutralization under oxidizing conditions. The sulphate content of the tailings samples was extremely low (at the detection limit of 0.01 wt. %) indicating that the bulk of sulphur (1.29-1.38 wt.%) of the tailings consists of sulphide-sulphur.

The tailings from other four deposits generally have similar ABA characteristics as Birmingham tailings: They had circumneutral to slightly alkaline paste pH (7.8 to 8.1) and high carbonate NP (273 to 389 kg CaCO₃/t). Their carbonate-NP was significantly higher than the siderite-corrected bulk NP (100 to 132 kg CaCO₃/t) indicating that ferrous and or manganese carbonates such as siderite (FeCO₃) comprise a substantial portion

of the carbonate mineralogy in the tailing like at Birmingham. The sulphate contents of the tailings from Flame & Moth, Bellekeno, Lucky Queen and Onek were also extremely low (maximum = 0.04 wt. %) indicating that the bulk of sulphur consists of sulphide-sulphur. The Bellekeno tailings contained the highest sulphide-sulphur content (2.21 wt.%), followed by the Birmingham tailings (1.29 and 1.38 wt.%). The tailings from the other three sites had sulphide-sulphur concentrations less than 0.5 wt.%; Table 4-1. The neutralization potential ratio (NPR), defined as the ratio of the (siderite-corrected) neutralization potential to the acid potential, provides an indication of acid generation over the long-term. A sample with an NPR less than one is termed “potentially acid generating (PAG), a sample with NPR greater than two is considered not potentially acid generating (non-PAG) and a sample with NPR between 1 and 2 is considered “Uncertain” with respect to acid generation and require further testing to confirm the potential ARD/ML classification.

The Birmingham tailings returned an NPR of 1.3 and was classified as “Uncertain” The other tailings had NPR greater than 2 except Bellekeno tailings which was classified as Uncertain (NPR = 1.9). Onek, Lucky Queen and Flame and Moth tailings where all non-PAG (calculated NPR > 7).

As indicated above, an NPR between 1 and 2 indicates that the potential to generate acid is Uncertain and further testing or expert judgment of the data available are needed to provide a final classification of the material. Given that the bulk NP available for acid neutralization may be underestimated due to the oxidation of Mn (II) during the siderite-corrected NP method, the NPR calculated for the Birmingham and Bellekeno tailings samples could be considerably higher. This is supported by detailed mineralogical examination of historic tailings deposited in the KHSD in which material initially classified as potentially acid generating by conventional ABA analysis but was found to be not potentially acid generating when its manganese carbonate content was included in the NPR calculation (SRK, 2009). Also, it is likely that the siderite calcian end-member will contribute some effective NP for acid neutralization.

Table 4-1: ABA Data for Birmingham LCT, Flame and Moth, Bellekeno, Lucky Queen and Onek Tailings

Sample	Paste pH	Total Sulphur	Sulphate Sulphur	Sulphide Sulphur	CO ₂	CO ₃ -NP	Siderite-Corrected NP	AP	NPR
	pH Units	%	%	%	%	kg CaCO ₃ /t			Unitless
Berm LCT1	7.6	1.30	0.01	1.29	8.09	184	50.5	40.3	1.3
Berm LCT2	8.2	1.39	0.01	1.38	8.96	204	56.3	43.1	1.3
Onek F7 + F8 average	7.8	0.16	0.04	0.12	n/a	n/a	31.4	3.8	8.4
Lucky Queen F9 + F10 average	7.9	0.19	0.04	0.15	n/a	n/a	19.1	4.5	4.2
Flame & Moth F4+F5 Composite Tailings	8.0	0.45	0.02	0.43	17.1	389	100	14.1	7.1
Bellekeno Tailings, Jan 11- July 13 Monthly Avg.	8.1	2.3	0.02	2.21	12	273	132	71.7	1.9

AP: acid potential:
 NP: neutralization potential
 NPR: neutralization potential ratio

4.2 SEQUENTIAL NAG

The NAG test is often used as a cross check on the ABA results regarding potential for net acid generation. The NAG test rapidly oxidizes the sulphide in the sample by reacting it with an excess of hydrogen peroxide. In this work, the NAG test was performed sequentially such that four successive NAG cycles were conducted on the same sample to ensure all of the available sulphide-sulphur was oxidized. The pH of the NAG leachate after each cycle provides an indication of the capacity of the acid neutralizing minerals in the sample to buffer the acid produced from sulphide oxidation and therefore the overall net acid generation potential of the sample.

The results of the sequential NAG reported in Table 4-2 show that a negligible amount of acidity (i.e., 0.19 kg CaCO₃/t) was generated during the test and only during the first cycle suggesting a very low oxidation rate or that the sulphides content of the tailings is not reactive. The potential for acid generation is considered low because the NAG pH was circumneutral during the four cycles; the NAG test indicates a sample is non-PAG if the NAG pH is greater than 4.5. In short, the sequential NAG provides clarification regarding the “Uncertain” acid generation potential indicated by the ABA work – that is, net acid generation is not expected from these tailings. Ongoing kinetic testing will provide further confirmation of the ARD potential of the Birmingham tailings. The NAG test was not conducted on tailings from other sites to provide a site wide comparative assessment.

Table 4-2: Sequential NAG Data for Birmingham Locked Cycle Tailings

Sample ID	Cycle Number	NAG pH	NAG Volume to pH 4.5	NAG Volume to pH 7.0	NAG NaOH Conc.	NAG Acidity pH 4.5	NAG Acidity pH 7.0
		pH Units	mL	mL	N	kg CaCO ₃ /t	kg CaCO ₃ /t
Berm LCT2	Cycle 1	6.56	0.0	0.1	0.1	0.000	0.192
	Cycle 2	7.81	0.0	0.0	0.1	0.000	0.000
	Cycle 3	8.28	0.0	0.0	0.1	0.000	0.000
	Cycle 4	7.81	0.0	0.0	0.1	0.000	0.000

4.3 MINERALOGY

The mineralogical composition of the tailings was determined by XRD and the results of the test are reported in Table 4-3. These results show that the Birmingham tailings are mainly composed of quartz (SiO₂; 59.3 to 63.2 wt. %) and calcium rich siderite (FeCO₃; 21.2 to 27.8 wt. % as calcian siderite) similar to the Flame & Moth and Bellekeno tailings. The Birmingham tailings contain sulphide minerals, the main source of acidity, as pyrite (FeS₂; 1.6 to 2.2 wt. %), sphalerite (ZnS; 0.3 to 0.6 wt. %) and galena (PbS; 0.3 to 0.8 wt. %). Pyrite content was similar to the concentration in the Bellekeno tailings (2.3 wt.%) but Flame and Moth pyrite content were low (0.7 wt.%). Sphalerite and galena were less abundant or comparable in the Birmingham tailings samples than in the Bellekeno tailings (2.4 wt.% sphalerite; 0.6 wt.% galena) and completely absent from the Flame and Moth composite tailings.

In addition to calcian siderite, the Birmingham tailings contained another carbonate mineral, ankerite (Ca (Fe, Mg, Mn) (CO₃)₂; 1.0 to 1.4 wt. %), with no effective buffering capacity. Ankerite was also identified in the

Bellekeno tailings (0.4 wt.%), but was not detected in the Flame & Moth composite. No calcite (CaCO₃) was detected in the Birmingham samples, which differed from the 1.2 and 3.2 wt.% calcite content in the Flame & Moth and Bellekeno tailings, respectively. These data indicate that the Birmingham tailings consist predominantly of geochemically inert silica (~ 60 wt.%) and iron and manganese carbonate minerals (28 wt. %) like other tailings. The major difference between the three is the lack of calcite in the Birmingham tailings, the lack of sphalerite and galena in the Flame and Moth tailings and the presence of trace chalcopyrite (0.1 wt. %) and wurtzite (0.2 wt. %) in Bellekeno tailings.

Iron and manganese carbonates have a net neutral buffering capacity under aerobic conditions because the amount of acidity consumed during dissolution is subsequently generated during the oxidation and hydrolysis of ferrous iron. However, the XRD data indicates a calcium rich siderite where substitution of calcium for iron occurs which may result in some neutralization capacity of a portion of the siderite.

The Birmingham potential AP estimated from the pyrite content of the tailings (AP = ~37 kg CaCO₃ /t) is slightly lower than the AP from the ABA meaning that the sulphide-sulphur from galena and sphalerite, minerals that do not generate acid when oxygen is the only oxidant, may be the source of excess of AP in the ABA test. The XRD data corroborate the Birmingham sample ABA showing that the lower siderite-corrected NP is likely due to the deficiency of calcite content relative to the other tailings. Although both the Birmingham and Bellekeno tailings samples share similar pyrite concentrations (1.6 to 2.2 and 2.3 wt.%, respectively), the higher AP for the Bellekeno sample mainly reflects its higher sphalerite content and the presence of trace chalcopyrite and wurtzite compared to that of the Birmingham samples. The low AP of the Flame & Moth sample is due to its low pyrite content (0.7 wt.%) and absence of other sulphides.

Table 4-3: Mineralogy of Birmingham LCT, Flame and Moth and Bellekeno Tailings

Mineral	Birmingham LCT1	Birmingham LCT2	Flame & Moth F4 + F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13
Ankerite – Dolomite	1.4	1.0	-	0.4
Calcite, Magnesian	-	-	1.2	3.2
Cassiterite	-	-	0.5	-
Clinocllore	-	-	1.3	0.4
Dravite	-	-	3.2	-
Galena	0.8	0.3	-	0.6
Illite-Muscovite 2M1	9.6	8.2	2.5	6.6
Kaolinite	1.0	0.9	-	-
Pyrite	1.6	2.2	0.7	2.3
Quartz	63.2	59.3	45.2	52.6
Rutile ?	0.6	-	-	0.3
Siderite, calcian	21.2	27.8	45.3	29.8
Sphalerite	0.6	0.3	-	2.4
Plagioclase	-	-	-	0.8
Gahnite	-	-	-	0.2

Mineral	Birmingham LCT1	Birmingham LCT2	Flame & Moth F4 + F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13
Chalcopyrite	-	-	-	0.1
Wurtzite	-	-	-	0.2
K-Feldspar	-	-	-	0.3
Total	100	100	100	100

4.4 METALS CONTENT

The bulk metal concentration of an element provides a preliminary indication of constituents that are elevated or depleted in a geologic material and should be monitored during leaching tests. However, the enrichment or depletion of a constituent in a sample is not a direct measure of their potential mobility or bioavailability (or lack thereof) because several parameters, including but not limited to, site hydrogeology, biogeochemistry, climate, pH and redox conditions ultimately determine the mobility and bioavailability of an element.

The results of the solid-phase metals analysis of the Birmingham LC tailings are presented in Table 4-4 alongside that of the Flame & Moth F4+F5 composite tailings, Onek F7+F8 tailings, Lucky Queen F9+F10 tailings, and the monthly average of tailings from Bellekeno between July 2012 and August 2013.

A preliminary screening of the tailings metal content against the 10x their crustal abundance (CRC, 2005) was done and revealed that antimony, arsenic, bismuth, cadmium, lead, manganese, selenium, silver, and zinc were typically high. The elevated metals and metalloids concentration were expected considering the source of the parent material (i.e., ore). The enrichment or depletion of metals in the Birmingham tailings was assessed by comparison with the tailings from other deposits and focused on a few of those identified during preliminary screening because of their potential for environmental concern namely; antimony, arsenic, cadmium, lead, selenium, silver and zinc.

The Birmingham tailings contained similar arsenic content to the Onek, 1.7 and more than 5 times lower than Flame and Moth tailings and Bellekeno, respectively, and twenty times higher than the arsenic concentration in the Lucky Queen tailings. The highest antimony was in the Bellekeno (121 mg/L) and was nearly three times greater than the Birmingham (BERM LCT2) and Flame and Moth tailings and more than thirteen times that of Onek and Lucky Queen.

The cadmium and zinc concentration in the Birmingham tailings were higher than that of both the Lucky Queen (ca. 4- to 11-fold higher) and Flame and Moth (ca. 2- to 3-fold higher) tailings, but approximately 2- to 7-fold lower than the Onek tailings and Bellekeno, respectively. Lead content of the Birmingham tailings sample BERM LCT1 was 3 times higher than BERM LCT2 and was the highest among the all tailings. The lead content of BERM LCT2 was approximately 3 to 6 times higher than the Onek, Lucky Queen, and Flame and Moth tailings but 2.7 lower than Bellekeno tailings. The Bellekeno tailings generally had the highest concentration of these elements, with arsenic, antimony, cadmium, and zinc concentrations present at levels three- to seven-fold higher levels than those in the Birmingham tailings.

The Birmingham, Flame and Moth and Bellekeno tailings contained comparable concentrations of selenium concentrations. Birmingham tailings sample LCT2 and Bellekeno also had comparable silver content 50 to 56 ppm, that was four to seven time higher than Flame and Moth, Onek and Lucky Queen. But Birmingham tailings sample LCT1 had a silver concentration nearly twice that of Bellekeno.

The metal concentrations of lead and zinc are particularly elevated in Bellekeno, Lucky Queen and Birmingham tailings because they are the main base metals in sphalerite, galena chalcopyrite and wurtzite remaining in the tailing after processing as indicated by the results of XRD. The high concentration of arsenic is likely due to its known presence as trace element in sulphidic ore. The potential for leachability and solubility of these metals and metalloids is assessed in the SFE and HC tests.

Table 4-4: Elemental Content of Birmingham LCT, Flame and Moth, Bellekeno, Lucky Queen and Onek Tailings

Element	Unit	Berm LCT1	Berm LCT2	Onek F7 + F8 average	Lucky Queen F9 + F10 average	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite Jul 12 - Aug 13
Aluminum (Al)	%	0.15	0.16	0.36	0.74	0.2	0.2
Antimony (Sb)	ppm	99.8	44.6	<5	9	41	120.6
Arsenic (As)	ppm	369	401	375	17.5	699	2147
Barium (Ba)	ppm	30	30	24	125	11.5	16.4
Bismuth (Bi)	ppm	0.06	0.04	<2	<2	6.59	2.1
Cadmium (Cd)	ppm	46.1	23.4	72.8	3.95	7.19	165.8
Calcium (Ca)	%	0.63	0.73	0.47	0.38	0.59	1.52
Chromium (Cr)	ppm	133	115	174	265.5	185.5	5.5
Cobalt (Co)	ppm	4.3	4.3	2	3	2.7	9.9
Copper (Cu)	ppm	60.8	57.5	377	254	565	242.4
Iron (Fe)	%	6.35	7.07	18.6	6.4	16.3	10.1
Lead (Pb)	ppm	7460	2330	413	555	789	6359
Magnesium (Mg)	%	0.32	0.36	0.47	0.34	0.31	0.31
Manganese (Mn)	%	37900	4.43	5.19	2.47	4.28	3.22
Mercury (Hg)	ppm	0.19	0.13	n/a	n/a	0.055	0.19
Molybdenum (Mo)	ppm	2.06	2.02	<1	2	3.74	1.16
Nickel (Ni)	ppm	49.8	49.1	44	51	86.6	19.5
Phosphorus (P)	%	290	0.032	0.014	0.013	0.01	0.02
Potassium (K)	%	0.07	0.08	0.08	0.275	0.03	0.04
Selenium (Se)	ppm	0.9	0.8	n/a	n/a	0.1	0.52
Silver (Ag)	ppm	99.6	56.4	6.4	16.4	12.35	50.1
Sodium (Na)	%	<0.01	<0.01	0.02	0.025	0.006	0.014
Strontium (Sr)	ppm	14.3	15	11	15	4.81	24
Thallium (Tl)	ppm	0.78	1.9	17.5	11	0.652	0.129
Tin (Sn)	ppm	2.7	2	n/a	n/a	32.9	17.6
Titanium (Ti)	%	<0.005	<0.005	<0.01	0.02	0.001	0.002
Uranium (U)	ppm	0.39	0.38	n/a	n/a	0.406	1.052
Vanadium (V)	ppm	6	5	5.5	12.5	9.4	5.18
Zinc (Zn)	ppm	3510	2080	8784	557	1265	12623

4.5 SHAKE FLASK EXTRACTION

SFE provides preliminary indication of the leachability, solubility and potential mobility of metals and metalloids during short-term leaching by meteoric water under oxidizing conditions. SFE is also used to screen for potential exceedances of water quality objectives, discharge standards or generic water quality guidelines.

The results of the SFE of all tailings are reported in Table 4-5 alongside the Keno Hill District Mill Site pond effluent quality standards (EQS) at KV-83. Table 4-5 shows that Birmingham tailings had a circumneutral pH (pH= 7.3-8.2) consistent with the ABA paste pH, low leachable sulphate content (19.1-46.1 mg/L) and no measurable acidity (less than the method detection limit of 0.5 mg/L CaCO₃). Table 4-5 also show that SFE was also circumneutral for those tailings (i.e., Lucky Queen) for which the SFE pH data was available.

To screen for potential water quality exceedances, the SFE data were compared with the Mill pond EQS as any seepage would report to the mill pond. No exceedance of the Mill pond EQS were found in any of the tailings. The solubility of metals and metalloids highlighted in Section 4.4 as elevated in the tailings did not generate exceedances despite the vigorous condition of the SFE test. Note that the comparison of result of SFE data with the EQS is not and should not be used as a measure of compliance with site water quality standards and objectives. Rather, the comparison provides a guide for potential constituents of concern in drainage from the tailings, which should be confirmed by kinetic testing.

Table 4-5: SFE Results for the Birmingham LCT, Flame and Moth, Bellekeno, Lucky Queen and Onek Tailings

Leachable Metals	Unit	Berm LCT1	Berm LCT2	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13	Lucky Queen F9	Lucky Queen F10	KHSD Mill Site EQS (KV-83)
pH	pH units	7.27	8.17	7.90	-	8.1	8.0	6.5-9.5
EC	uS/cm	154.5	97.1	547	-	434	352	
SO ₄	mg/L	46.1	19.1	245	-	183	140	
Acidity to pH4.5	mg/L	<0.5	<0.5	-	-	-	-	
Acidity to pH8.3	mg/L	2.1	<0.5	-	-	-	-	
Total Alkalinity	mg/L	11	14	39.9	-	28.2	25.1	
Bicarbonate	mg/L	14	18	-	-	-	-	
Carbonate	mg/L	<0.5	<0.5	-	-	-	-	
Hydroxide	mg/L	<0.5	<0.5	-	-	-	-	
Fluoride	mg/L	0.27	0.2	0.189	-	0.078	0.035	
Hardness CaCO ₃	mg/L	55.6	35	-	-	204	158	
Aluminum (Al)-Leachable	mg/L	0.00609	0.0214	0.0109	0.0282	<0.0050	<0.0005	
Antimony (Sb)-Leachable	mg/L	0.00419	0.0111	0.0217	0.0387	0.016	0.0116	
Arsenic (As)-Leachable	mg/L	0.000219	0.000331	0.0061	0.0072	<0.0010	<0.0010	0.1
Barium (Ba)-Leachable	mg/L	0.0354	0.0134	0.0253	0.0234	0.037	0.0459	

Leachable Metals	Unit	Berm LCT1	Berm LCT2	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13	Lucky Queen F9	Lucky Queen F10	KHSD Mill Site EQS (KV-83)
Beryllium (Be)-Leachable	mg/L	<0.000010	<0.000010	<0.00050	<0.00050	<0.00050	<0.00050	
Bismuth (Bi)-Leachable	mg/L	<0.0000050	<0.0000050	<0.00050	<0.00050	<0.00050	<0.00050	
Boron (B)-Leachable	mg/L	<0.050	<0.050	0.071	0.0942	0.025	0.014	
Cadmium (Cd)-Leachable	mg/L	0.0027	0.000309	0.0024	0.00318	0.00164	0.0509	0.01
Calcium (Ca)-Leachable	mg/L	18.7	12.4	105	138	74.9	59.6	
Chromium (Cr)-Leachable	mg/L	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	<0.00050	
Cobalt (Co)-Leachable	mg/L	0.000925	0.000099	0.0004	0.00031	0.0002	0.00702	
Copper (Cu)-Leachable	mg/L	0.000116	0.000334	0.0271	0.0096	0.0303	0.0503	0.1
Iron (Fe)-Leachable	mg/L	0.0022	<0.0010	<0.030	<0.030	<0.030	<0.030	
Lead (Pb)-Leachable	mg/L	0.0607	0.0188	0.0144	0.0593	0.0181	0.112	0.2
Lithium (Li)-Leachable	mg/L	0.00339	0.00294	0.0071	0.0339	<0.00050	<0.00050	
Magnesium (Mg)-Leachable	mg/L	2.15	0.988	6.9	6.01	3.96	2.27	
Manganese (Mn)-Leachable	mg/L	2.28	0.445	1.95	0.797	0.765	1.14	
Mercury (Hg)-Leachable	mg/L	<0.000050	<0.000050	0.0001	<0.000050	<0.000050	<0.000050	
Molybdenum (Mo)-Leachable	mg/L	0.000225	0.000928	0.0024	0.0108	0.00318	0.000718	
Nickel (Ni)-Leachable	mg/L	0.00213	0.000368	0.0012	0.0009	0.0006	0.00253	0.5
Phosphorus (P)-Leachable	mg/L	0.0503	0.0414	<0.30	<0.30	<0.30	<0.30	
Potassium (K)-Leachable	mg/L	1.89	1.7	2.04	10.6	3.93	1.87	
Selenium (Se)-Leachable	mg/L	0.000058	0.000041	0.0009	0.00106	0.00871	0.00463	
Silicon (Si)-Leachable	mg/L	0.42	0.45	1.55	3.4	1.91	1.11	
Silver (Ag)-Leachable	mg/L	<0.0000050	0.00003	0.0009	0.0018	0.000144	0.00627	0.02
Sodium (Na)-Leachable	mg/L	0.854	0.596	2.36	24.1	6.19	4.57	
Strontium (Sr)-Leachable	mg/L	0.0261	0.0172	0.38	0.515	0.193	0.141	
Thallium (Tl)-Leachable	mg/L	0.000335	0.000177	0.0001	0.0002	0.00011	<0.00010	
Tin (Sn)-Leachable	mg/L	<0.00020	<0.00020	<0.00050	<0.00050	<0.00050	<0.00050	
Titanium (Ti)-Leachable	mg/L	<0.00050	<0.00050	0.01	0.012	<0.010	<0.010	
Uranium (U)-Leachable	mg/L	<0.0000020	<0.0000020	0.000048	0.00162	0.000011	<0.000010	
Vanadium (V)-Leachable	mg/L	<0.00020	<0.00020	<0.0010	<0.0010	<0.0010	<0.0010	
Zinc (Zn)-Leachable	mg/L	0.142	0.017	0.156	0.051	0.0189	0.0955	0.5

Note: EQS: effluent discharge standards at KV-83 for the KHSD

4.6 HUMIDITY CELL

The HC test provides an indication of the long-term acid generation and rate of release of constituents (i.e., acidity, alkalinity, sulphate, major and trace elements) and constitutes robust evidence on the ARD/ML potential of a geologic material.

The results of 103 weeks (cycles) of Birmingham HC testing are discussed herein. Time series of selected constituents of interest are provided and discussed below to assess the rate of release and the long-term ARD/ML potential of the Birmingham tailings. The HC data were plotted with HC results for Bellekeno and Flame and Moth tailings to provide a site wide comparison. The Mill pond EQS are also plotted for comparative purposes only rather than an assessment of compliance with site water quality standards.

4.6.1 pH, Sulphate, Acidity and Alkalinity

The pH, acidity, alkalinity and sulphate released from the Birmingham tailings during the tests are plotted in Figure 4-1. The plot shows a stable neutral pH of between 7.1 and 8.0 (median = 7.4) within the EQS range (6.5 - 9.5), very low acidity (maximum 7.4 mg/L CaCO₃; median equivalent to the detection limit 0.5 mg/L CaCO₃), alkalinity high enough to buffer the acidity released (maximum 39.6 mg/L CaCO₃; median 20.8 mg/L CaCO₃), and relatively low sulphate concentrations (median 51 mg/L), indicating a low sulphide oxidation rate. The acidity, alkalinity and sulphate concentrations showed a first flush effect resulting from the release of readily soluble products followed by a decrease then stabilization of the concentrations until cycle 43 and 37 for acidity and alkalinity, respectively, although recurrent spikes of acidity were observed until cycle 69 after which the acidity was typically below the detection limit. Alkalinity gradually increased after cycle 37 from 12 mg/L to 40 mg/L at cycle 99, coincident with an increase in pH from 7.3 to 8.0. The sulphate concentrations showed a slight increase between cycles two and nine (85 mg/L), then decreased and continued to decline during the test reaching 29 mg/L during the last two cycles.

The pH and alkalinity levels in the leachate from the Birmingham tailings humidity cell were lower than those observed in the Flame and Moth and Bellekeno tailings HCs (Figure 4-1), reflecting its lower NP and lack of calcite, however the pH was comparable to that observed for Bellekeno and Flame and Moth during the last three cycles due to the gradual increase observed since cycle 37. The Birmingham sulphate concentrations recorded during the test (29 to 374 mg/L) were markedly lower than those observed in the Bellekeno HC (158 to 1,150 mg/L) during the first 30 cycles then the gap gradually shrank until reaching a comparable level at cycle 55 onward. The Birmingham sulphate concentrations were also lower than in the Flame and Moth HC leachate (120 to 1130 mg/L) during the first 17 cycles after which the sulphate concentration in the HC leachate from the Birmingham tailings increased and remained above that of the Flame and Moth HC during the remainder of the test. This trend is expected for Bellekeno, which has a higher sulphide-sulphur content (2.2 wt.%) than the Birmingham tailings (1.4 wt.%), but is somewhat unexpected for the early cycles of the test for Flame and Moth because of its lower sulphide-sulphur content (0.4 wt.%). Sulphides in the Flame and Moth tailings were likely exposed to leaching at the onset of the test resulting in higher release rate early on and gradual decline thereafter. However, the three tailings generally showed a similar sulphate release pattern despite the difference in absolute concentration, although the sulphate released from the Flame and Moth HC stabilized whereas sulphate concentrations in the Birmingham and Bellekeno HCs continued to slowly decrease (Figure 4-1).

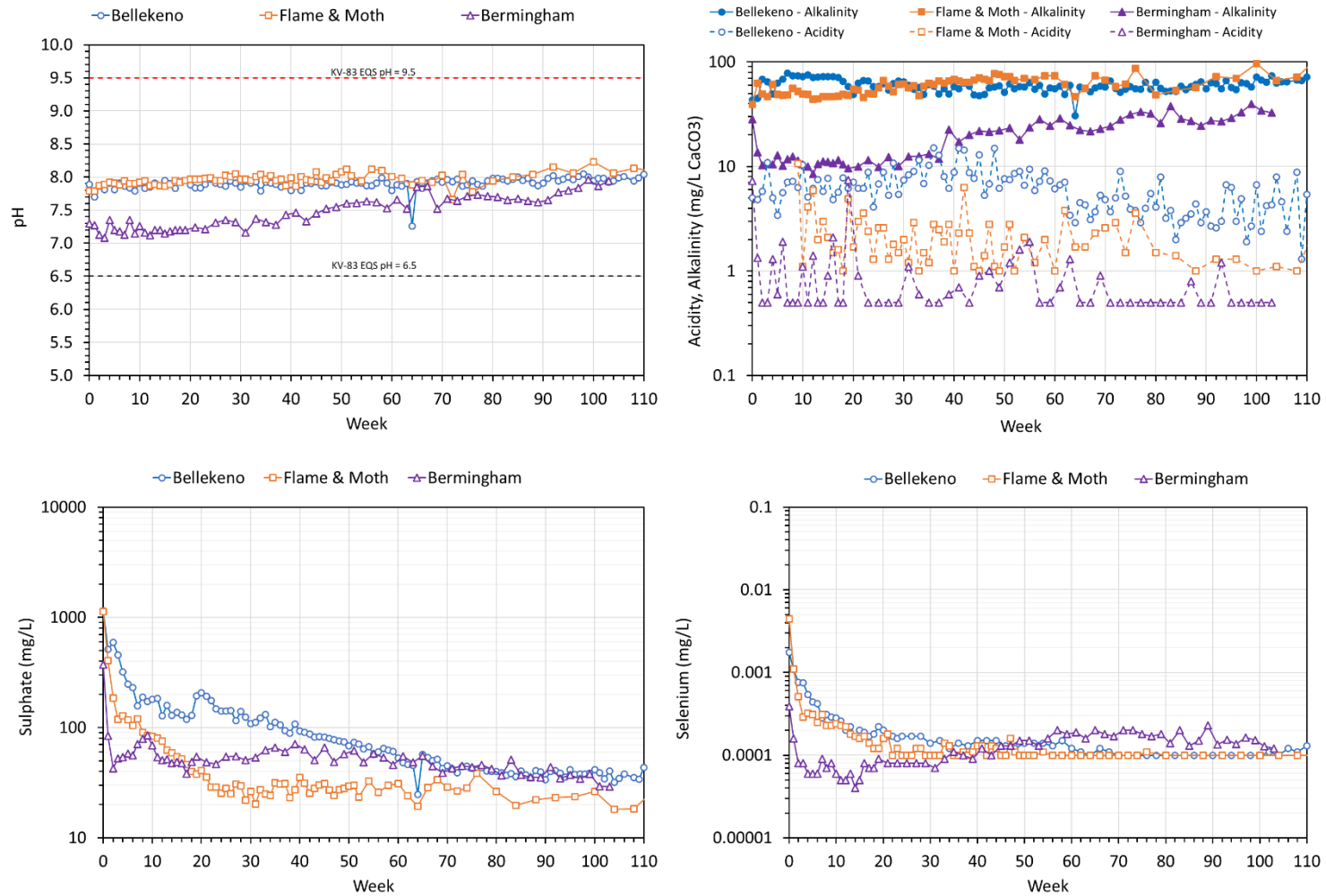


Figure 4-1: pH (top left), Acidity and Alkalinity (top right), Sulphate (bottom left) and Selenium (bottom right) Trends within the Bermingham LC, Flame and Moth and Bellekeno Tailings Humidity Cells

4.6.2 Constituents of Potential Concern

The times series of metals and metalloids of potential environmental concern in the Birmingham tailings HC are plotted in Figure 4-2 and Figure 4-3 alongside those of Bellekeno and Flame and Moth.

The time series of arsenic, antimony, cadmium, and copper are displayed in Figure 4-2 and lead, nickel, silver, and zinc are shown in Figure 4-3. Analysis of the Birmingham tailings metals and metalloids time series showed similar patterns characterized by a flush effect during cycle 0 followed by a decrease of concentration during the following two to three weeks and then a short-term increase which peaked between cycles six and eight. This was followed by a second short or extended decrease and a stabilization as early as cycle 11 onward (antimony and silver) or later (cycle 55 onward for arsenic, copper; cycle 81-89 onward for cadmium, lead and nickel; cycle ~95 for zinc.). However, sporadic fluctuations of concentration were visible in the plots of arsenic, nickel, silver, lead, and copper.

Aside from the initial flush, the arsenic concentration in the HC leachate from the Birmingham tailings was lower than that of the Bellekeno and Flame and Moth HC leachates, likely due to its lower bulk arsenic concentration. Arsenic concentrations in the HC leachate from the Birmingham HC were an order of magnitude or more lower than those of the Bellekeno and Flame and Moth HCs since cycle 35 and no exceedance of the arsenic EQS (0.1 mg/L) was observed in any of the cells. Cadmium and zinc concentrations in the Birmingham tailings HC leachate were comparable to those of Flame and Moth during the first 35 cycles, then their concentrations sharply decreased below Flame and Moth. Cadmium and zinc concentrations in the Birmingham tailings HC leachate were markedly lower (up to two orders of magnitude) than those observed from the Bellekeno humidity cell during the same period. Besides the first cycle, exceedances of the cadmium and zinc EQS (0.01 and 0.5 mg/L, respectively) were only observed in the Bellekeno HC leachate. The Birmingham tailings cadmium and zinc trends likely reflects the lower concentration of these elements in the Birmingham tailings relative to Bellekeno but somewhat expected compared to Flame and Mock considering its higher cadmium and zinc (Table 4-4). Lead concentrations in the Birmingham humidity cell leachate were almost comparable to the Bellekeno tailings cell during the initial flush, then the concentration markedly decreased to levels that were one order of magnitude lower at cycle 11 and more than two orders of magnitude during the last cycles. Lead concentrations in the Birmingham humidity cell leachate were generally comparable to those of Flame and Moth during the first 11 cycles, then decreased to levels that were one order of magnitude lower than lead concentrations measured in the Flame and Moth HC leachates. Lead concentrations increased again after cycle 59 surpassing and remaining above the Flame and Moth HC after the 79th cycle. Occasional high releases of lead from the Birmingham tailings HC were observed during the test resulting in peak concentrations above those of the Flame and Moth HC. The Birmingham tailings HC leachate generally had the highest nickel concentrations during the first 35 cycles, then the nickel concentration decreased sharply such that it was below the nickel concentration in the Flame and Moth and Bellekeno HC leachates from cycle 43 onwards and generally stabilized after cycle 89. Note that nickel concentrations in the three cells were orders of magnitude lower than the nickel EQS (0.5 mg/L; Figure 4-3).

Aside from sulphate, selenium (last phase of the test), and nickel (early phase of the test), the Bellekeno and Flame and Moth tailings HCs had higher constituent concentrations than the Birmingham HC during the test period. The Bellekeno tailings had the highest concentration release for sulphate during the first half of the test, and the highest cadmium, lead, zinc, and nickel concentrations during the last 68 cycles. The Flame and Moth HC had the highest concentration release for arsenic, antimony, copper, and silver during the first 50 to 70

cycles then their concentrations become comparable or decreased below those in the Bellekeno cell. Copper concentrations in the Birmingham tailings HC leachate were slightly lower than the Bellekeno HC leachate during the first 23 cycles after which time the gap increased markedly (approximately two orders of magnitude difference at the last cycle). Silver concentrations in the Birmingham tailings cell leachate were generally below the detection level (i.e., <0.000005 mg/L) similar to the silver release from the Bellekeno cell although spikes of concentration (0.0001 mg/L) were recurrent during the test. Antimony concentrations in the HC leachate from the Birmingham tailings were lower than that of the Bellekeno and Flame and Moth HC leachate despite a bulk antimony concentration (44.6 ppm) that was comparable with the Flame and Moth tailings (41 ppm; Table 4-4).

Selenium concentrations in the Birmingham tailings HC exhibited a pattern different from all the parameters of interest (Figure 4-1). The concentration decreased after the first flush and was up to an order of magnitude lower than the Flame and Moth and Bellekeno leachate selenium levels during the first 20 cycles. After a stabilization at 0.00008 mg/L during the next 10 cycles, selenium concentrations in the Birmingham tailings cell leachate gradually increased to approximately 0.0002 mg/L, surpassing and remaining slightly above those of the Flame and Moth cell at cycle 49 and Bellekeno at cycle 55 (both approximately 0.0001 mg/L). The selenium concentration then decreased to levels that were comparable to the other cells during the last three cycles.

The tailings kinetic test results indicate that the trace element release rates for Birmingham were lower than the effluent quality standards at KV-83, the KHSD Mill Site. The data also suggest that the trace element release rates for the last ten cycles observed for the Bellekeno and Flame and Moth tailings may be used as a conservative proxy (upper boundary) for most constituents, except selenium, for the Birmingham tailings under the circumneutral conditions expected in the tailings storage facility.

It is worth noting that trace element concentrations released from the Bellekeno and Flame and Moth tailings cells were also lower than the effluent quality standards at KV-83, the KHSD Mill Site with the exception of zinc and cadmium in Bellekeno (Figure 4-2 and Figure 4-3). This is likely related to the elevated bulk zinc and cadmium concentrations in the Bellekeno tailings compared to the other tailings.

Additional information derived from the analysis of Birmingham HC data included:

- The concentration of ammonia was very low (median = 0.005 mg/L), at or below the detection limit in 76% of the cycles and well below the EQS of 5 mg/L;
- The concentrations of the following constituents were below the detection limit in all or the majority of leachates since cycle four: nitrate, nitrite, ammonia, beryllium, bismuth, boron, cesium chromium, lanthanum, iron, mercury, silver, sodium, tellurium, thorium, tin, titanium, tungsten, vanadium and zirconium; and
- The concentration of molybdenum was below the detection limit in the second half of the test.

The neutral pH, significant alkalinity, low acidity and sulphate releases, and lower concentration of metal and metalloids compared to the EQS are evidence of low potential for acid generation and metal release from the Birmingham (and other) tailings consistent with the sequential NAG and SFE results.

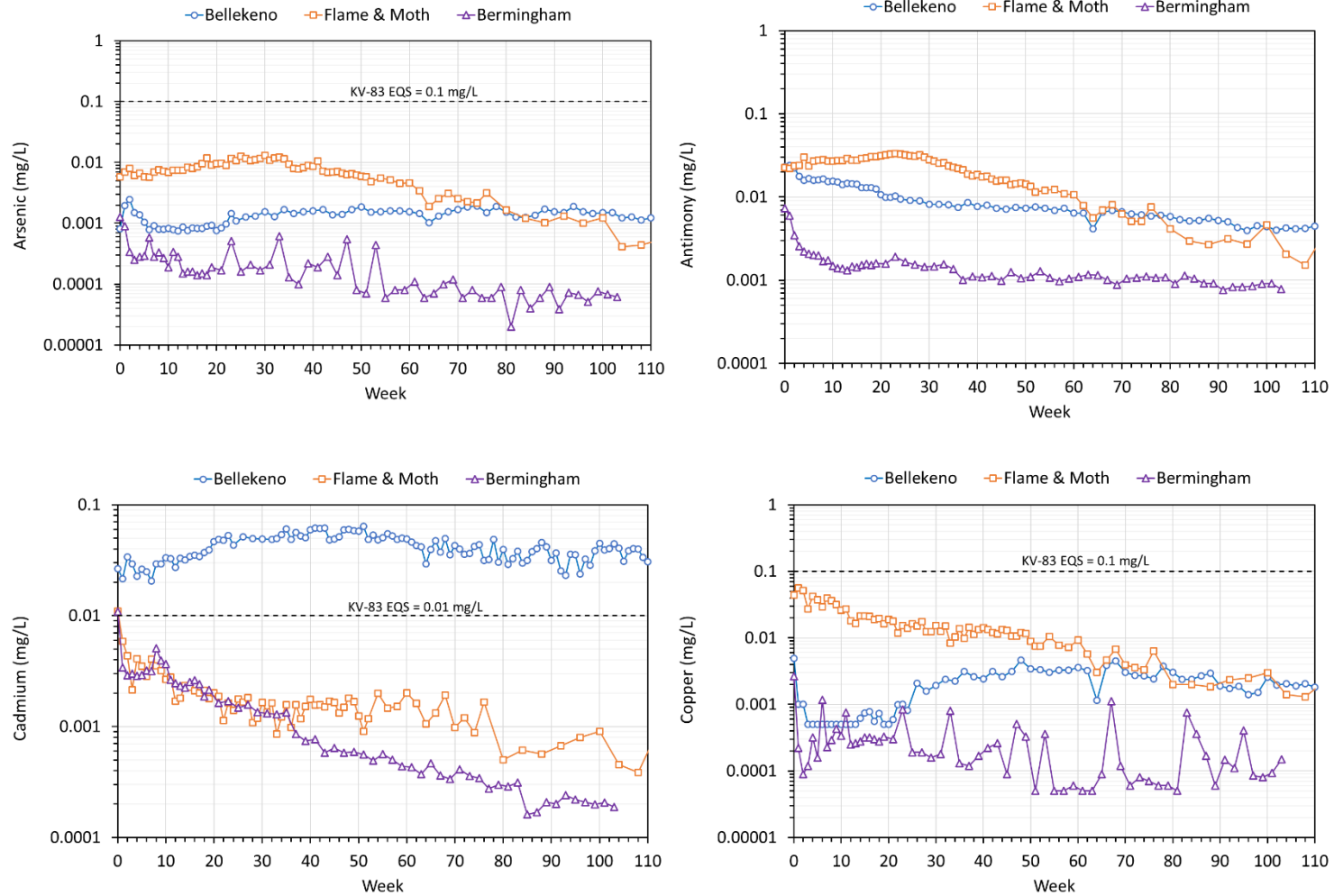


Figure 4-2: Arsenic (top left), Cadmium (bottom left), Antimony (top right), and Copper (bottom right) Trends within the Bermingham LC, Flame and Moth and Bellekeno Tailings Humidity Cells

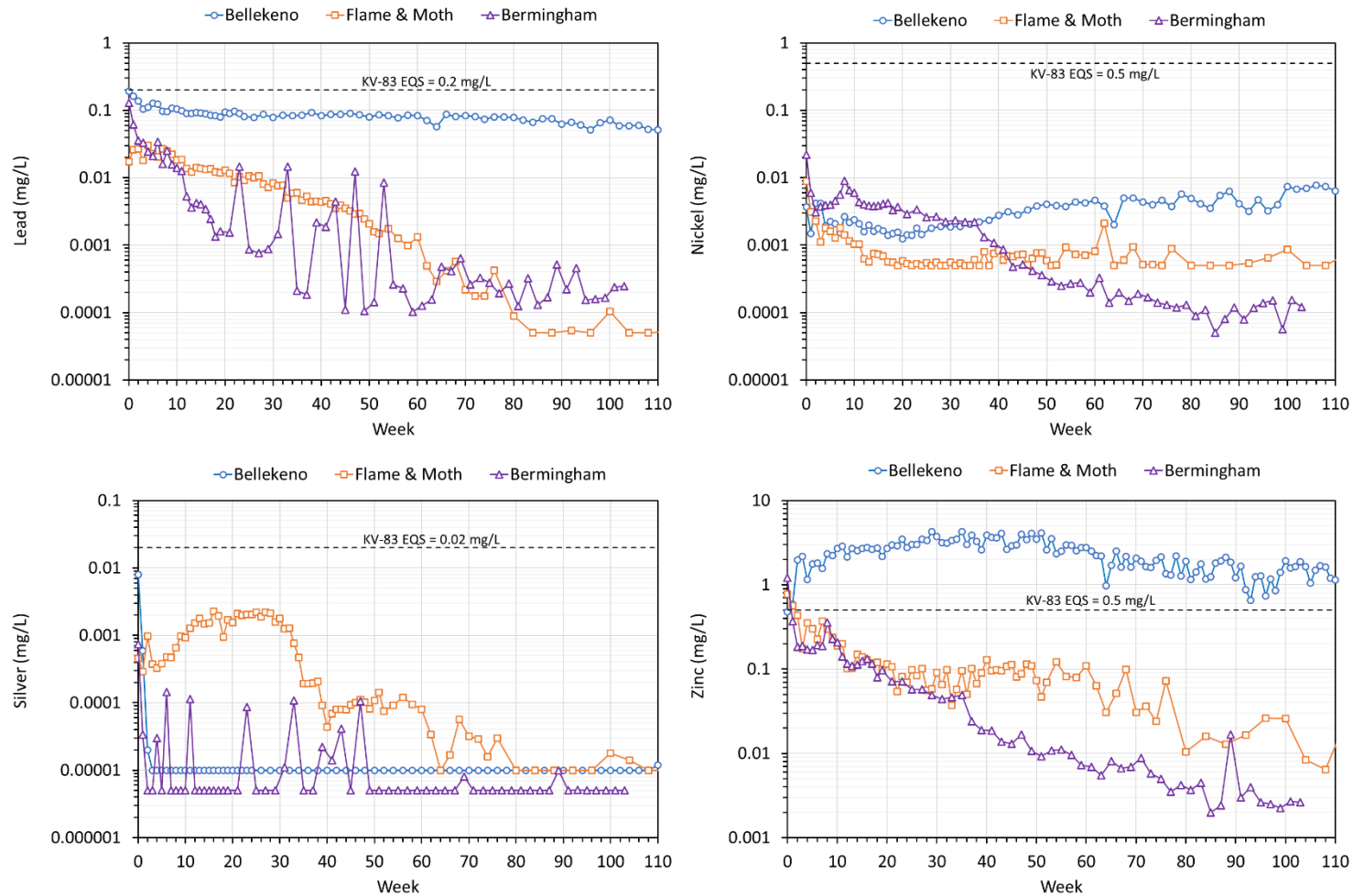


Figure 4-3: Lead (top left), Silver (bottom left), Nickel (top right), and Zinc (bottom right) Trends within the Bermingham LC, Flame and Moth and Bellekeno Tailings Humidity Cells

The estimation of the lag time to acid generation for the Birmingham tailings HC indicates that the times to sulphide and bulk NP depletion are approximately 31 and 40 years, respectively (Figure 4-4). Therefore, some bulk NP will remain in the tailings after the sulphide has been depleted, suggesting that net acid generation is not expected from the tailings. This is consistent with the sequential NAG results.

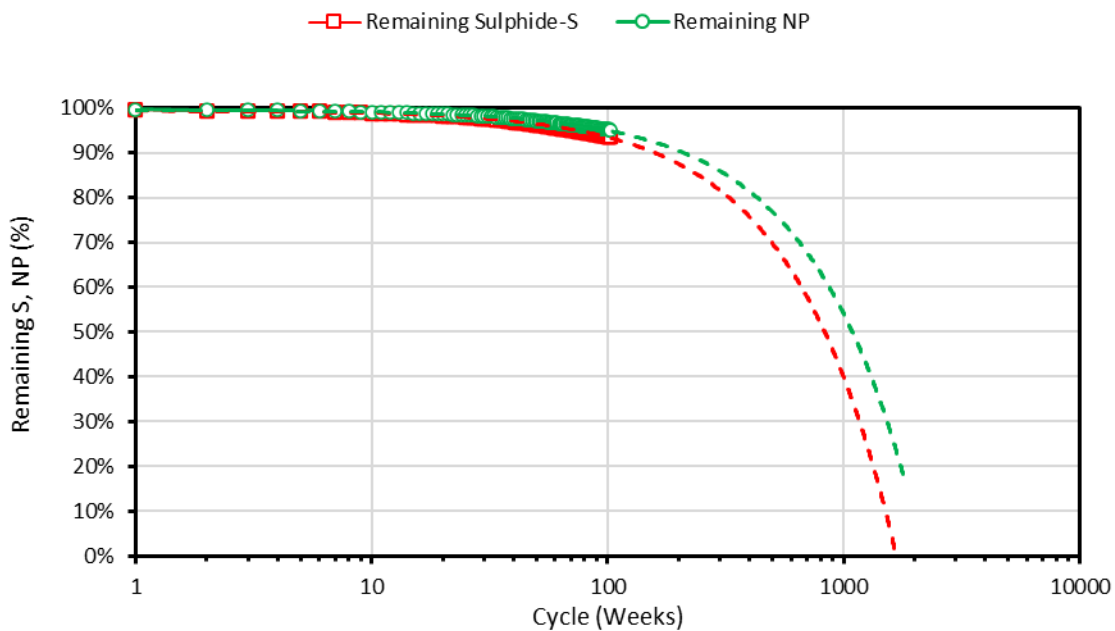


Figure 4-4: Calculations of Sulphide Sulphur and NP Depletion in Birmingham Tailings Humidity Cell

4.6.3 Humidity Cell Closedown

The purpose of the closedown procedure is to help in the interpretation of humidity cell test results by identifying and estimating the changes that may have occurred during the test. The results of the closedown tests on HC residue are reported in Table 4-6 to Table 4-9. The results of the ABA, metal, and XRD analyses on the tailings sample before the HC test are also included for comparison.

The XRD results suggest that weathering and leaching of sulphides (i.e., pyrite, sphalerite, and galena) and carbonate minerals (i.e., ankerite-dolomite and calcian siderite) identified in the head (pre-kinetic) samples occurred. The weathering process resulted in the reduction of the sulphides by 27% to 67% and of carbonates by 10% to 60% (Table 4-6). The changes induced by the leaching and weathering process and the loss of readily soluble minerals resulted in a higher percentage of less soluble minerals (i.e., quartz and aluminosilicates). Sample heterogeneity and/or normalization of the XRD results are the likely explanation for the appearance of

paragonite and rutile. The ABA results confirm these changes as indicated by a decrease in total sulphur and carbonate NP by 15% and 16%, respectively (Table 4-7). However, the cell residue still contains enough carbonate and bulk NP to prevent the onset of ARD. The bulk NP apparent increase in the residue by 4% is likely due to the heterogeneity of the sample.

Table 4-6: Mineralogy of Original Tailings and Residue of Tailings Humidity Cell

Mineral	Birmingham LCT2 Tailing	
	Pre-kinetic (%)	Post-kinetic (%)
Ankerite – Dolomite	1	-
Dolomite	-	0.4
Galena	0.3	0.1
Illite-Muscovite 2M1	8.2	7.8
Kaolinite	0.9	1.4
Pyrite	2.2	1.6
Quartz	59.3	61.2
Rutile?	-	0.4
Siderite, calcian	27.8	25.1
Sphalerite	0.3	0.2
Paragonite	-	1.8
Total	100	100

Table 4-7: ABA Results for Original Tailings and Residue of Tailings Humidity Cell

Sample	pH Units	Birmingham LCT2 Tailing	
		Pre-kinetic	Post-kinetic
Paste pH	-	8.2	8.2
Total Sulphur	%	1.39	1.18
Sulphate Sulphur	%	0.01	<0.01
Sulphide Sulphur	%	1.38	1.18
Total Inorganic Carbon	%	8.96	7.52
Carbonate-NP	kg CaCO ₃ /t	204	170.9
Siderite-Corrected NP	kg CaCO ₃ /t	56.3	58.5
AP	kg CaCO ₃ /t	43.1	36.9
NPR	-	1.3	1.6

No marked change of concentration was observed for the majority of elements. Aside from antimony, calcium, magnesium, selenium, sodium, and thallium, the decreases of metal concentration was less than 16%. Aluminum, barium, molybdenum, nickel uranium, and vanadium reported concentrations higher than the pre-kinetic test. Likely due to sample heterogeneity.

Table 4-8: Elemental Content of Original Tailings and Residue of Tailings Humidity Cell

Element	Unit	Birmingham LCT2 Tailing	
		Pre-kinetic	Post-kinetic
Aluminum (Al)	%	0.16	0.17
Antimony (Sb)	ppm	44.6	30.9
Arsenic (As)	ppm	401	371
Barium (Ba)	ppm	30	34
Bismuth (Bi)	ppm	0.04	<0.1
Cadmium (Cd)	ppm	23.4	20.6
Calcium (Ca)	%	0.73	0.54
Chromium (Cr)	ppm	115	114
Cobalt (Co)	ppm	4.3	3.9
Copper (Cu)	ppm	57.5	54.7
Iron (Fe)	%	7.07	6.01
Lead (Pb)	ppm	2330	2230
Magnesium (Mg)	%	0.36	0.35
Manganese (Mn)	%	4.43	>1
Mercury (Hg)	ppm	0.13	0.12
Molybdenum (Mo)	ppm	2.02	2.5
Nickel (Ni)	ppm	49.1	51.1
Phosphorus (P)	%	0.032	0.028
Potassium (K)	%	0.08	0.07
Selenium (Se)	ppm	0.8	<0.5
Silver (Ag)	ppm	56.4	48.8
Sodium (Na)	%	<0.01	0.003
Strontium (Sr)	ppm	15	13
Thallium (Tl)	ppm	1.9	0.7
Tin (Sn)	ppm	2	-
Titanium (Ti)	%	<0.005	<0.001
Uranium (U)	ppm	0.38	0.4
Vanadium (V)	ppm	5	7
Zinc (Zn)	ppm	2080	1790

The closedown SFE results generally returned lower constituent concentrations than those observed for the pre-humidity cell sample except for some major elements (Table 4-9). Electric conductivity, sulphate, alkalinity, calcium, magnesium, potassium, sodium, strontium, copper, and cadmium returned leachable concentrations higher (1.6 to 10 times higher) than the pre-humidity cell sample indicating the accumulation of some soluble products in the cell. However, no leachable concentrations exceeded the EQS.

To determine and estimate the load of constituents that may have accumulated in the HC, the closedown SFE concentrations were normalized by the weight of the tailing cell residue and compared with the normalized data for the last cycle of the humidity cell (Table 4-10). The load released from the closedown SFE was more than six-fold higher than that observed for the final humidity cell cycle for the majority of constituents. Several

metals (i.e., aluminum, arsenic, barium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, potassium, silicon, sodium, uranium, tin, and zinc) were twenty to more than hundred times higher. This confirms the accumulation of constituents during the humidity cell testing and redistribution of the closedown SFE load evenly over all weeks of the test is likely to increase the loading of each cycle by at least 6%. However, the redistribution of the closedown SFE concentration evenly over all weeks of the test will result in a modest increase of the weekly concentration released and unlikely to result in weekly or steady-state concentrations higher than the Bellekeno, Flame and Moth or EQS. Thus, the trace element release rates for the last ten cycles observed for the Bellekeno and Flame and Moth tailings are still a valid conservative proxy for most constituents, except selenium, for the Birmingham tailings.

Table 4-9: Comparison of Pre-Humidity Cell SFE, Closedown SFE and Humidity Cell Last Cycle

Leachable Metals	Unit	Birmingham LCT2 Tailing			KHSD Mill Site EQS (KV-83)
		Pre-kinetic SFE	Closedown SFE	Last Kinetic Cycle	
pH	pH units	8.17	8.02	7.94	6.5-9.5
EC	uS/cm	97.1	180	131	-
SO ₄	mg/L	19.1	31	29.1	-
Acidity to pH4.5	mg/L	<0.5	<0.5	<0.5	-
Acidity to pH8.3	mg/L	<0.5	<0.5	<0.5	-
Total Alkalinity	mg/L	14	65.3	32.7	-
Fluoride	mg/L	0.2	0.05	<0.05	-
Hardness CaCO ₃	mg/L	35	132	60.8	-
Aluminum (Al)-Leachable	mg/L	0.0214	0.00438	0.00101	-
Antimony (Sb)-Leachable	mg/L	0.0111	0.0019	0.000783	-
Arsenic (As)-Leachable	mg/L	0.000331	0.000264	0.000062	0.1
Barium (Ba)-Leachable	mg/L	0.0134	0.005	0.000264	-
Beryllium (Be)-Leachable	mg/L	<0.000010	<0.000010	<0.000010	-
Bismuth (Bi)-Leachable	mg/L	<0.0000050	<0.0000050	<0.0000050	-
Boron (B)-Leachable	mg/L	<0.050	<0.050	<0.050	-
Cadmium (Cd)-Leachable	mg/L	0.000309	0.000526	0.000189	0.01
Calcium (Ca)-Leachable	mg/L	12.4	40.3	14	-
Chromium (Cr)-Leachable	mg/L	<0.00010	<0.00010	<0.00010	-
Cobalt (Co)-Leachable	mg/L	0.000099	0.0000783	0.0000089	-
Copper (Cu)-Leachable	mg/L	0.000334	0.0026	0.00015	0.1
Iron (Fe)-Leachable	mg/L	<0.0010	0.006	0.0016	-
Lead (Pb)-Leachable	mg/L	0.0188	0.00119	0.000247	0.2
Lithium (Li)-Leachable	mg/L	0.00294	0.00284	0.00062	-
Magnesium (Mg)-Leachable	mg/L	0.988	7.52	6.24	-
Manganese (Mn)-Leachable	mg/L	0.445	0.343	0.0211	-
Mercury (Hg)-Leachable	mg/L	<0.000050	<0.000050	<0.000010	-
Molybdenum (Mo)-Leachable	mg/L	0.000928	0.00105	<0.000050	-
Nickel (Ni)-Leachable	mg/L	0.000368	0.000335	0.000121	0.5
Phosphorus (P)-Leachable	mg/L	0.0414	0.0074	0.0041	-
Potassium (K)-Leachable	mg/L	1.7	3.41	0.192	-
Selenium (Se)-Leachable	mg/L	0.000041	0.000117	0.00012	-
Silicon (Si)-Leachable	mg/L	0.45	0.88	0.15	-
Silver (Ag)-Leachable	mg/L	0.00003	0.0000131	<0.0000050	0.02
Sodium (Na)-Leachable	mg/L	0.596	2.44	<0.050	-
Strontium (Sr)-Leachable	mg/L	0.0172	0.183	0.0143	-
Thallium (Tl)-Leachable	mg/L	0.000177	0.000105	0.0000808	-
Tin (Sn)-Leachable	mg/L	<0.00020	0.00077	<0.00020	-
Titanium (Ti)-Leachable	mg/L	<0.00050	<0.00050	<0.00050	-
Uranium (U)-Leachable	mg/L	<0.0000020	0.00019	0.0000071	-
Vanadium (V)-Leachable	mg/L	<0.00020	<0.00020	<0.00020	-
Zinc (Zn)-Leachable	mg/L	0.017	0.0152	0.00263	0.5

Table 4-10: Comparison of Tailing Cell Last Cycle and Closedown SFE Loadings

Leachable Metals	Unit	Last Kinetic Cycle	Closedown SFE
pH	pH units	7.9	8.0
EC	uS/cm	-	-
SO ₄	mg/kg	13.8	93
Acidity to pH4.5	mg/kg	0.24	1.5
Acidity to pH8.3	mg/kg	0.24	1.5
Total Alkalinity	mg/kg	15.53	195.9
Fluoride	mg/kg	0.024	0.15
Hardness CaCO ₃	mg/kg	28.9	396
Aluminum (Al)-Leachable	mg/kg	0.00048	0.01314
Antimony (Sb)-Leachable	mg/kg	0.00037	0.0057
Arsenic (As)-Leachable	mg/kg	0.0000295	0.000792
Barium (Ba)-Leachable	mg/kg	0.000125	0.015
Beryllium (Be)-Leachable	mg/kg	0.0000047	0.00003
Bismuth (Bi)-Leachable	mg/kg	0.0000024	0.000015
Boron (B)-Leachable	mg/kg	0.0237	0.15
Cadmium (Cd)-Leachable	mg/kg	0.000089	0.001578
Calcium (Ca)-Leachable	mg/kg	6.65	120.9
Chromium (Cr)-Leachable	mg/kg	0.000047	0.0003
Cobalt (Co)-Leachable	mg/kg	0.00000423	0.0002349
Copper (Cu)-Leachable	mg/kg	0.000071	0.0078
Iron (Fe)-Leachable	mg/kg	0.00076	0.018
Lead (Pb)-Leachable	mg/kg	0.00012	0.00357
Lithium (Li)-Leachable	mg/kg	0.000295	0.00852
Magnesium (Mg)-Leachable	mg/kg	2.96	22.56
Manganese (Mn)-Leachable	mg/kg	0.01	1.029
Mercury (Hg)-Leachable	mg/kg	0.0000047	0.00015
Molybdenum (Mo)-Leachable	mg/kg	0.000024	0.00315
Nickel (Ni)-Leachable	mg/kg	0.000057	0.001005
Potassium (K)-Leachable	mg/kg	0.09	10.23
Selenium (Se)-Leachable	mg/kg	0.000057	0.000351
Silver (Ag)-Leachable	mg/kg	0.0000024	0.0000393
Sodium (Na)-Leachable	mg/kg	0.024	7.32
Strontium (Sr)-Leachable	mg/kg	0.0068	0.549
Thallium (Tl)-Leachable	mg/kg	0.000038	0.000315
Tin (Sn)-Leachable	mg/kg	0.000095	0.00231
Titanium (Ti)-Leachable	mg/kg	0.00024	0.0015
Uranium (U)-Leachable	mg/kg	0.0000034	0.00057
Zinc (Zn)-Leachable	mg/kg	0.00125	0.0456

4.7 DISCUSSION AND TAILINGS MANAGEMENT

The comparison of the results of geochemical testing of the Birmingham tailings sample with Onek, Lucky Queen, Flame and Moth, and Bellekeno tailings indicates that the tailings share similar geochemical characteristics with respect to ARD/ML. All the tailings had low potential for ARD/ML, with lower SFE-leachable metal(loid) concentrations observed for the Birmingham tailings compared to other tailings. Also, the Birmingham tailings HC data indicated that most metal(loid) concentrations release rates were comparable or markedly lower than those observed from Flame and Moth and Bellekeno tailings. One exception was the slightly elevated nickel concentration compared to those observed in the Flame and Moth and Bellekeno tailings humidity cell leachate during the first thirty cycles of the test but nickel concentrations later decreased mirroring the other metal(loid)s. The other exception was the higher selenium concentration above that of the Flame and Moth and Bellekeno HC during the second half of the test. Aside from the first flush cadmium and zinc concentrations, no exceedance of the Mill site EQS were observed in the Birmingham SFE or HC test indicating low potential for metal leaching.

While ABA work indicated that the Birmingham tailings had an Uncertain potential for acid generation, the sequential NAG and the kinetic results confirmed their low potential for acid generation. The Uncertain acid potential based on calculated NPR could be explained by the following:

1. The siderite-corrected NP method likely underestimated the effective NP available for acid neutralization. A portion of the iron and manganese carbonate material will likely contribute to net acid neutralization given the slow oxidation kinetics of manganese at circumneutral pH and siderite calcian end-member.
2. XRD analysis identified sphalerite (0.3 to 0.6 wt.%), galena (0.3 to 0.8 wt.%), and pyrite (1.6 to 2.2 wt.%) in the Birmingham tailings sample. Under oxic weathering conditions, the oxidation of galena and sphalerite by oxygen is not an acid generating process. Both these minerals constitute approximately 20% to 47% of the XRD-measured sulphide mineralogy, indicating that the AP was likely overestimated.

Furthermore, sequential NAG testing revealed that there is sufficient NP in the Birmingham tailings to buffer the acid generated from sulphide oxidation. Sulphide and NP depletion calculations for the Birmingham tailings humidity cell also confirmed that the NP will outlast the AP generated from sulphide, indicating that net acid generation is not anticipated from the Birmingham tailings.

The results of the humidity cell closedown tests indicated that geochemical changes consisting of the removal of some constituents from the sample and the accumulation of others in the residue occurred during the kinetic test. Despite these changes, the tailings material remains low potential for long-term acid generation and metal leaching.

The tailings deposited in the DSTF or underground as cemented tailings backfill at Birmingham will either be standalone Birmingham tailings or a combination of tailings originating from the mines currently permitted in the KHSD. Blending and/or co-disposal of the Birmingham tailings with high effective NP (high in fast reactive calcite) tailings from the Flame and Moth and Bellekeno in the DSTF would significantly increase the bulk NP of the tailings mix, thus the net long-term acid generation is not anticipated. The geochemical testwork

completed on the Bellekeno tailings stored on the DSTF and their performance indicate that the tailings are not a concern from an acid generating potential perspective.

5 SUMMARY

The results of static and kinetic tests conducted on the Birmingham tailings indicate that the tailings were mainly composed of silica, calcian iron and manganese carbonates and minor sulphides. They had low potential for long-term acid generation due to an adequate NP buffering the acidity released from sulphide oxidation. The tailings had elevated bulk concentrations of several metals and metalloids but laboratory simulated short- and long-term leaching tests (SFE and HC) suggests that relatively low levels of metal leaching may be expected from the Birmingham tailings. Similar geochemical characteristics were observed for the tailings humidity cell residue.

The Birmingham tailings had similar geochemical characteristics as the tailings from other deposits. Their lower bulk metal composition might be in part due to spatial variability in mineralization between the deposits. The SFE leachable metal(loid)s and HC metal(loid) release rates were comparable or markedly lower than those observed from other tested tailings, except for nickel and selenium, with leachate constituent concentrations well below the EQS at the Mill site pond. Their low fast reactive carbonate content (e.g., low readily available NP) will be compensated by NP from calcian siderite and by NP from other tailings with high NP during co-disposal or blending. Overall, the Birmingham tailing have low potential for acid and metal release.

6 REFERENCES

- Access Consulting Group. (2015) Summary of Geochemical Characterization of Flame & Moth Tailings. Memorandum prepared for Alexco Keno Hill Mining Corp., August 6, 2015.
- CRC (2005). *CRC Handbook of Chemistry and Physics, 85th Edition*. CRC Press. Boca Raton, Florida.
- Price, W.A. (2009) *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials*. MEND Report 1.20.1. CANMET – Mining and Mineral Science Laboratories, Smithers, BC.