# KENO HILL SILVER DISTRICT MINING OPERATIONS

# MONITORING, SURVEILLANCE AND REPORTING PLAN

January 2023

Prepared by:

**HECLA YUKON**

Prepared for:

**ALEXCO KENO HILL MINING CORP.**

# DOCUMENT REVISIONS

| SECTION | SUMMARY OF CHANGES |
|---|---|
| Entire document | Updated to reflect new ownership of company and revised reporting structure<br>Figures updated<br>Added reference to New Bermingham mine in multiple sections |
| Document Revisions | Table added to indicate areas where changes have been made to the previous revision of the Plan |
| Introduction | Overview of the KHSD mining operations added<br>Change of ownership explained |
| Water Surveillance Network | Removed reference to ERDC water quality monitoring<br>Added monitoring and sampling requirements for raw mine water discharge from Bellekeno<br>Added water quality objectives (sourced from the December 2022 AMP)<br>Removed heading 2.1<br>Updated text about set point triggers to be consistent with the December 2022 AMP<br>Updated monitoring station tables to be consistent with the December 2022 |
| Environmental Effects Monitoring | Updated the information provided about study design's and interpretive reports |
| Air Quality Monitoring | Directed the reader to the January 2023 Dust Abatement and Monitoring Plan for details about the monitoring program and deleted the outdated discussion on the monitoring program |
| Noise Monitoring | Directed the reader to the October 2021 Noise Monitoring and Management Plan for an update on the current monitoring program |
| Waste Rock Monitoring | Adding information about the studies completed after 2013 to be consistent with the October 2021 Waste Rock Management Plan |
| Adaptive Management Plan | Replaced all the text in this section |
| References | Section updated<br>Removed current AKHM Management Plans submitted under the Water Licence and Quartz Mining Licence |

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# 1 INTRODUCTION

This plan is comprised of the monitoring, surveillance and reporting that will be carried out to ensure that the Keno Hill Silver District (KHSD) Mining Operations are managed in a manner that provides human and environmental protection. The framework of this plan includes monitoring and reporting of:

- the local and receiving environment through scheduled inspections and monitoring programs,
- effluent discharge points and treatment system performance,
- site facilities and incorporated design measures to ensure structural stability and prevention of accidents and malfunctions,
- remediation success, and
- adaptive management responses.

If monitoring indicates that physical structures, treatment systems or mitigative measures are not performing, then maintenance or contingency plans can be implemented following an adaptive management approach as discussed in Section 11.

The site is 354 km north of Whitehorse, in the vicinity of Keno City in the central Yukon. AKHM owns and operates of a series of small underground silver/lead/zinc mines with a centralized mill, as described in Table 1-1 and shown on Figure 1-1. On September 7, 2022, Alexco Resource Corp. (doing business as Hecla Yukon), the parent company of AKHM, was acquired by Hecla Mining Company.

**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<br>Flame & Moth (Development 2018, suspended 2018 – 2020, development and production 2020 - present)<br>New Bermingham (Advanced exploration 2017 – 2018, development and production 2020 - present)<br>Lucky Queen, Onek 990 (Advanced exploration 2013, not active) |
| **MILL** | District Mill location at Flame & Moth Mine area (Constructed 2010)<br>Tailings placed in Dry Stack Tailings Facility (Established 2010) or underground as backfill |
| **WORK FORCE** | ~ 250 employees and contractors during active mine and reclamation operations (as per Yukon Environmental and Socio-economic Assessment Act [YESAA] 2018-0169 Decision Document) |
| **AIRSTRIP** | Village of Mayo, YT |
| **CAMP FACILITIES** | Flat Creek camp facilities include a trailer camp, kitchen facility, welcoming center and dry<br>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<br>Water treatment plants at Bellekeno 625, Flame & Moth, and New Bermingham for mine effluent<br>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 environmental 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.

Prior to mine development in the KHSD, a number of monitoring programs and a surveillance network were already in place as per care and maintenance activities (Water Licence QZ06-074), advanced exploration and development activities at the Bellekeno, Flame & Moth and New Bermingham mines (Water Licence QZ18-044) as well as district-wide closure and new mine permitting studies. These programs include but are not limited to physical inspections, a water quality surveillance network, old mine workings monitoring, aquatic resources monitoring for benthic invertebrate and fisheries populations, sediment monitoring, waste rock and mine wall sampling and the Adaptive Management Plan. Monitoring, surveillance and reporting applicable to Bellekeno, Flame & Moth and New Bermingham mines are presented in this plan.

475,000 477,500 480,000 482,500 485,000 487,500

7,092,500 7,090,000 7,087,500 7,085,000

N W E S

South

HANSON MCQUESTEN ROAD

Christal Creek

South McQuesten River

Sandy Creek

SILVER TRAIL HIGHWAY

Christal Creek

KENO SUMMIT

Star Creek

No Cash Creek

WERNECKE ROAD

Erickson Gulch

Charity

SIGN POST ROAD

CALUMET DRIVE

BERMINGHAM ACCESS ROAD

GALENA HILL

CHRISTAL LAKE

CHRISTAL LAKE ROAD

FLAME AND MOTH PORTAL

DISTRICT MILL SITE

BELLEKENO HAUL ROAD

KENO CITY

FLAT CREEK CAMP

FORMER ELSA TOWNSITE

Porcupine Gulch

Brefalt Creek

NEW BERMINGHAM PORTAL

HISTORIC BERMINGHAM 200 ADIT

DUNCAN CREEK ROAD

Lightning Creek

BELLEKENO 625

BELLEKENO EAST PORTAL

Thunder Gulch

Flat Creek

SOURDOUGH HILL

1:40,000 (when printed on 11 x17 inch paper)

0 0.5 1 2 Kilometres



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



- Adit
- AKHM / ERDC Quartz Claims
- Silver Trail Highway
- Other Road
- Limited-Use Road
- Tailings Area
- Waterbody
- Watercourse
- Contours (100 ft intervals)

Hecla YUKON

ENSERO solutions

# FIGURE 1-1

## KENO HILL SILVER DISTRICT MINING OPERATIONS OVERVIEW

**DECEMBER 2022**

D:\Project\AllProjects\Keno_Area_Mines\ALL-SITES\02-Map\01_Overview\01-Property Overview\01-District_WideOverview_20221115.mxd
(Last edited by: fspalling; 21/22/2022/10:33 AM )

# 2 WATER SURVEILLANCE NETWORK

KHSD Mining Operations Water Licence QZ18-044 provides Effluent Quality Standards (EQS) which dictate maximum concentrations of specific parameters allowed to be discharged at locations where water treatment is being undertaken.

The Bellekeno Mine stopped dewatering activities in October 2021, and discharge from the Bellekeno 625 Treatment Pond Decant (KV-43) ceased. The raw mine water discharging from the Bellekeno 625 Adit (KV-42) will be tested monthly for glycol, benzene, ethylbenzene, toluene, xylene (BETX), styrene volatile petroleum hydrocarbons (VPHw), light extractable petroleum Hydrocarbons (LEPHw) and polycyclic aromatic hydrocarbons (PAH). Upon reaching a steady and compliant state in these parameters a request to reduce the testing program in accordance with the *Yukon Contaminated Sites Regulation* (YCSR) will be submitted to the Yukon Department of Environment, Environment Protection and Assessment Branch.

In addition to the monitoring of treated effluent discharge and associated adits, background surface water stations upstream of project facilities are also monitored along with the receiving environment.

Surface water quality objectives (WQOs) that are broadly protective of aquatic resources for the receiving environment have been established for Christal Creek (KV-50, KV-6, and KV-7), Lightning Creek (KV-81), and No Cash Creek (KV-21, KV-111), Star Creek (KV-56), and the South McQuesten River (KV-2). The results are used to calculate loading and potential effects to the receiving environment (Figure 2-1).

WQOs are thresholds of acceptable water quality conditions in specific receiving waters that may be affected by a project, including both narrative descriptions of expectations for acceptable water quality conditions and numerical benchmarks that define specific chemical or physical characteristics of acceptable water quality (Government of Yukon, 2021). The WQOs were established using generic Canadian Council of Ministers of the Environment (CCME) or British Columbia Ministry of Environment (BCMoE) guidelines or using the background concentration procedure. The background concentration procedure (BCP) was used to develop WQOs for constituents that frequently exceed CCME and BCMoE guidelines (i.e., >10% of samples exceed guideline). Short-term maximum and long-term average threshold concentrations were developed from the 95$^{th}$ percentile (P95) and upper confidence limit (95%) mean (UCLM) of the data set (past ten years, where available), respectively. The WQOs for Christal, Lightning, No Cash, and Star Creeks and the South McQuesten River are presented in Table 2-1.

Monitoring wells are used to measure and sample groundwater in the receiving environment and have been established as per Water Licence QZ18-044. Refer to Type A Water Licence QZ18-044, which specifies Effluent Quality Standards (Part G), monitoring and surveillance (Part H and Schedule B) and Reporting (Part I) required for the KHSD Mining Operations, which is available for download at www.yukonwaterboard.ca/waterline.

A Groundwater Monitoring Plan for the KHSD Mining Operations was developed in February 2011 and was last updated in October 2021 to include the New Bermingham Mine per Water Licence QZ18-044 (see Appendix A). This plan outlines monitoring locations and frequency for the District Mill and Dry Stack Tailings Facility (DSTF), the non-acid metal leaching (N-AML) waste rock disposal areas (New Bermingham and Bellekeno). Groundwater wells are scheduled for monthly monitoring for both water level and quality for 12 months to establish well conditions, followed by quarterly sampling thereafter for the duration of the project, as per Clause 87(a). Groundwater data will be compared to the Yukon *Contaminated Sites Regulations* Schedule 3:

Generic Numerical Water Standards (Aquatic Life) and to the Yukon *Contaminated Sites Regulations* Drinking Water Standards when near potable or potentially potable aquifers, as per Clauses 82 and 83.

Table 2-2 outlines the sampling stations and schedule for internal and external lab analysis in the area of the New Bermingham, Bellekeno, and Flame & Moth mines and in the vicinity of the District Mill site. Table 2-2 has been updated to includes requirements for monthly petroleum hydrocarbon and glycol testing at Bellekeno 625 Adit (KV-42). Figure 2-1 shows the surface water monitoring locations and includes three insets for the respective surface water quality location by mine component for the DSTF/District Mill/Flame & Moth, New Bermingham and Bellekeno. Figure 2-2 shows the existing and proposed groundwater locations for the District Mill and Flame & Moth Mine Mining Operations, while Figure 2-3 provides the New Bermingham Mine groundwater monitoring locations.

Hydrology monitoring is undertaken on a continuous basis during the open water season at stations on Christal Creek (KV-6), No Cash Creek (KV-21) and Lightning Creek (KV-41), as per Part H, Clause 73. In June 2015, a water level recorder with staff gauge were installed in Christal Lake and KV-51 (Christal Creek downstream of Hinton Creek). Should flow be present at site KV-11 and KV-118 manual measurements will be completed, and data submitted as part of monthly report, as per Part H, Clause 75. Instantaneous measurements of flow are also collected during monthly/quarterly sample events at all stations possible. Flow monitoring stations will be established for all locations where water is withdrawn from surface or ground for use with mining activities and discharged into the receiving environment.

Quality assurance and quality control (QA/QC) protocols have been implemented during collection, storage and shipping of samples. Standard QA/QC procedures conducted by field and laboratory staff including duplicate, relative percent difference analysis, analytic matrix spikes, spike blanks, and field, trip and method blanks.

Laboratory quality control analysis includes method blanks, laboratory duplicates, matrix spikes and blank spikes which are required to be reported by the laboratory showing acceptability criteria prior to issuing AKHM the data.

One field blank is collected per monthly event and is completed by taking de-ionized water (analyte free media) to the sample station, opening it and exposing it to ambient air and 'collecting' it in the sample bottles. These samples are treated the same as the actual water samples, preserved and filtered as necessary, and their analysis can provide an indication of contamination that may affect the actual samples. Additionally, one travel blank will accompany the samples for each monthly event and will be analysed for the same parameters as the routine samples.

Field duplicates are collected at a rate of 10% or 1 for every 10 samples. Relative Percent Difference (RPD) is used to determine field variability and is the difference between the sample result and replicate result, divided by the average of the sample result and replicate result and expressed as a percentage. Where analyte results have RPD greater than 25% a subsequent check is done against the laboratory detection limit (DL) to establish if the practical quantitation limit (PQL) was met. The PQL is five times the DL and is defined as the minimum concentration that can be measured within specified limits of precision and accuracy. Both results need to be above the PQL for the analyte to be considered as 'meeting the PQL'. If one result from the sample or duplicate is greater than 5X DL and the other result is less than 5X DL then the 'PQL is not met'. An analyte with results not meeting the PQL indicates that the constituent being analyzed is not present in a sufficient amount to be reliably quantified. Typically, as parameters approach their detection limit, high variability is more likely to

occur. The RPD of 25% can be used as a benchmark whereby an RPD greater than 25% warrants further comment or consideration.

All water quality data is stored in an EQWin database and additional QA/QC steps to determine potential outliers are identified. A variance report is generated on at least a quarterly basis for sitewide information that outlines the comparison off field vs laboratory pH and conductivity, and comparison to recent samples collected (i.e., RPD compared to samples from last 12 months).

As part of evaluation of the data a number of environmental models are updated with the water quality and quantity information outlined in Section 2, which include groundwater models, water quality models, water balances and water quality objectives (WQO) for Christal Creek, Lightning Creek and No Cash Creek. These tools are updated with additional water information available on an annual or as needed basis to inform decision making process or to further evaluate adaptive management responses. As an example, a number of stations (i.e., KV-6, KV-21 and KV-41) record continuous stream flow measurements. This information, in combination with the meteorology data, is used to refine the parameters and assumptions used in the water balances.

The surface water quality monitoring locations by mine are presented in Table 2-3. The water quality information collected under this plan is integrated into the existing water quality models to verify or adjust calibration factors used in the model. This advances the understanding of the dynamic nature of the district and numerous load sources including evaluation and determination of natural attenuation capacity in the receiving environment.

Additionally, the water quality data are compared with set point triggers placed in the EQWin database. In this way, parameters can be tracked, and fluctuations out of the normal levels where management is required to respond can be monitored. The set point triggers are based on the established WQOs (Table 2-2) and Adaptive Management Plan thresholds as part of the routine review.

The groundwater monitoring locations per mine is presented in Table 2-3. The groundwater levels collected as part of this program will be used to prepare groundwater contours maps twice per year and refinements to the groundwater models as required.

## Table 2-1: Water Quality Objectives for Christal Creek, Lightning Creek, No Cash Creek, Star Creek, and South McQuesten River

| | KV-50 | KV-6 | KV-7 | KV-81[A] | KV-21[A] | KV-56 | KV-111[A] | KV-2 |
|---|---|---|---|---|---|---|---|---|
| | MG/L | MG/L | MG/L | MG/L | MG/L | MG/L | MG/L | MG/L |
| Ammonia-N | CCME | CCME | CCME | CCME | CCME | CCME | CCME | CCME |
| Nitrate-N | CCME | CCME | CCME | CCME | CCME | CCME | CCME | CCME |
| Nitrite-N | CCME | CCME | CCME | CCME | CCME | CCME | CCME | CCME |
| Arsenic | 0.0432[b], 0.0277[c] | 0.0167[b], 0.0098[c] | 0.0102[b], 0.0043[c] | 0.005 | 0.025[f] | 0.005 | 0.005 | 0.005 |
| Cadmium | BCMoE | 0.00218[b], 0.00142[c] | 0.00251[b], 0.000945[c] | BCMoE | 0.0445[d], 0.0209[e] | 0.000297[d], 0.000132[e] | 0.000541[b], 0.000258[c] | 0.000941[b], 0.000647[c] |
| Copper | 0.00602[b], 0.00280[c] | 0.0321[b], 0.00115[c] | 0.00726[b], 0.00216[c] | 0.00148[b], 0.00070[c] | 0.00359[d], 0.00193[e] | BCMoE | BCMoE | 0.00651[b], 0.00376[c] |
| Lead | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE |
| Nickel | CCME | CCME | CCME | CCME | CCME | CCME | CCME | CCME |
| Silver | CCME | CCME | CCME | CCME | CCME | CCME | CCME | CCME |
| Uranium | CCME | CCME | CCME | CCME | CCME | CCME | CCME | CCME |
| Zinc | 0.271[b], 0.205[c] | 0.367[b], 0.207[c] | 0.220[b], 0.120[c] | CCME | 4.94[d], 2.28[e] | CCME | 0.179[b], 0.0602[c] | 0.152[b], 0.103[c] |
| Sulphate | 544[b], 409[c] | BCMoE | BCMoE | BCMoE | 539[d], 349[e] | BCMoE | BCMoE | BCMoE |
| Selenium | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE | BCMoE |
| Radium | - | 0.037 Bq/L | - | 0.037 Bq/L | - | - | 0.037 Bq/L | - |

Notes:

a) Objectives for KV-81, KV-21, and KV-111 metals are dissolved

b) 95th percentile from July 2011 to August 2021 data set, except for KV-111 which ranges from September 2017 to August 2021

c) Upper confidence level mean from July 2011 to August 2021 data set, except for KV-111 which ranges from September 2017 to August 2021

d) 95th percentile from July 2017 and June 2018 to August 2021 data set for KV-21 and KV-56, respectively

e) Upper confidence level mean from July 2017 and June 2018 to August 2021 data set for KV-21 and KV-56, respectively

f) Site specific based on Golder (2013) presented in Bermingham Water Quality Model (AEG, 2019a)

**Table 2-2 Keno Hill Silver District Mining Operations Water Monitoring Program Summary**

| SITE | SITE DESCRIPTION | WATER LICENCE | INSITU MEASUREMENTS / INTERNAL ANALYSIS | | | | | | | | | EXTERNAL LAB ANALYSIS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | QZ18-044 Monitoring Status | Level | Synoptic Levels | Flow | pH | Temperature | Conductivity | Total Zn | Ammonia | Turbidity | Total Metals | Dissolved Metals | Hardness | pH | Conductivity | TSS | Alkalinity | Sulphate | Nitrate | Nitrite | Ammonia-N | DOC | Total Phosphorous | Total and Free Chlorine | Petroleum Hydrocarbons* * and Glycol | Radium 226 | Acute Lethality LC50 Rainbow Trout 96 Hour |
| **Mine Treatment / Effluent Discharge Sites** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| KV-42 | Bellekeno 625 Adit | Existing | - | | C | D | D | D | D | D | D | W | W | W | W | W | W | W | W | W | W | W | M | W | | M | - | - |
| KV-43 | Bellekeno 625 Settling Pond Decant | Existing | - | | C | D | D | D | D | D | D | W | W | W | W | W | W | W | W | W | W | W | W | W | | | W/Q | M |
| KV-82 | Flame and Moth Mill Site Collection and Sediment Pond | Existing | D | | - | D | D | D | D | D | D | M | M | M | M | M | M | M | M | M | M | M | M | M | | | - | - |
| KV-83 | Flame and Moth Mill Treatment Plant Discharge | Existing | - | | C-WD | D-WD | D-WD | D-WD | D-WD | D-WD | D-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | Q-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | | | W/Q | M |
| KV-105 | Flame and Moth Adit Discharge | Existing | - | | C | D-WD | D-WD | D-WD | D-WD | D-WD | D-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | | | - | - |
| KV-104L | Flame and Moth Settling Pond Decant discharge to Lightning Creek | Existing | D | | C-WD | D | D | D | D | D | D | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | | | W/Q | M |
| KV-104C | Flame and Moth Settling Pond Decant discharge to Christal Creek | Existing | D | | C-WD | D | D | D | D | D | D | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | | | W/Q | M |
| KV-110 | New Bermingham Portal | Existing | - | | C-WD | D-WD | D-WD | D-WD | D-WD | D-WD | D-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | D-WD* | | - | - |
| KV-114 | New Bermingham Pond Decant | Existing | D | | C-WD | D | D | D | D | D | D | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | W-WD | D-WD* | | W/Q | M |
| **Mine Surface Water Surveillance Sites** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| KV-1 | South McQuesten River u/s Christal Creek | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-2 | South McQuesten River @ Pumphouse | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-6 | Christal Creek @ Keno Highway | Existing | - | | C | M-WD | M-WD | M-WD | - | - | - | W-WD/M | W-WD/M | W-WD/M | W-WD | W-WD | W-WD | W-WD | W-WD/M | W-WD/M | W-WD/M | W-WD/M | W-WD/M | W-WD/M | | | - | - |
| KV-7 | Christal Creek @ Hanson Road | Existing | - | | M | M | M | M | - | - | - | M | M | M | M | M | M | M | M | M | M | M | M | M | | | - | - |
| KV-8 | Christal Creek @ mouth | Existing | - | | Q | M | M | M | - | - | - | M | M | M | M | M | M | M | M | - | - | - | M | M | | | - | - |
| KV-21 | No Cash Creek at Silver Trail Highway | Existing | - | | C | M | M | M | - | - | - | M | M | M | M | M | M | M | M | M | M | M | M | M | | | - | - |
| KV-37 | Lightning Creek u/s Hope Gulch | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-38 | Lightning Creek u/s Thunder Gulch | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-39 | Hope Gulch u/s Lightning Creek | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-40 | Charity Gulch u/s Lightning Creek | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-41 | Lightning Creek u/s Bridge @ Keno City | Existing | - | | C | M | M | M | - | - | - | M | M | M | M | M | M | M | M | M | M | M | M | M | | | - | - |
| KV-44 | Bellekeno 625 Seep | Existing | - | | Ms | Ms | Ms | Ms | Ms | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | Q |
| KV-45 | Onek 400 Adit | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-49 | Hinton Creek u/s Christal Creek | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-50 | Christal Creek u/s Hinton Creek | Existing | - | | M-WD | M-WD | M-WD | M-WD | - | - | - | W-WD/M | W-WD/M | W-WD/M | W-WD | W-WD | W-WD | W-WD | W-WD/M | W-WD/M | W-WD/M | W-WD/M | W-WD/M | W-WD/M | | | - | - |
| KV-51 | Christal Creek d/s Hinton Creek | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-52 | Natural spring to Christal Lake @ Old Mackeno Pumphouse | Existing | - | | M | M | M | M | - | - | - | M | M | M | M | M | M | M | M | - | - | - | M | M | | | - | - |
| KV-56 | Star Creek at Silver Trail Highway | Existing | - | | M | M | M | M | - | - | - | M | M | M | M | M | M | M | M | M | M | M | M | M | | | - | - |
| KV-65 | Thunder Gulch u/s of Bellekeno 625 | Existing | - | | Q | Q | Q | Q | - | - | - | M | M | M | M | M | M | M | M | - | - | - | M | M | | | - | - |
| KV-72 | South McQuesten River at McQuesten Lake | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | | | | Q | Q | | | | |
| KV-76 | Thunder Gulch d/s Bellekeno 625 | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-77 | Thunder Gulch u/s Bellekeno East | Existing | - | | Q | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-78B | Bellekeno East Temporary Waste Rock Storage Facility | Existing | Ms | | - | Ms | Ms | Ms | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-79 | Christal Creek d/s MacKeno Tailings | Existing | - | | - | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-80 | Christal Creek u/s Mackeno Tailings | Existing | - | | - | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-81 | Lightning Creek Southwest of Mill Site | Existing | - | | M-WD | M-WD | M-WD | M-WD | - | - | - | W-WD/M | W-WD/M | W-WD/M | W-WD | W-WD | W-WD | W-WD | W-WD/M | W-WD/M | W-WD/M | W-WD/M | W-WD/M | W-WD/M | | | - | - |
| KV-106 | Flame and Moth Temporary P-AML Waste Rock Storage Facility | Existing | Q | | - | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-111 | No Cash Creek above No Cash 500 Adit | Existing | - | | M | M | M | M | - | - | - | M | M | M | M | M | M | M | M | M | M | M | M | M | | | - | - |
| KV-115 | Bermingham P-AML Facility #1 | Existing | Ms | | - | Ms | Ms | Ms | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-119 | Bermingham P-AML Facility #2 | Pending | Ms | | - | Ms | Ms | Ms | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q | | | - | - |
| KV-118 | No Cash Creek at Calumet Drive | Existing | - | | M | M | M | M | - | - | - | M | M | M | M | M | M | M | M | M | M | M | M | M | | | - | - |
| **Mine Groundwater Monitoring Wells** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| KV-84Nd | Keno City Well #1 | Existing | Q | - | - | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-85D | Keno Hill Silver Distirict Mill Site Groundwater Well #1 (PH2) Deep | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-85S | Keno Hill Silver Distirict Mill Site Groundwater Well #2 (Shallow) | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-86 | Keno Hill Silver Distirict Mill Site Groundwater Well #3 (PH5) | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-87 | Keno Hill Silver Distirict Mill Site Groundwater Well #4 (PH6) | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-88D | Keno Hill Silver Distirict Mill Site Groundwater Well #5 (Deep) | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-88S | Keno Hill Silver Distirict Mill Site Groundwater Well #6 (Shallow) | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-89D | Keno Hill Silver Distirict Mill Site Groundwater Well #7 (Deep) | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-89S | Keno Hill Silver Distirict Mill Site Groundwater Well #8 (Shallow) | Existing | Q | | - | Q | Q | Q | - | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| KV-122 | Bermingham - downgradient of BH SW pit well #1 | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-123 | Bermingham - downgradient of BH SW pit well #2 | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-124 | Bermingham - upgradient of BH SW pit | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | | |
| KV-125 | Bermingham - downgradient of BH P-AML well #1 | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | | |
| KV-126 | Bermingham - downgradient of BH P-AML well #2 | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-127 | Bermingham - upgradient of BH P-AML | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KC-MW-4 | Keno City Well #3 (Well south of Onek 400 adit) | Existing | Q | - | - | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| ON-MW-2 | Keno City Well #2 (Onek Monitoring Well d/g Project Facilities) | Existing | Q | - | - | Q | Q | Q | - | - | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | | | - | - |
| ON-MW-3 | Keno City Well (Well south of Onek 400 adit) | Pending | M/Q | - | - | M/Q | M/Q | M/Q | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| FM-MW-01 | Flame and Moth Well #1 (KAR-01) | Existing | M | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| FM-MW-02 | Flame and Moth Well #2 (KAR-02) | Existing | M | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| FM-MW-03 | Flame and Moth Well #3 (KAR-03) | Existing | M | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| BH39 | DSTF phase 1 area | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-107 | DSTF phase II expansion area | Pending | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-108 | Upgradient of DSTF Phase 2 Expansion Area | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | | |
| RB-MW-1 | Ruby 400 adit Monitoring Well | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| BH-MW-1 | Historical Bermingham 200 adit monitoring well | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-116 | Bermingham Waste Rock Disposal Area Well | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| NC-MW-1 | No Cash 500 | Existing | M/Q | | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-109 | Lightning Creek near KV-81 | Existing | M/Q | - | - | M/Q | M/Q | M/Q | - | - | - | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | | - | - |
| KV-103 | District Mill Supply Well | Existing | Q | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| KV-84 | Overburden Monitoring Well | Existing | Q | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| KC-MW-1B | Bedrock Groundwater Monitoring Well | Existing | Q | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| KC-MW-2 | Overburden Groundwater Monitoring Well | Existing | Q | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| KC-MW-3 | Bedrock Groundwater Monitoring Well | Existing | Q | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| ON-MW-1 | Onek Monitoring Well #1 d/g Project Facilities | Existing | Q | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |
| ON-MW-4 | Bedrock monitoring well | Existing | Q | SA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | - | - |

Pending Stations to be established

C = Continuous
C-WD = Continuous While Discharging
D = Daily
D-WD = Daily While Discharging
D-WD* = Daily While Discharging from breakpoint chlorination system
W = Weekly
W-WD = Weekly While Discharging
Petroleum Hydrocarbons** include BETX + Styrene, VPHw, LEPHw, and PAH

W/Q = Weekly migrating to quarterly to accord with monitoring frequency pursuant to MDMER
M = Monthly
Ms = Monthly (May - Oct)
M/Q = Monitoring to occur monthly for first 12 months, reverting to quarterly thereafter.
Q = Quarterly
A = Annually

470000 480000 490000

7100000 7090000

DISTRICT MILL AND KENO CITY INSET

BELLEKENO INSET

BERMINGHAM INSET

McQuesten Lake
KV-72
Cache Creek
Hanson Lakes
Ladue Lake
South McQuesten River
HANSON/MCQUESTEN ROAD
Ladue Creek
Faro Gulch
Silver Basin Gulch
Keno Ladue River
Gambler Lake
Germaine Lake
Sadie Ladue Creek
Gambler Gulch
McKay Gulch
Allen Creek
Faith Creek
Christal Creek
KV-1
KV-8
KV-7
SILVER TRAIL HIGHWAY
No Cash Creek
Sandy Creek
Star Creek
KV-2
KV-56
KV-21
KV-20
KV-111
NO CASH 500
CALUMET DRIVE
GALKENO 300
KV-118
KV-48
Breriatt Creek
VALLEY TAILINGS WEATHER STATION
CALUMET WEATHER STATION
WERNECKE ROAD
SIGN POST ROAD
KENO 700
Hope Gulch
Charity Gulch
McMillan Gulch
McNeill Gulch
KV-39
KV-40
KV-37
Lightning Creek
Thunder Gulch
DISTRICT MILL AND KENO CITY INSET
BELLEKENO INSET

### DISTRICT MILL AND KENO CITY INSET

N W E S

Christal Creek
KV-6
SILVER TRAIL HIGHWAY
WERNECKE ROAD
SIGN POST ROAD
KV-79
KV-80
KV-52
GALKENO 900
Christal Lake
CHRISTAL LAKE ROAD
ONEK 400 ADIT
KV-45
KENO CITY BYPASS ROAD
KV-51
KV-49
KV-50
KV-121
KV-117
KV-104C
KV-82
KV-83
KV-105
KV-106
FLAME AND MOTH PORTAL
BELLEKENO HAUL ROAD
KV-41
Lightning Creek
DISTRICT MILL WEATHER STATION
KV-104L
KV-81
1:20,000

### BELLEKENO INSET

SIGN POST ROAD
BELLEKENO HAUL ROAD
KV-38
KV-76
KV-44
Lightning Creek
KV-43
KV-42
KV-65
BELLEKENO 625 ADIT
BELLEKENO EAST PORTAL
KV-78B
KV-77
TEMPORARY P-AML WRSF
Thunder Gulch
1:30,000

### BERMINGHAM INSET

BERMINGHAM ACCESS ROAD
KV-114
KV-110
HISTORIC BERMINGHAM 200
KV-18
NEW BERMINGHAM PORTAL
P-AML
KV-115
P-AML
KV-119
1:7,500

National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced underlicense from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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



1:90,000 (when printed on 11 x17 inch paper)

0 1 2 3 4 5 Kilometers

- Active Surface Water Quality Station
- Pending/Proposed Water Quality Station
- Weather Station
- Adit
- As Built Mine Feature
- Valley Tailings
- Silver Trail Highway
- Other Road
- Watercourse
- Waterbody

Hecla YUKON

KENO HILL SILVER DISTRICT MINING OPERATIONS

# FIGURE 2-1
# SURFACE WATER QUALITY MONITORING LOCATIONS

DECEMBER 2022

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(Last edited by: amalla/shevska; 2022-12-08 15:01 PM)


Monitoring Well

Proposed Monitoring Well

Adit

Proposed Road

DSTF 322k Tonnes Design

Current DSTF

To Be Constructed Features

# KENO HILL SILVER DISTRICT MINING OPERATIONS

## FIGURE 2-2

## DISTRICT MILL AND FLAME & MOTH GROUNDWATER MONITORING LOCATIONS

DECEMBER 2022

Satelite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on December 2022

Datum: NAD 83; Projection: UTM Zone 8N



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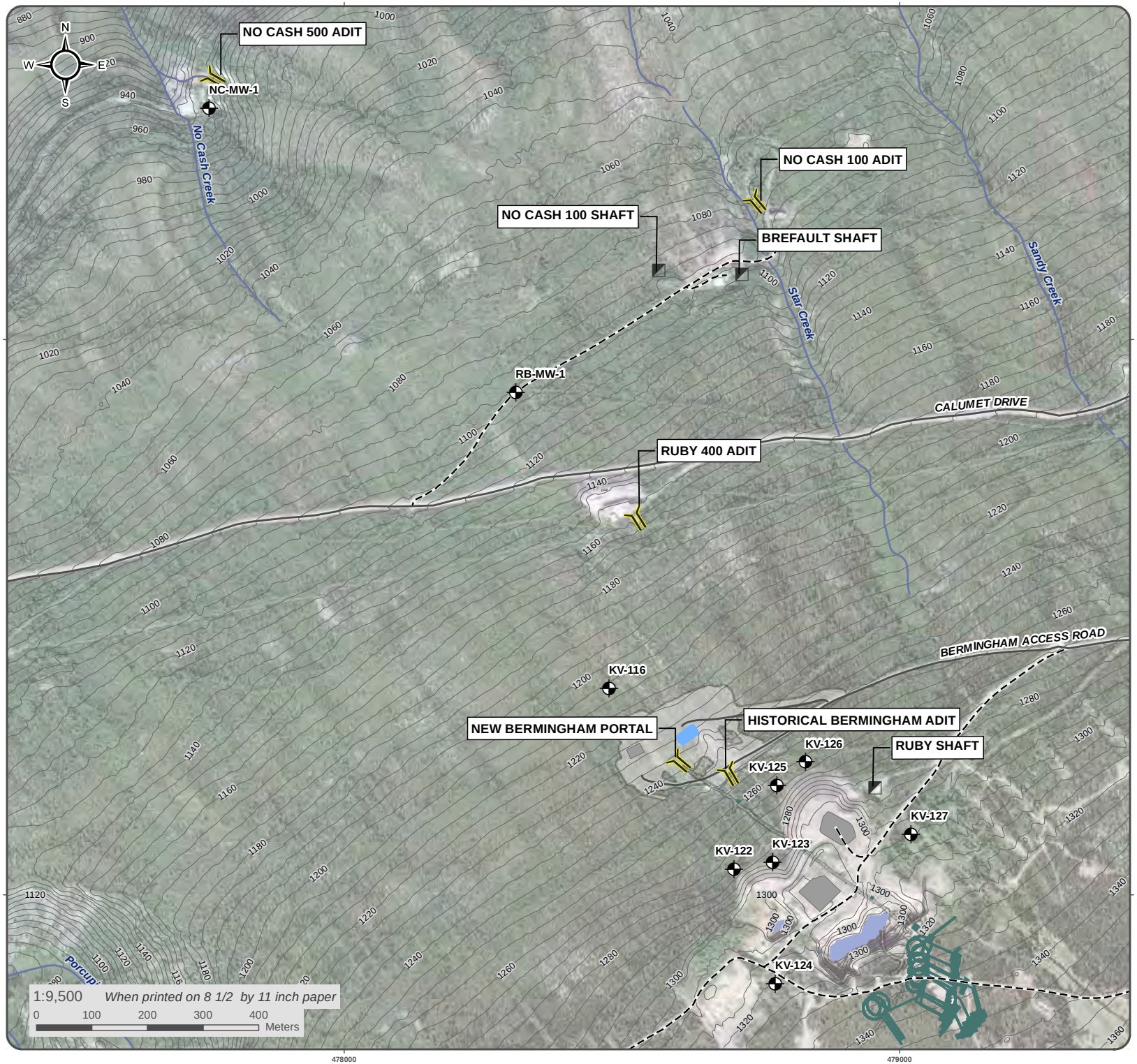
*(Last edited by: amatlashevska; 2022-12-08/15:13 PM)*




KENO HILL SILVER DISTRICT
MINING OPERATIONS

# FIGURE 2-3

# NEW BERMINGHAM GROUNDWATER MONITORING LOCATIONS

DECEMBER 2022

- Adit/Portal
- Shaft
- Groundwater Quality Monitoring, Existing
- Pond
- Proposed Underground Workings
- Road
- Limited-Use Road
- Contour (5m interval)

Satellite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on November 22 2022

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



Hecla YUKON

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(Last edited by: fsparling;11/22/2022/11:06 AM )

### Table 2-3: Surface water quality monitoring stations per mine

| MINE | MAIN WATER COURSES MONITORED | MINE ASSOCIATED STATIONS | RECEIVING ENVIRONMENT STATIONS USED FOR WATER BALANCE AND WATER QUALITY MODEL | LOCATIONS FOR WATER QUALITY PREDICTIONS AND WATER QUALITY OBJECTIVES |
|---|---|---|---|---|
| Bellekeno | Lightning Creek and Thunder Gulch | KV-42, KV-43, KV-44, KV-78b | KV-37, KV-38, KV-39, KV-40, KV-41, KV-76, KV-77 | KV-41 |
| Flame & Moth | Christal Creek and Lightning Creek | KV-104, KV-105, KV-106 | KV-49, KV-50, KV-51, KV-6, KV-7, KV-41, KV-81 | KV-81, KV-6, KV-7 |
| District Mill/DSTF | Christal Creek | KV-82, KV-83 | KV-50, KV-6, KV-7 | KV-6, KV-7 |
| New Bermingham | No Cash Creek | KV-114, KV-115 | KV-56, KV-111, KV-118 | KV-21 |

### Table 2-4: Groundwater monitoring stations per mine

| MINE | MINE INFRASTRUCTURE MONITORED | UPGRADIENT WELLS | DOWNGRADIENT WELLS |
|---|---|---|---|
| Bellekeno | | | |
| Flame & Moth | Mine and P-AML WRSF | KV-108 | FM-MW-2 and FM-MW-3, KV-103, KV-109 |
| District Mill/DSTF | Mill and DSTF | KV-87N, KV-108 | KV-85D/S, KV-86, KV-88D/S, KV-89S, BH-39, KV-107 |
| New Bermingham | Mine, N-AML WRDA, P-AML WRSF and Bermingham SW Pit | - | KV-116, BH-MW-1, RB-MW-1, NC-MW-1, KV-122, KV-123, KV-124, KV-125, KV-126, KV-127 |

Bold wells are pending

# 3 ENVIRONMENTAL EFFECTS MONITORING (UNDER MDMER)

The KHSD mines are subject to the Metal and Diamond Mining Effluent Regulations (MDMER), administered under the federal Fisheries Act, which apply to mining and milling operations that discharge effluent(s) at a rate greater than 50 m3/day. The MDMER outline requirements for routine effluent monitoring, acute lethality testing, Environmental Effects Monitoring (EEM) and provides maximum authorized limits of deleterious substances.

Effluent monitoring under MDMER tends to overlap with that required under Water Licence QZ18-044; although, unlike the Water Licence a reduction or increase in monitoring frequency may be triggered based on analysis results. Maximum authorized concentrations of deleterious substances for MDMER Schedule 4 is presented below in Table 3-1 below. The MDMER also requires Daphnia magna monitoring tests at the same time as acute lethality testing.

**Table 3-1: MDMER authorized limits of deleterious substances**

| | Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|---|
| Item | Deleterious Substance | Maximum Authorized Monthly Mean Concentration | Maximum Authorized Concentration in a Composite Sample | Maximum Authorized Concentration in a Grab Sample |
| 1. | Arsenic | 0.50 mg/L | 0.75 mg/L | 1.00 mg/L |
| 2. | Copper | 0.30 mg/L | 0.45 mg/L | 0.60 mg/L |
| 3. | Cyanide | 1.00 mg/L | 1.50 mg/L | 2.00 mg/L |
| 4. | Lead | 0.20 mg/L | 0.30 mg/L | 0.40 mg/L |
| 5. | Nickel | 0.50 mg/L | 0.75 mg/L | 1.00 mg/L |
| 6. | Zinc | 0.50 mg/L | 0.75 mg/L | 1.00 mg/L |
| 7. | Total Suspended Solids | 15.00 mg/L | 22.50 mg/L | 30.00 mg/L |
| 8. | Radium 226 | 0.37 Bq/L | 0.74 Bq/L | 1.11 Bq/L |

NOTE: All concentrations are total values.

The objective of EEM is to determine whether mining activity is causing an effect on fish or fish habitat, benthic invertebrate communities and/or the use of fisheries resources. A Bellekeno Mine Cycle 5 EEM Study Design is being developed with Environment and Climate Change Canada. Effluent monitoring, acute lethality testing and EEM Study Designs have been implemented as required by MDMER for Flame & Moth. The Flame & Moth Cycle 1 interpretive report is to be issued to Environment and Climate Change Canada. The interpretive reports are provided in the Quartz Mining Licence (QML-0009) annual reports.

Sampling requirements under the EEM program are as follows:

**Part 1. Effluent and Water Quality Monitoring Studies**

a) Effluent Characterization: Quarterly sampling from final discharge point includes extra parameters,

b) Water Quality Monitoring: Quarterly sampling of sites within reference and exposure areas,

c) Reference Area: Water frequented by fish that is not exposed to effluent and that has fish habitat that, as far as is practicable is most similar to the exposure area,

d) Exposure Area: All fish habitat and waters frequented by fish that are exposed to effluent, and

e) Sublethal Toxicity Testing: Semi-annual sampling required at each final discharge point and analysis of effects on reproduction or growth of a fish species, a plant species, an invertebrate species and an algal species as acceptable to MDMER.

**Part 2: Biological Monitoring Studies**

A number of study cycles that each include:

- a study design,
- Environment Canada and stakeholder review,
- a Field Sampling Program, and
- submission of an Interpretive Report that indicates whether or not an effect is observed.

Within each cycle, studies are conducted to determine if the effluent is having an effect on the following biological components including:

a) Fish Population: Studies conducted in exposure and reference areas;

b) Fish Tissue Studies: Only required if concentrations in effluent is equal to or greater than 0.1 µg/l or ppb – as determined by the effluent characterization program);

c) Benthic Invertebrate Community: Studies conducted in exposure and reference areas following the Canadian Aquatic Biomonitoring Network's (CABIN) protocols; and

d) Sediment sampling for analysis of particle size distribution and total organic carbon content. Sediment samples will be collected in replicates of three from active channels, placed in plastic containers and sent to an accredited laboratory where they are dried and sieved. Frequency of benthic and sediment sampling required by QZ18-044 is presented in Table 3-2.

The first study cycle (Cycle 1) is 30 months in duration, while subsequent cycles are 24 to 72 months in duration, depending on previous results (i.e., if an effect is indicated). A final cycle is required if notification of mine closure is issued. To avoid redundancy in sampling sites and monitoring programs, final discharge points for MDMER will be considered final discharge points under Water Licence QZ18-044.

**Table 3-2: Sediment and benthic invertebrate sampling frequency under QZ18-044**

| STATION | SEDIMENT SAMPLING | BENTHIC SAMPLING |
|---|---|---|
| KV-38 | Annual | Annual |
| KV-41 | Annual | Annual |
| KV-6 | Biannual | Biannual |
| KV-21 | Annual | Annual |
| KV-42 | Annual | - |
| KV-82 | Annual | - |
| KV-104L | Annual | - |
| KV-104C | Annual | - |
| KV-111 | Annual | Annual |

# 4 PERMAFROST MONITORING

While the broad region in which the KHSD Mining Operations are located is generally characterized by discontinuous permafrost, Hecla Yukon has not encountered significant permafrost anywhere in the Keno Hill mining camp. Notwithstanding, geotechnical programs have identified areas of permafrost within operational areas; specifically, some permafrost was encountered beneath the Bellekeno mine N-AML Waste Rock Storage Area (WRSA) and in the vicinity of the Dry Stack Tailings Facility (DSTF). Ground temperature and permafrost monitoring is currently in place at these locations. Details on monitoring for the DSTF are included in the DSTF Operation, Maintenance, and Surveillance Manual, which forms a part of the DSTF Development and Operations Plan. Details on permafrost monitoring for the N-AML WRDA and potential acid or metal leaching (P-AML) WRSF are included in the KHSD Mining Operations Mine Development and Operations Plan. Appendix A provides analysis for potential effects from blasting occurring during the development of the Flame & Moth decline to the monitoring wells in the vicinity of the District Mill and DSTF. The analysis shows that with appropriate management of the blasting the integrity of the monitoring wells including the ground temperature and slope indicator monitoring will not be compromised. Monitoring outlined in the analysis will be undertaken as part of the plan to ensure the integrity of the instrumentation is not compromised.

Similarly, permafrost monitoring will be implemented should it be encountered during construction of facilities for new mine development in the KHSD. Monitoring activities will consider the use of ground temperature and slope indicator monitoring devices to track potential changes in the ground conditions. Since much of the surface development is likely to occur on previously disturbed areas, the likelihood of encountering permafrost at surface is relatively low. However, if significant permafrost is encountered in areas of development an engineer will be consulted on the best practice to mitigate further degradation and plan around the permafrost laden material.

Specifically, for the final design, construction and operations of the phase 2 of the DSTF permafrost characterization and monitoring will be undertaken per Water Licence Clause 18 (below) and subsurface investigation program listed in Schedule C 1.5 (d) in the Quartz Mining Licence.

> 18. Prior to construction of the DSTF expansion, the Licensee must conduct a subsurface investigation program and submit the results of that investigation to the Board. The program must provide for representative sampling from the entire footprint of the DSTF expansion and include, but not be limited to:
>
> a) a minimum of 12 holes advanced to bedrock using a drill capable of recovering undisturbed frozen overburden samples;
>
> b) installation of sub-surface monitoring instrumentation including slope indicators and ground temperature cables; and
>
> c) laboratory testing of samples for shear strength, particle size and moisture content, as described in the Application in exhibit 1.13 .4 of Register QZ09-092-2.

# 5 PHYSICAL INSPECTIONS AND REPORTING PLAN

The purpose of physical inspection is to observe and record sufficient information for mine related structures to determine a course of action, repair or rehabilitation if it is required. Physical inspections are conducted under the Physical Inspections and Reporting Plan updated in October 2020 (Appendix B). Photo documentation at photo hubs is undertaken on a monthly basis in order to aid in identifying temporal changes and as a record keeping tool. The Physical Inspection and Reporting Plan describes scheduled physical inspections of infrastructure associated with the New Bermingham, Bellekeno Mine, Flame &Moth and District Mill operations. Information is collected through use of weekly and monthly checklists and reporting forms and any damage or movement is noted. If any seepage is noted from any water retaining structures it will be noted on the next monthly inspection report and a plan will be in place sample, test and manage the discharge within 60 days of the discovery. All annual monitoring and inspections for water conveyance and retaining structures and associated mine waste and earthworks structures will be conducted by a professional engineer.

In the vicinity of the Bellekeno mine, physical inspections include the Bellekeno 625 settling ponds, the Bellekeno East Temporary P-AML Waste Rock Storage Facility, and the haul road and Lightning Creek Bridge along the Keno City Bypass road. In the vicinity of the mill, physical inspections include the water supply and discharge pipelines and infrastructure, the mill site water collection and diversion structures, the mill site collection and sedimentation pond, the Flame and Moth P-AML facility and the dry stack tailings facility.

The Physical Inspection and Reporting Plan was updated in accordance with Water Licence QZ18-044 to include provisions for the New Bermingham structures. Such facilities for Bermingham include settling pond, N-AML waste rock disposal area, and P-AML waste rock storage facilities.

# 6 METEOROLOGICAL MONITORING

Meteorological data have been collected in the KHSD since 2007 at the Calumet weather station (Figure 6-1) as part of the development of the ESM Reclamation supporting studies), since 2011 at the District Mill meteorological station (installed as part of Bellekeno mining operations) and since 2012 at the Valley Tails meteorological station. All three stations collect air temperature, relative humidity, rainfall, solar radiation, wind speed and wind direction, as per Clause 80. In addition, the District Mill station has a snowfall conversion adaptor and calculates evapotranspiration, while the Valley Tailings station collects barometric pressure and soil water content. The Calumet station collects soil temperature. Instrumentation used at each of the weather stations is listed in Table 6-1, Table 6-2, and Table 6-3.

AKHM conducted manual snow surveys at thirteen monitoring stations in order to adequately represent the varying snow conditions as a function of aspect, elevation, etc. A Yukon Government monitored snow course station located at 1,310 masl elevation also exists in the area and has been monitored for over 30 years. Thirteen snow survey locations have been established at the District Mill Site, Bellekeno and New Bermingham sites, as per Clause 81. Information collected is submitted as part of the annual report.

Data collected from these stations will be used to update meteorological/hydrological information and water balances.

**Table 6-1: Galena Hill HOBO meteorological station components**

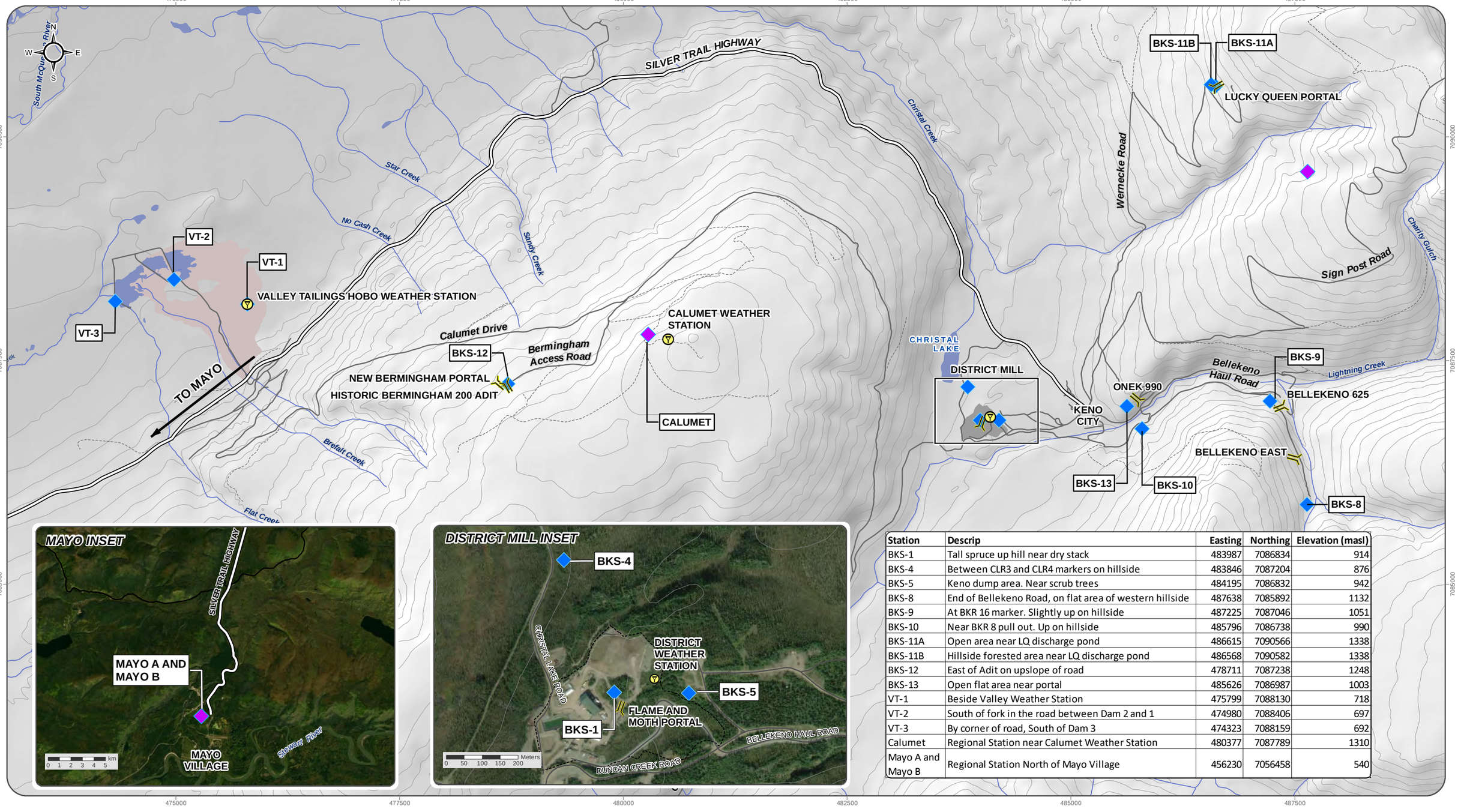
| COMPONENT | MODEL | SERIAL NUMBER |
|---|---|---|
| Datalogger | HOBO Weather Logger | 1153440 |
| Temp & RH Sensor | S-THB-XXXX | 10064003 |
| Soil Temp Sensor | S-TMB-XXXX | 985390 |
| Pyranometer | S-LIB-XXXX | 1048627 |
| Rain Gauge | S-RGB-M002 | 1017667 |
| Wind Speed & Direction Sensor | S-WCA-XXXX | 1254995 |
| BP Sensor | S-BPA-XXXX | 1037089 |

**Table 6-2: District Mill Campbell Scientific meteorological station components**

| COMPONENT | MODEL | SERIAL NUMBER |
|---|---|---|
| Air Temperature and Relative Humidity Sensor | HMP45C212 | n/a |
| Tipping Bucket Rain Gauge | TE525M | 45303-910 |
| Wind Speed and Direction Sensor | 05103AP-10-L | WM105907 |
| Solar Panel | SX320J | T21008289B30EC8 |
| Datalogger | CR800 | 16119 |
| Battery | PS-12120 F2 | 06299-HC |
| Pyranometer | SP Lite2 | 125766 |

**Table 6-3: Valley Tailings HOBO meteorological station components**

| COMPONENT | MODEL | SERIAL NUMBER |
|---|---|---|
| Datalogger | U30 NRC | 10231016 |
| Input Expander kit | | |
| Solar Panel | 6W | |
| AC Power Adaptor | 120V - 60Hz | |
| HOBOware | Pro | 2580 2976 6309 4793 |
| Temp & RH Sensor | THB-M002 | 10220040 |
| Solar Radiation Shield | RS3 | |
| Pyranometer | LIB-M003 | 10191222 |
| Rain Gauge | RGB-M002 | 10222664 |
| Light Sensor Bracket | LBB | |
| Light Sensor Level | LLA | |
| Wind Speed & Direction Sensor | WSET-A | 10233230 |
| Full Cross Arm | CAA | |
| BP Sensor | BPB-CM50 | 10212093 |
| Soil Moisture Sensor | SMC-M005 | 10225679 |
| Tripod | TPA-KIT 3m | |




| Station | Descrip | Easting | Northing | Elevation (masl) |
|---|---|---|---|---|
| BKS-1 | Tall spruce up hill near dry stack | 483987 | 7086834 | 914 |
| BKS-4 | Between CLR3 and CLR4 markers on hillside | 483846 | 7087204 | 876 |
| BKS-5 | Keno dump area. Near scrub trees | 484195 | 7086832 | 942 |
| BKS-8 | End of Bellekeno Road, on flat area of western hillside | 487638 | 7085892 | 1132 |
| BKS-9 | At BKR 16 marker. Slightly up on hillside | 487225 | 7087046 | 1051 |
| BKS-10 | Near BKR 8 pull out. Up on hillside | 485796 | 7086738 | 990 |
| BKS-11A | Open area near LQ discharge pond | 486615 | 7090566 | 1338 |
| BKS-11B | Hillside forested area near LQ discharge pond | 486568 | 7090582 | 1338 |
| BKS-12 | East of Adit on upslope of road | 478711 | 7087238 | 1248 |
| BKS-13 | Open flat area near portal | 485626 | 7086987 | 1003 |
| VT-1 | Beside Valley Weather Station | 475799 | 7088130 | 718 |
| VT-2 | South of fork in the road between Dam 2 and 1 | 474980 | 7088406 | 697 |
| VT-3 | By corner of road, South of Dam 3 | 474323 | 7088159 | 692 |
| Calumet | Regional Station near Calumet Weather Station | 480377 | 7087789 | 1310 |
| Mayo A and Mayo B | Regional Station North of Mayo Village | 456230 | 7056458 | 540 |



1:40,000 (when printed on 11 x17 inch paper)

0 500 1,000 1,500 2,000 Meters

- ERDC Snow Monitoring Station
- Regional Snow Monitoring Stations
- Audit
- AKHM District Mill
- Tailings Area
- Waterbody
- Watercourse
- Silver Trail Highway
- Other Road
- Limited-Use Road
- Contours (100 ft)

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**FIGURE 6-1**

**METEOROLOGICAL STATIONS AND SNOW SURVEY STATIONS LOCATION**

OCTOBER 2021

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(Last edited by: amadashevska; 2021-10-19/3:0:28 AM)

# 7 AIR QUALITY MONITORING

In accordance with Clause 69 of the Decision Document for the assessment of the Bellekeno Mine Project (YESAB File Number 2009-0030), dustfall monitoring was installed at two initial locations near the Keno District Mill site in March 2011 and two additional sampling locations were established in August 2011. Bergerhoff dust monitoring gauges were initially selected as the appropriate instrumentation to carry out this program. In accordance with Clauses 36 and 37 of the Decision Document for the assessment of the Onek and Lucky Queen Deposit production (YESAB File Number 2011-0315), total suspended particulates (TSP) monitoring was subsequently initiated in August 2012 and dustfall monitoring was discontinued in January 2013. Additional sampling for coarse and fine fractions of particulate matter ($PM_{10}$ and $PM_{2.5}$ respectively) was instigated in August 2015, in accordance with the revised Dust Abatement and Monitoring Plan required in the Decision Document (Clause 19) for the assessment of the Flame & Moth Development and Production Program (YESAB file Number 2013-0161).

Details of the air quality monitoring and pre-emptive and reactive dust control procedures are provided in the 2023 Dust Abatement and Monitoring Plan. The plan has been updated for New Bermingham and includes the District Mill, and Flame & Moth. This plan was developed to ensure that fugitive dusting does not become an issue.

# 8 NOISE MONITORING

AKHM has monitored noise at the five locations selected in the noise impact assessment as being potential noise receptors within a 2 km radius study area around Keno City. Since November 2013, noise has also been monitored at a sixth location, the Keno City Campground. These monitoring locations are listed in Table 8-1 and shown in Figure 8-1.

**Table 8-1: Representative locations assessed in Keno City**

| MONITORING LOCATION | GPS LOCATION | DESCRIPTION |
|---|---|---|
| R01 | N63.90827 W135.29599 | East end Residence, north side of Lightning Creek Road |
| R02 | N63.91019 W135.29968 | Residence, east side of Sign Post Road |
| R03 | N63.91023 W135.30205 | Town Center, north from the Snack Bar |
| R04 | N63.91239 W135.30376 | Residence, west side of Wernecke Road |
| R05 | N63.90851 W135.30993 | Residence, about 850 m east from the Mill |
| Campground | N63.90772 W135.29998 | Keno City campground |

The background noise levels experienced by these locations vary considerably, depending on location and local activities. Climate parameters, such as relative humidity, temperature, and temperature inversions impact the sound level and propagation experienced by each of these receptors.

Noise impacts and sound monitoring programs are discussed in the 2021 Noise Monitoring and Management Plan. The plan has been updated for New Bermingham and includes the District Mill, and Flame & Moth.

484000 484500 485000 485500

7087500 7087000 7086500

N W E S

CHRISTAL LAKE

CHRISTAL LAKE ROAD

Christal Creek

DRY STACK TAILINGS STORAGE FACILITY

TSP-2 AQ1

MILL

FLAME AND MOTH

MILL POND

CRUSHER

TSP-1

FLAME & MOTH WATER TREATMENT POND

P-AML

DUNCAN CREEK ROAD

Lightning Creek

AQ2

R05

TSP-4

SILVER TRAIL HIGHWAY

R04

SIGN POST ROAD

ONEK 400

WERNECKE ROAD

R03

R02 AQ3

KENO CITY BYPASS ROAD

ONEK 990 PORTAL

R01

KENO CAMPGROUND

BELLEKENO HAUL ROAD

SOURDOUGH TRAIL

484000 484500 485000 485500

Satelite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on October 2021

Datum: NAD 83; Projection: UTM Zone 8N



1:6,000 *(when printed on 11 x17 inch paper)*

0 50 100 150 200 250 Meters

- Noise Monitoring Stations
- Former Air Quality Monitoring Station
- Proposed Air Quality Monitoring Station
- Adit

- Infrastructure Footprint
- Pond
- DSTF 322k Tonnes Design
- Current DSTF
- Permitted To Be Constructed Features

- Watercourse
- Silver Trail Highway
- Secondary Road

Hecla YUKON

**ALEXCO KENO HILL MINING CORP.**

**FIGURE 8-1**

**NOISE MONITORING STATIONS**

OCTOBER 2021

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*(Last edited by: amallashevska;2021-10-19/14:14 PM)*

# 9 WASTE ROCK MONITORING

Between May and October of each year, all waste rock management facilities are subject to monitoring for physical and geochemical stability (acid rock drainage and/or metal leaching) including seep surveys, as per Clause 96 of Water Licence QZ18-044. The waste rock management plan presents rock characterization processes, field screening protocols, rock management, confirmatory testing and rock monitoring. A complete Waste Rock Management Plan was first prepared in 2009 and includes detailed descriptions of waste rock monitoring and mine wall testing. The waste rock monitoring plan was implemented in 2012 at the Bellekeno Mine with a detailed report testing and describing the effectiveness of waste rock screen procedures as presented in the plan (ACG, 2013).

Since the Bellekeno Waste Rock Management Plan was developed, permitting and licencing of the Flame & Moth and New Bermingham deposits has been completed. Clause 9.10 of QML-0009 and Clause 21 of Water Licence QZ18-044 outline the maximum quantities waste rock that are to be removed from the Bellekeno, Flame & Moth, and New Bermingham workings during the undertaking. To use the Waste Rock Management Plan for Flame & Moth and New Bermingham, geochemical characterization studies of the Flame & Moth deposit (AEG, 2016) and New Bermingham deposit (AEG, 2019b) were completed. The Waste Rock Management Plan was updated in October 2021 to include the New Bermingham deposit.

As part of annual reports for the Quartz Mining License and Water Licence a waste rock management summary report will be submitted presenting the results for all of the static and kinetic data generated from the Waste Rock Management Plan in a given year. The report will compare the field screening and on-site classification of waste rock to the laboratory analysis outlining the effectiveness of the implementation of the plan including tonnage of waste rock brought to the surface and a percentage breakdown of the N-AML and P-AML for each mine site, as per Clause 97.

# 10 SPILL CONTINGENCY PLAN

The Spill Contingency Plan has been updated per Clauses 110 to 115 of Water Licence QZ18-044 that specifies:

> 110. Where a spill or an unauthorized discharge occurs that is of a reportable quantity under the Yukon Spills Regulations, the Licensee must immediately contact the 24-hour Yukon Spill Report telephone number, (867) 667-7244 and implement the Spill Contingency Plan. A detailed written report on any such event including, but not limited to, dates, quantities, parameters, causes and other relevant details and explanations, must be submitted to the Board not later than 10 days after the occurrence.
>
> 111. The Licensee must apply the relevant procedures in the Spill Contingency Plan. The Licensee must review the Spill Contingency Plan annually and must provide a summary of that review, including any revisions to the plan, as a component of the annual report.
>
> 112. The Licensee must maintain a log book of all spills or unauthorized discharge occurrences, including spills that are less than the reportable quantities under the Yukon Spills Regulations. The log book must be made available at the request of an Inspector. The log book must include, but not necessarily be limited to the:
>
> a) date and time of the spill,
>
> b) substance spilt or discharged,
>
> c) approximate amount spilt or discharged,
>
> d) location of the spill,
>
> e) distance between the spill or discharge and the nearest Watercourse, and
>
> f) remedial measures taken to contain and clean-up the spill area or to cease the unauthorized discharge.
>
> 113. The Licensee must include a summary of all spills or unauthorized discharges that occur, as part of the monthly reports, within 30 days of the spill occurrence.
>
> 114. The Licensee must ensure all relevant personnel are trained in procedures to be followed and equipment to be used in the containment of a spill.
>
> 115. The Licensee must post the Spill Contingency Plan on site for the duration of the project.

For more details, see the KHSD Mining Operations Spill Contingency Plan and the Emergency Response Plan updated in November 2020. All incident reports including the occurrence of a spill, should it occur, will be forwarded to the FNNND.

# 11 ADAPTIVE MANAGEMENT PLAN

An Adaptive Management Plan (AMP) is a management tool designed to guide responses to unforeseen or contingency events respecting. The adaptive management approach provides for assessment of mitigation measures and their effectiveness and guides the orderly implementation of responses. The AMP provides procedures that can be implemented to ensure appropriate action is taken before adverse effects are realized. The AMP and Management Response Plan developed as a result, provide possible management responses that range in level of intervention or mitigation.

The AMP was updated in December 2022. Adaptive management initiatives (AMIs) have been developed for KHSD Mining Operations to address the following risks:

1. Increase in contaminant load from mine water discharge or the water treatment plant effluent causes adverse effects to aquatic resources in the receiving environment;
2. Acidic or metal leachate occurs because of seepage or runoff though N-AML waste rock or the DSTF;
3. Seepage from or lack of storage capacity in the sludge storage areas results in a risk to aquatic resources;
4. Physical instability of waste rock disposal areas or underground workings endangers the health and safety of site employees or visitors, or leads to an increase in contaminant loading to the receiving environment.
5. Public access to the site creates an unacceptable safety risk to mine employees, contractors, and the public;
6. Modelling has underestimated the foundation pore pressures leading to slope failure and exposure of tailings in the long term;
7. Large precipitation event erodes through the surface cover, exposes the tailings resulting in transport of tailings into the natural environment;
8. Erosion develops because of water being discharged from a WTP or the District Mill ponds;
9. Transport of sediment from the District Mill or WTP discharge areas causes an adverse effect to the receiving environment;
10. Large differential settlement in the long-term leads to tailings exposure on the surface from compromised cover;
11. Large differential settlement of a water conveyance or water retaining structure leads to an uncontrolled release of contact water to the environment or effluent to the environment.
12. Surface water quality objectives exceeded in the receiving environment occurring irrespective of compliance with effluent discharge standards;
13. Flux of geochemical load from the mines, waste rock disposal areas, or DSTF via groundwater pathways causes surface water quality objectives to be in exceeded downgradient;
14. Fugitive dust generated exhibits potential effects on the community of Keno City; and
15. Natural attenuation of several metals in Christal Creek or No Cash Creek is reduced or stopped, which results in a risk to aquatic resources resident in the creeks.

# 12 RECLAMATION EFFECTIVENESS MONITORING PROGRAM

With the cessation of mining, the monitoring and surveillance programs will be tailored to assess closure measures and continue as necessary. At closure, Water Licence QZ18-044 will undergo amendment to regulate activities around reclamation and reclamation monitoring. Post closure reclamation benchmarks should be well defined, measurable and documented. A thorough effectiveness monitoring program will allow for recognition of restoration successes and needed improvements.

Section 7.10 of the Reclamation and Closure Plan for KHSD Mining Operations (Revision 6 – November 2021) states:

> *"Monitoring activity will be required to determine the on-going and continued success of closure measures in meeting the closure objectives for a period of 10 years. The adaptive management approach will be used to determine thresholds identifying when remedial action have been triggered, and then the success of the remedial measures will need to be incorporated into the monitoring and surveillance regime."*

Proposed closure monitoring activities include:

- water quality monitoring at some of the stations identified in the Water Licence,
- monitoring of road bank and drainage along access road,
- physical inspection of the passive water treatment systems,
- physical stability of all waste rock disposal areas,
- success of revegetation measures (principally portal area, DSTF and mill pad area),
- monitoring of cover system integrity (P-AML WRSFs and DSTF), and
- physical inspection of impacted earthen surfaces for evidence of erosion, gullying or sediment transport to watercourses.

Permafrost beneath the waste rock disposal areas will be monitored at least 10 years post closure, after which time the necessity of the requirement will be reviewed. An annual geotechnical inspection should be conducted on the waste rock disposal areas for at least 5 years post closure, after which time the necessity of this requirement will also be re-evaluated. Success of implementation of final reclamation will be measured by the ability to achieve stated closure objectives in the Reclamation and Closure Plan. The Reclamation and Closure Plan has been updated to include Flame & Moth and New Bermingham.

As part of progressive reclamation monitoring will be completed to assess the effectiveness of the progressive reclamation activities completed on an annual basis. For example, the progressive reclamation completed for the DSTF cover, monitoring has been conducted and will continue to be conducted to assess the cover effectiveness including infiltration, stability/erosion, vegetation establishment and metal uptake in cover vegetation. The vegetation monitoring program will be established to measure the success of interim revegetation and gain information about cover effectiveness, vegetation health and metal uptake to inform final closure revegetation prescriptions. Vegetation monitoring will occur on a reoccurring timeline to build a temporal dataset of vegetation success and performance.

# 13 REPORTING

Reporting on water quality monitoring and management issues will be directed to the Yukon Water Board (YWB) and YG Energy, Mines and Resources in accordance with the requirements of the Water Licence (Part I, Clause 119 and 120) and Quartz Mining License (Clause 13). Monthly and annual reporting will be carried out during mine development activities and through the implementation of site decommissioning until it can be demonstrated through the monitoring results that the final closure objectives have been achieved.

AKHM also continues to liaise with the regulatory agencies, FNNND, the Mayo Renewable Resource Council and the local communities on environmental issues relating to KHSD Mining Operations; all monthly and annual reports are provided to FNNND.

# 14 REFERENCES

Access Consulting Group (ACG), 2013. *Waste Rock Management Plan, Keno Hill Silver District Mining Operations*.

Alexco Environmental Group (AEG), 2016. *Geochemical Rock Characterization, Flame & Moth Project, Keno Hill District, Yukon*. Report prepared for Alexco Keno Hill Mining Corp. March 2016.

Alexco Environmental Group (AEG), 2019a. Mass Load Model for Bermingham Productions and Development Program, December 2, 2019.

Alexco Environmental Group (AEG), 2019b. *Bermingham Waste Rock Static Geochemical Characterization*. Report prepared for Alexco Keno Hill Mining Corp. April 2019.

Government of Yukon, 2021. *Yukon Guide for Developing Water Quality Objectives and Effluent Quality Standards for Quartz Mining Projects*. October 2021.

# APPENDIX A

## GROUNDWATER MONITORING PLAN (OCTOBER 2021)

# KENO HILL SILVER DISTRICT MINING OPERATIONS

# GROUNDWATER MONITORING PLAN

October 2021

Prepared for:

**ALEXCO KENO HILL MINING CORP.**

Prepared by:

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# 1. INTRODUCTION

## 1.1 PURPOSE OF THE PLAN

This plan was originally submitted to fulfill the conditions set out in Part H, Clauses 85, 86, and 87 of Water Licence QZ09-092 issued to Alexco Keno Hill Mining Corp. (AKHM or the Company) on August 19th, 2010. This plan was subsequently updated to fulfill the conditions set out in Part G, Clauses 94, 95, 96 and 97 of Water Licence QZ12-053 issued to Alexco Keno Hill Mining Corp. (AKHM) on May 16th, 2013. The Plan was revised to fulfill the conditions set out in Part G, Clauses 105, 106, 107, 108 and 109 of Water Licence QZ09-092-2 issued to AKHM on December 22, 2017.

This version of the Plan has been updated to fulfill the conditions set out in Part F, Clauses 45, 46 and 47 of Water Licence QZ18-044 (hereafter referred to as the Licence) issued to AKHM on July 22, 2020 as summarized below:

45. Within 90 days of the effective date of this Licence, the Licensee must submit to the Board an update to the Keno Hill Silver District Mining Operations: Groundwater Monitoring Plan (GMP), dated January 2018. The updated plan must include all groundwater monitoring associated with the Bellekeno Mine, Keno Hill Silver District Mill Site, and Flame and Moth Mine, Historic Bermingham SW Open Pit and New Bermingham Mine.
46. With respect to groundwater monitoring:
    a. the Licensee must install the following:
        i. one groundwater well within the DSTF Phase 2 Expansion area (KV-107) to be installed as part of the DSTF expansion;
        ii. one groundwater well upgradient of the DSTF Phase 2 Expansion area (KV-108) six months prior to the expansion;
        iii. at least three groundwater monitoring wells within 100 meters of the Historic Bermingham SW Open Pit prior to placement of any sludge;
        iv. at least three groundwater monitoring wells within 100 meters of the historical waste rock dump underlying the proposed New Bermingham P-AML facility prior to commencement of operations at the New Bermingham Mine; and
        v. at least three groundwater monitoring wells within 100 meters of the VTBSSA prior to disposal of any sludge;
    b. groundwater monitoring wells must be:
        i. designed, installed, and developed under the supervision of a qualified professional;
        ii. individually completed at all depths required to monitor upgradient and downgradient groundwater level and quality for these features;
        iii. equipped with datalogging pressure transducers (and an associated barometric logger) to log groundwater level, at minimum frequency of daily; and
        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.
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.

In addition, Part H Clauses 82, 83, 84, 85, 86 87,119 and 120of the Licence provided additional guidance on the groundwater monitoring program:

82. The Licensee must compare groundwater monitoring data to the Yukon Contaminated Sites Regulation (YCSR) Schedule 3: Generic Numerical Water Standards (Aquatic Life) and submit the data and analysis as part of the annual report.
83. The Licensee must compare data from wells screened in the potable, or potentially potable aquifer near Keno City to the YCSR Schedule 3: Generic Numerical Water Standards (Drinking Water Standards) and submit the data and analysis as part of the annual report.
84. The Licensee must submit all documentation and data produced by the Groundwater Monitoring Plan (GMP) as part of the monthly report and ensure all monitoring and reporting is certified by a professional hydrogeologist registered with a provincial regulatory organization.
85. The Licensee must provide the Board with a summary of hydrogeological monitoring which interprets the sources of inflows and contaminant loads into the underground mine workings as part of the annual report.
86. For those wells subject to freezing, pressure transducers must be installed as soon as wells are ice-free.
87. The Licensee must adhere to the groundwater monitoring schedule in Schedule B3 with the exception that:
    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.

119. The 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 31 of the year following the year reported. The annual report must include the information required by the Regulation as well as:

    f. documentation and data produced by the HMP as required by Clause 49;
    g. updated site groundwater contour maps as required by Clause 50;
    h. if required by Clause 50, an update to the conceptual site groundwater model as required by Clause 51;
    x. all data generated as a result of the monitoring requirements of this licence, 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 vs real data model trajectory;
    z. a discussion of any proposed changes to the monitoring programs or WQOs; and

120. Unless otherwise specified in this Licence, the Licensee must submit to the Board a copy of all monitoring data no more than 30 days after the conclusion of the month in which that data was collected. Monthly reports must include:

a. a summary of recent groundwater monitoring well(s) installation as required by Clause 47, when applicable;
f. all data collected in accordance with Schedule B3.

# 2. MINE LOCATION AND DESCRIPTION

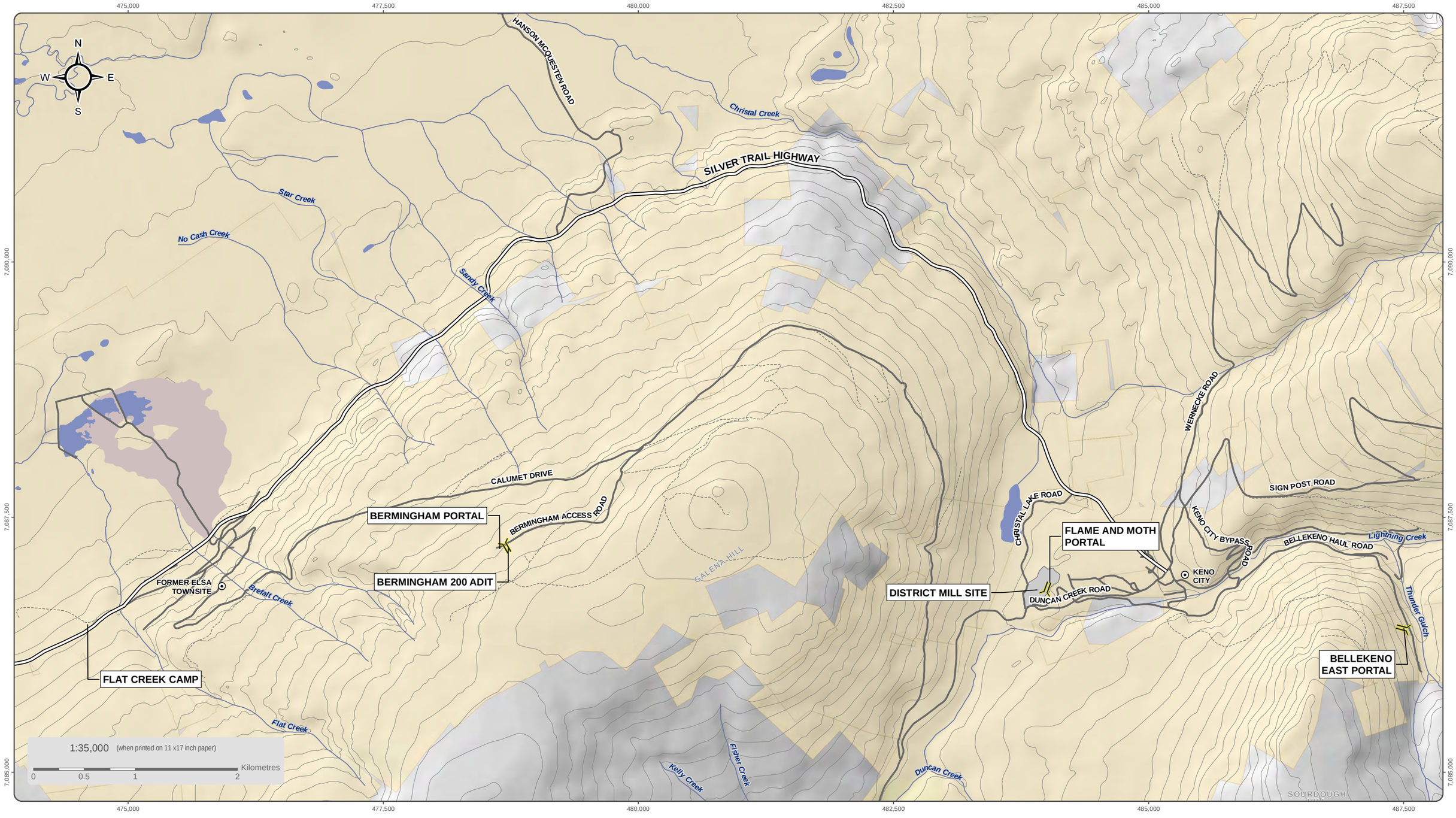
The KHSD is located in central Yukon (63° 54' 32" N, 135° 19' 18" W; NTS 105M/14 & 105M/13), 354 km due north of Whitehorse. Access to the property is via the Alaska, Klondike and Silver Trail Highways from Whitehorse to Mayo (407 km) and an all-weather gravel road northeast from Mayo to Elsa (45 km); a total distance of 452 km. The KHSD is located on and around Galena Hill, Keno Hill and Sourdough Hill and are collectively known as the KHSD. The property lies along the broad McQuesten River valley with three prominent hills to the south of the valley. The property, as well as the mines covered under the water license are located on Figure 2-1.

The District Mill Site and Dry Stack Tailings Facility (DSTF) are located approximately 1 km west of Keno City. The mill site contains offices, crusher, water management ponds, water supply well, and other infrastructure.

The Flame and Moth mine is located adjacent to the District Mill. Currently the portal and the first 20 m of ramp down towards the ore body have been constructed. Up to 8,000 $m^3$ of mine workings are planned for future development.

The Bellekeno portal is located on a slope in Thunder Gulch, which is narrow tributary of Lightning Creek. The mine site is ~ 3km to the mill site, which crosses over Lightning Creek. The Flame and Moth mine is located adjacent to the District Mill.

The Bermingham deposit is located on northwest slope of Galena Hill ~6.8 km east of Keno City in the No Cash Bog catchment. Bermingham Mine is located up gradient from the Ruby Mine and is drained by the Bermingham 200 adit, which is located at an elevation of ~1,250 masl. The Bermingham 200 adit is near the plateau area of Galena Hill, which limits the available gradient towards the mine opening and there is some recharge from the overlying pit.






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



- Place of Interest
- Adit
- Alexco/ERDC Quartz Claims
- Tailings Area
- Waterbody
- Watercourse
- Silver Trail Highway
- Road
- Limited-Use Road

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# FIGURE 2-1
# KENO HILL SILVER DISTRICT MINING OPERATIONS OVERVIEW

OCTOBER 2020

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# 3. PREVIOUS GROUNDWATER STUDIES

Surface and underground mining conducted throughout the KHSD have altered natural groundwater flow such that mine workings dictate recharge/discharge. Groundwater is most likely to travel from high elevation to low elevation, resulting in a water table (phreatic surface) that is a muted image of the surface topography. Much of the groundwater flow is concentrated at relatively shallow depths, as shallower material typically has higher hydraulic conductivities.

Extensive groundwater studies have been conducted throughout the KHSD, which include reasonably extensive mapping of the geology and mine development in the District, hydrogeological investigations and ongoing monitoring, as well as a Conceptual Model and Preliminary 3D Groundwater Model that also includes preliminary particle tracking to map of the potential groundwater flow paths.

The following subsections summarise the main findings for groundwater flow paths from the AKHM proposed and license mines.

## 3.1 FLAME AND MOTH, ONEK, AND KENO CITY

In 2009, SRK Consulting Canada Inc. (SRK) was retained by AKHM to investigate groundwater conditions at the Mill Site in relation to Keno City and Lightning Creek. Three groundwater monitoring wells were installed for this program (PH2, PH5, and PH6). These wells will be referred to in this plan according to their KV station numbers as listed in Schedule A of the Licence (KV-85D, KV-86 and KV-87), respectively. Key findings of the SRK groundwater investigation (SRK, 2010) include the following:

- The water table is in bedrock beneath the site. South of the site, the water table in a relatively thick overburden unit at a depth of greater than 25 meters below ground surface;
- Water-level data from monitoring wells at site and Keno City indicate that groundwater flows from east to west/northwest); that is, from Keno City towards the Mill Site and Christal Lake;
- Water level data also indicate ground water flow from Lightning Creek towards the Keno City area; and
- The probability of groundwater wells in Keno City being affected by Mill activities is very low given the current understanding of local groundwater gradients and large distance between the Mill Site and Keno City.

Interralogic, Inc. conducted a groundwater evaluation for Keno City between October 2010 and March 2012. During this program, two trenches were excavated within the dry stream channel downstream of the Onek 400 adit, and these verified that the adit discharge was not flowing within the channel alluvium. As part of the groundwater evaluation, Interralogic installed five monitoring wells in the Keno City area (KC-MW-1a, 1b, 2, 3, and 4) to determine water levels, water chemistry, and approximate material transmissivities. Interralogic sampled these five wells, as well as a monitoring well, ON-MW-1, installed in 2011 to understand groundwater elevations near the historic Onek waste rock dumps and open pit.

To evaluate groundwater flow paths, water levels in available wells were measured and water-level contour maps were prepared (ITL, 2012a). Based on this evaluation, Interralogic set forth the following conclusions:

- There is a convergence of southwest and northward flowing groundwater below the central portion of Keno City.

- The groundwater below Keno City is conveyed northwest along a postulated feature that appears to have higher permeability than adjacent geologic units. Evidence for this is:
    - The interpretation that groundwater converges toward this feature;
    - The change in hydraulic head is relatively small between upgradient wells in Keno City and downgradient wells MW-1A, MW-1B, and MW-2; and
    - The relatively high initial yield of the Firehall well (57 to 96 litres per minute), which is located within the postulated high permeability feature.
- Water-level contours suggest that groundwater discharges to Lightning Creek east of Keno City. However, South of Keno City, there appears to be seepage loss from the stream that recharges the groundwater system below the townsite. The zone of seepage loss from the stream could be associated with the southeast extension of the postulated higher permeability feature.
- At and downgradient (west) of the Onek 400 portal, the groundwater flow direction is generally southwest towards the postulated higher permeability feature, but not towards any of the Keno City water wells.

In September 2012, Interralogic completed a preliminary conceptual groundwater model for the proposed Onek 990 mine workings and two potential pathways were identified (ITL, 2012b). The first was a direct pathway from the mine to Keno City, with bedrock monitoring well ON-MW-02 providing an adequate monitoring location to identify if Onek 990 mine water were to migrate in that direction. The second pathway was perpendicular to the water-level contours, but following a trajectory where groundwater would veer east of the mine before migrating through Keno City. The overburden monitoring well KC-MW-4 is along this pathway; however, a bedrock well (ON-MW-3), was recommended as an additional monitoring point along the pathway. The overburden/bedrock well combination was considered adequate to monitor if Onek 990 mine water were to migrate along this pathway (ITL, 2012b).

During August and September 2013, three deep monitoring wells (FM-MW-1, FM-MW-2 and FM-MW-3) were installed in and around the Flame and Moth deposit. Interralogic Inc. summarised the results from the drilling and associated air-lift testing of these wells (ITL, 2013). A long-term (72 hour) air-lift pump test was conducted on well FM-MW-1 to provide data for estimating the potential mine inflows for the Flame and Moth Mine. At maximum mine depth of about 270 mbgs the computed inflow rate is 35 L/s (ITL, 2013). The Interralogic report concludes that Flame and Moth Mine dewatering would not have a significant impact on surface water flows in Lightning Creek and it is highly unlikely that mine dewatering would have an effect on groundwater levels and the availability of water supply in the Keno City area.

Morrison Hershfield (MH) was retained by Yukon Government (YG) Community Services (CS) in 2015 to upgrade the Keno City Firehall well to meet current well-head construction standards. During the rehabilitation, an open portion of the hole collapsed and had to be re-bored with steel casing driven down the hole to prevent further collapse. Following the rehabilitation work, the Fire hall well was sampled and it was found that the water quality had deteriorated such that concentrations of arsenic and uranium no longer met the Guidelines for Canadian Drinking Water Quality.

In 2016 MH was retained by YG CS to conduct a review of the groundwater resources around Keno City and provide support for future water supply options. MH created a conceptual hydrogeological model which describes two distinct aquifer systems below Keno City; the overburden aquifer and the bedrock aquifer (MH, 2017).

- The saturated thickness of the overburden aquifer within Keno City is thin, generally less than 10 m, and is not suitable for water production, even for low-flow, small scale, municipal groundwater supply. The groundwater chemistry of the overburden aquifer is variable from well to well, but is typically quite mineralized and contains parameters that do not meet the aesthetic and health-related parameters of the GCDWQ.
- The bedrock aquifer is fractured and has a greater potential for groundwater production; however, the wells are typically low-yield (produce only a few gallons per minute). The bedrock groundwater is typically of lower quality than the overburden aquifer, with water chemistry that is very mineralized and contains parameters that do not meet the aesthetic and health-related parameters of the GCDWQ.

The overarching conclusion of the MH report was that any groundwater in the Keno City area used for municipal water supply would likely require advanced treatment to meet the GCDWQ (MH, 2017).

## 3.2 BERMINGHAM

In 2016, Piteau Associates Engineering Ltd. (Piteau) developed a preliminary groundwater model for the KHSD for Elsa Reclamation and Development Corporation for mine reclamation. The preliminary model included particle tracking to determine probable groundwater flow paths from historic mine workings. The particle tracking indicates that regional groundwater derived from the Ruby, Bermingham, and No Cash Mine workings discharges downgradient between the lower reaches of Star Creek and Christal Creek (Piteau, 2017).

In October 2016 drilling and testing of two boreholes at Bermingham were performed. The best-estimate hydraulic conductivities were calculated for the two boreholes and were found to be similar, providing evidence that the rock mass is relatively homogeneous with regard to hydraulic properties. The average of the calculated hydraulic conductivities is $4.3 \times 10^{-6}$ cm/s, which is taken as the best-estimate of the large-scale (bulk) hydraulic conductivity for rock within the mine area. Based on the average hydraulic conductivities a portal discharge rate during closure was estimated to be 2.L/s (AEG, 2017).

# 4. REGIONAL GEOLOGY AND HYDROGEOLOGICAL IMPLICATIONS

The long history of mining and exploration in the KHSD means that regional geology has been well studied. Although no comprehensive studies specific to groundwater have been completed in the district, a number of observations can be made relating to bedrock and surficial geology and their hydrogeological characteristics. Some background information pertinent to district geology and groundwater, are summarized below from the Environmental Conditions Report (Ensero, 2020a).

The KHSD is underlain primarily by Yukon Group metasedimentary rocks, locally divided into three formations; Upper Schist, Central Quartzite and Lower Schist. The Upper Schist (Hyland Group, pre-Cambrian to Cambrian age) overlies the quartzite in what is inferred to be a thrust contact (Robert Service Thrust) and consists of quartz-mica schist, quartzite, graphitic schist and minor limestone.

The Central Quartzite (Keno Hill Quartzite, Mississippian age) contains thick-and thin-bedded quartzite, massive quartzite, graphitic phyllite, graphitic schist, calcareous schist and minor Triassic greenstone. This unit is approximately 700 m thick and host most of the past producing ore bodies. Structurally juxtaposed below the quartzite is the Lower Schist which includes graphitic schist, argillite, thin-bedded quartzite, calcareous schist, phyllite, slate, sericite schist, minor thick-bedded quartzite and locally significant intervals of Triassic greenstone. The greenstone forms sills and / or boudins and consists of metadiorite and metagabbro. A number of quartz-feldspar porphyritic sills have intruded the stratigraphy parallel to schistosity. The sills are most common in the Lower and Upper Schists and can reach thicknesses of up to fifty metres.

Structurally, the property is characterized by four sets of faults; many of which have been filled by hydrothermal minerals veins. The oldest fault set consists of south dipping structures that are generally parallel to foliation. Locally, brittle deformation has been observed along these structures. A second fault set, known as “longitudinal veins”, strikes north east to east northeast and dips steeply southeast. Depending on the competency of the host rock, longitudinal veins can be up to thirty metres wide in an anastomosing system of sub-veins. Essentially, all mineralized rock was mined from these longitudinal veins. A third set of faults, known as “transverse faults”, is north-west striking and dips steeply to the north. Transverse faults typically do not contain silver and lead mineralization but are commonly filled by quartz with trace to minor arsenopyrite, pyrite and jamesonite.

A younger set of faults, known as cross faults, strike north to north east with a dip of sixty degrees west to south west and offset vein or longitudinal faults by up to 2,000 metres.

At Keno Hill, the largest accumulation of ore minerals occurred in structurally prepared competent rocks, such as the Central Quartzite, resulting in areas of increased fluid flow. Incompetent rocks like phyllites tend to produce fewer and smaller, if any, open spaces, limiting fluid flow and resulting mineral precipitation.

Mineralization in the District is of the polymetallic silver-lead-zinc vein type. In general, common gangue minerals include manganiferous siderite and to a lesser extent quartz and quartz breccia as well as calcite. Silver occurs in argentiferous galena and argentiferous tetrahedrite (freibergite). In supergene assemblages, silver is further found as native silver, in polybasite, stephanite, and pyrargyrite. Lead occurs in galena and

zinc in iron-rich sphalerite. Other sulphides include pyrite, arsenopyrite (locally gold-bearing) and chalcopyrite.

The veins of the District display characteristics associated with both mesothermal and epithermal deposits and it is not clear if a continuum exists or if separate and distinct mineralizing events are involved. The most prominent examples of epithermal style mineralization are found in the western part of the District, although the Lucky Queen mine on Keno Hill produced native silver and ruby silver in quantity. Proximity to a magmatic heat source has often been called upon to explain the District zonation, though this is by no means a complete explanation.

Mineral zonation is common within base metal-rich veins (zinc-rich margin and silver/lead-rich center). Changes in mineralogy within individual ore shoots are less clearly documented, although there has long been a conviction that silver and lead rich zones occur higher in the veins while zinc becomes dominant at depth. Anecdotal evidence suggests that vertically stacked ore shoots may repeatedly show zoning of lead rich upper portions to zinc dominant roots, but data confirming this has not been found. In general, lead-zinc mineralization appears to be nearly contemporaneous in age.

Irrespective of stratigraphic formations or regional map units only a few major rock types are commonly encountered in the area of the old mine workings. These are:

- schists and phyllites with variable carbonate content;
- chloritic phyllites or schists;
- quartzites and phyllitic quartzites;
- sericite-quartz phyllites; and
- greenstones.

SRK (2009) further described the bedrock geology of the site as it relates to hydrogeological characteristics:

"The bedrock geology of the area around Keno consists predominantly of layered metasedimentary rocks consisting mainly of quartzite, schist and phyllite. Unlike high yielding aquifer rocks such as sandstone, where groundwater can flow through connected 'pores' in the rock mass, the metasediments typically found in the Keno Hill district have a very low permeability, with little or no space between rock grains due to the metamorphosed character. The main medium through which water travels in these metasedimentary rocks therefore is via fractures and joints within the rock. The permeability of the rock (or the ease at which groundwater can flow through the rock formation) in this case is dependent on how many fractures are within the rock, and how well they are connected to each other, and how well connected to a water source (such as rainfall, a lake or a river) these fractures are."

SRK (2009) also describes surficial sediments and their hydrology:

"Shallow surficial sediments are found locally and typically are present in topographic lows which control surface drainage patterns. These overburden deposits have limited thickness and lateral extent, and likely form only small local aquifers. It is generally recognised that metasedimentary rocks do not commonly form high yielding aquifers. Fractures are not typically well connected and the resulting permeability is low. Evidence for this around Keno City can be seen in the characteristic marshy conditions seen in the area. The surface water found within these marshy areas is unable to drain easily

down through the underlying rocks. The regional groundwater flowpaths can be generally described as mimicking surface water pathways."

It is further recognized in that the presence of complex glacial and glaciofluvial sediments present in the valley bottoms and along the margins of the hills produces complex overburden stratigraphy. Overburden thickness and composition are known to vary widely, which can result in complex hydrology (e.g., perched aquifers) and generally poor drainage and low permeability. Also, the ubiquitous presence of permafrost and, in some areas, massive ground ice further complicate near surface groundwater regimes. In general, surficial sediment drainage can be described as generally poor, and complex, while bedrock hydrogeology can be described as generally low permeability with groundwater flow controlled by fractures and joints.

# 5. DISTRICT MILL AND FLAME & MOTH GROUNDWATER MONITORING

As per Clause 109a of Licence QZ09-092, three multi-level groundwater monitoring wells were installed down gradient of the DSTF. Clause 97 of Water Licence QZ09-092 specified that three multi-level groundwater monitoring wells (e.g., Westbay type) are to be installed down gradient of the DSTF. However, because of the known challenges in the ground conditions near the DSTF (the presence of permafrost and massive ice, in some cases), AKHM believes that separate boreholes to monitor each potential groundwater zone (shallow overburden, and deep bedrock) are more likely to provide reliable results than complicated multi-level monitoring well systems, which are more likely to fail. The decision to use individual monitoring wells was also based on discussions with professional hydrogeologists experienced in monitoring well installations.

AKHM believes that the intention of Clause 109a of QZ09-092 was to ensure that three relatively shallow overburden monitoring wells and three deeper, bedrock groundwater monitoring points were installed down gradient of the DSTF to allow for monitoring of both shallow and deep groundwater. AKHM complied with Clause 109a of QZ09-092 through the use of the groundwater monitoring network described below in Table 5-1 and shown on Figure 5-1. The selection of these wells were based on a review of available geotechnical and hydrogeological information for the site and in discussion with EBA Engineering Consultants on the location of ground ice in this area.

**Table 5-1: District Mill Site Groundwater Monitoring Well Summary**

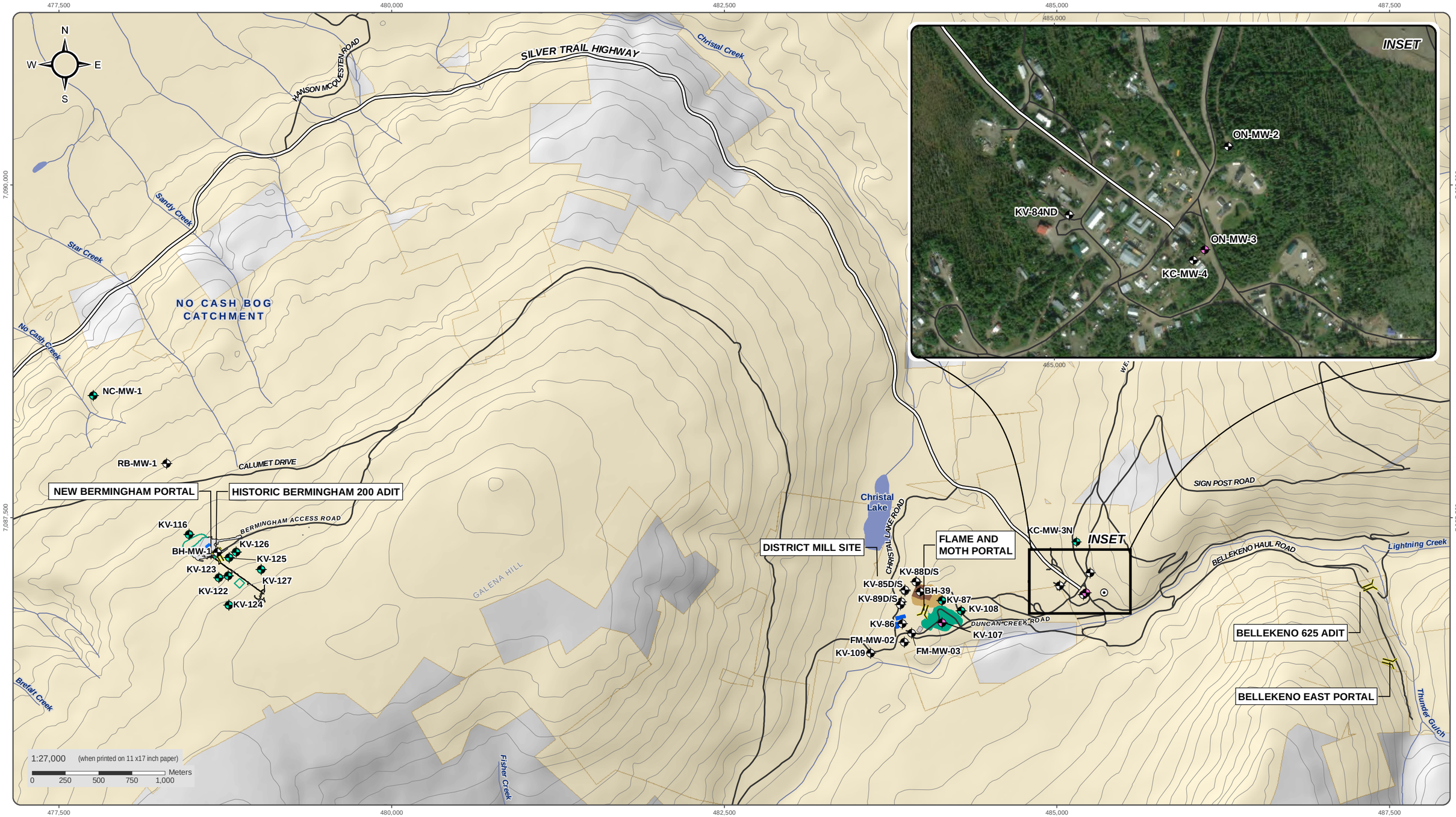
| Station # | Hole # | Purpose | Total Depth (m) | Depth in Overburden (m) | Depth in Bedrock (m) | Northing[1] | Easting[1] |
|---|---|---|---|---|---|---|---|
| KV-85D | PH2 | Deep bedrock groundwater monitoring | 42.7 | 11.5 | 31.2 | 7,086,952 | 483,864 |
| KV-85S | TBD2 | Shallow or perched groundwater monitoring | 4.2 | 4.2 | - | 7,086,952 | 483,858 |
| KV-86 | PH5 | Overburden Groundwater Monitoring Well with Pressure Transducer Wire | 36 | 36 | - | 7,086,707 | 483,836 |
| KV-87 | PH6 | Bedrock Groundwater Monitoring Well upgradient of DSTF | 94.79 | - | 94.79 | 7,086,865 | 484,138 |
| KV-88D | - | Deep bedrock groundwater monitoring | 50.1 | 4.3 | 45.8 | 7,087,016 | 483,946 |
| KV-88S | - | Shallow or perched groundwater monitoring | 3.72 | 3.72 | - | 7,087,016 | 483,942 |
| KV-89D | - | Deep bedrock groundwater monitoring | 39.12 | 14.5 | 20.5 | 7,086,864 | 483,831 |
| KV-89S | BH17 | Shallow or perched groundwater monitoring | 4.8 | 4.8 | - | 7,086,844 | 483,825 |
| KV-103 | - | District Mill Supply Well | 85.3 | 2.4 | 82.9 | 7,086,752 | 483,778 |
| FM-MW-1 | KAR1301 | Christal Zone | 182.3 | 12 | 160 | 7,086,770 | 484,026 |
| FM-MW-2 | KAR1302 | Lightning Zone | 244.4 | 0 | 244.4 | 7,086,562 | 483,854 |
| FM-MW-3 | KAR13016 | Mill Fault | 195.7 | 15 | 180.7 | 7,086,628 | 483,910 |
| BH39 | BH39 | DSTF phase I GW monitoring | 7.5 | - | - | 7,086,938 | 483,973 |
| KV-107 | | Proposed well in phase II of DSTF | TBD | - | - | TBD | TBD |
| KV-108 | | well upgradient of phase II of DSTF | 90.68 | - | 90.68- | 7,086,795 | 484,284 |
| KV-109 | - | Well near KV-81 on Lightning Creek | 26.7 | 4.0 | 22.7 | 7,086,479 | 483,601 |

1Coordinates are UTM Zone 8 NAD 1983
*Estimated based on nearby wells or boreholes

Well BH39 is a monitoring well within phase I of the DSTF which is screened within tailings to identify if porewater is present. Well KV-109 has been installed prior to the construction of the expanded mill area and development of the underground mine. Well KV-107 will be installed in phase II of the DSTF following the completion of the initial bench. Well KV-108 will be installed in the fall of 2020, which will be at least six months prior to the DSTF phase 2 expansion.

KV-85D and KV-89s are monitoring wells that were installed down gradient of the DSTF. These serve as one of the deep and shallow groundwater monitoring locations (PH2 and BH17, respectively). KV-85D is located in an ice wedge and is currently frozen.

Appendix A, EBA blasting analysis, provides analysis for potential effects from blasting occurring during the development of the Flame and Moth decline to the monitoring wells in the vicinity of the District Mill and DSTF. The blasting analysis shows that with appropriate management of the blasting the integrity of the monitoring wells, including the ground temperature and slope indicator monitoring, will not be compromised. Monitoring outlined in the analysis will be undertaken as part of the plan to ensure the integrity of the instrumentation is not compromised.

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



- Proposed Monitoring Well
- Monitoring Well
- Newly Installed Groundwater Monitoring Well
- Adit
- Infrastructure Footprint
- Pond
- DSTF 322k Tonnes Design
- Current DSTF
- To Be Constructed Mine Features
- Alexco/ERDC Quartz Claims
- Silver Trail Highway
- Other Road

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# FIGURE 5-1
# KHSD GROUNDWATER MONITORING LOCATIONS

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# 6. BERMINGHAM GROUNDWATER MONITORING

Groundwater around the Bermingham project has been studied and understood over the last several years as part of permitting process for the Bermingham mine and licensing of the Elsa Reclamation and Development Company (ERDC) Care and Maintenance activities (QZ17-076). Groundwater flow direction is to the northwest following the contours of Galena Hill and groundwater in the vicinity is monitored by ten wells: BH-MW-1, RB-MW-01, NC-MW-1, KV-116, KV-122, KV-123, KV-124, KV-125, KV-126 and KV-127.

**Table 6-1: Bermingham Groundwater Monitoring Wells**

| Station # | Purpose | Total Depth (mbgs) | Depth in Overburden (m) | Depth in Bedrock (m) | Northing[1] | Easting[1] |
|---|---|---|---|---|---|---|
| BH-MW-1 | Well d/g of Bermingham 200 Adit | 21.3 | 3.8 | 17.5 | 7,087,273 | 478,690 |
| RB-MW-1 | Well d/g of Ruby 400 Adit | 13.4 | 12.4 | 1.0 | 7,087,905 | 478,309 |
| NC-MW-1 | Well downgradient of No Cash 500 | 34.44 | - | 34.44 | 7,088,416 | 477,766 |
| KV-116 | Well downgradient of Bermingham Portal | 12.04 | - | 12.04 | 7,087,372 | 485,156 |
| KV-122 | Bermingham - downgradient of BH SW pit well #1 | 25.78 | - | 25.78 | 7,087,037 | 484,284 |
| KV-123 | Bermingham - downgradient of BH SW pit well #2 | 43.43 | - | 43.43 | 7,087,059 | 478,472 |
| KV-124 | Bermingham - upgradient of BH SW pit | 14.84 | 1.75 | 13.09 | 7,086,840 | 478,702 |
| KV-125 | Bermingham - downgradient of BH P-AML well #1 | 58.19 | - | 58.19 | 7,087,199 | 478,768 |
| KV-126 | Bermingham - downgradient of BH P-AML well #2 | 70.61 | - | 70.61 | 7,087,235 | 478,779 |
| KV-127 | Bermingham - upgradient of BH P-AML | 26.64 | 1.25 | 25.39 | 7,087,109 | 478,781 |

# 7. REVIEW OF RESULTS

Results of all groundwater monitoring activities will be subject to periodic review and interpretation by AKHM as part of the monthly and the annual reports, which will compare the data to the Yukon Contaminated Sites Regulation (YCSR) Schedule 3: Generic Numerical Water Standards (Aquatic Life). Data from wells screened in the potable, or potentially potable aquifer near Keno City shall also be compared to the YCSR Schedule 3: Generic Numerical Water Standards (Drinking Water Standards). This review and interpretation is important in identifying any potential changes in baseline conditions, and if necessary, trigger mitigation and/or adaptive management measures.

# 8. GROUNDWATER MONITORING SCHEDULE

Groundwater monitoring will follow the schedule as described in Table 8-1. Groundwater sampling and monitoring will be carried out by competent and trained field operators. The operators will also document the condition of the well at each location and record any non-standard observations (e.g., icing, blockage, physical damage to wellhead) for maintenance planning.

A groundwater quantity monitoring plan that assesses potential effects from the District Mill well to the Keno City and Mill areas, in terms of water levels, water contour maps, and flow paths is described under the Keno Hill Silver District Mining Operations Hydrogeological Monitoring Plan (Ensero, 2020b). These sites are summarized in Table 8-2.

## 8.1 MONITORING WELL SAMPLING

Representative groundwater samples will be collected from each identified site as per Groundwater Standard Operating Procedure (GW SOP). Below is a summary of sampling activities to take place:

- Depth to water level will be recorded prior to sampling.
- The well volume will be calculated.
- Purging will consist of either removal of three (3) well volumes (volume of standing water in the well) by an appropriate method (manually, submersible pump, hydrolift, etc.) or by utilizing a low-flow sampling method, such that the discharge rate does not exceed 500 ml/min, drawdown within the well is not greater than 0.1m and stabilization of water quality parameters inclusive of oxidation reduction potential (ORP), dissolved oxygen (DO), pH, conductivity, and temperature have been achieved.
- Following purging of three volumes with stabilization of parameters, or low flow stabilization of parameters, groundwater sample collection can then take place.
- For quality assurance/quality control, field duplicates and blank will be collected with a frequency of 1 in 10 groundwater samples collected.

## 8.2 GROUNDWATER SAMPLE COLLECTION AND ANALYSES

Groundwater samples will be collected in appropriately labelled laboratory grade bottleware with preservation for the analytes requested as per GW SOP.

## 8.3 GROUNDWATER SAMPLE CHAIN-OF-CUSTODY RECORD, PACKING AND SHIPPING

Based on the remote location of the sites, groundwater samples will be collected and shipped to coincide with immediate offsite transportation. The samples will be shipped via air courier from Whitehorse to a lab in the Vancouver area for analyses.

**Table 8-1: Groundwater Monitoring Program Summary**

| Site | Description | Water Licence | In situ Measurements/ Internal Analysis | | | | External Lab Analysis | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Proposed & Existing Monitoring | Level | pH | Temp. | Conductivity | Total Metals | Diss. Metals | Hardness | pH | Conductivity | TSS | Alkalinity | Sulphate | Nitrate | Nitrite | Ammonia(-N) | DOC | Phosphorous |
| KV-84Nd | Bedrock well on Keno Firehall lot to replace KV-84 | Existing | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | - | - | - | Q | Q |
| KV-85D | DSTF and Mill Site Groundwater Well #1 (PH2) Deep | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KV-85S | DSTF and Mill Site Groundwater Well #1 (Shallow) | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KV-86 | DSTF and Mill Site Groundwater Well #2 (PH5) | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KV-87 | DSTF and Mill Site Groundwater Well #3 (PH6) | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KV-88D | DSTF and Site Groundwater Well #4 (Deep) | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KV-88S | DSTF and Mill Site Groundwater Well #4 (Shallow) | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KV-89D | Flame and Moth Site Groundwater Well #5 (Deep) | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KV-89S | DSTD and Mill Site Groundwater Well #5 (Shallow) | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | - | - | Q | Q | Q |
| KC-MW-4 | Well south of Onek 400 adit | Existing | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q |
| ON-MW-2 | Onek Monitoring Well #1 d/g Project Facilities | Existing | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q |
| ON-MW-3 | Well south of Onek 400 adit | To be developed | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| FM-MW-1 | Flame and Moth Well #1 (KAR-01) | Existing | M | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FM-MW-2 | Flame and Moth Well #2 (KAR-02) | Existing | M | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FM-MW-3 | Flame and Moth Well #3 (KAR-16) | Existing | M | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| BH39 | Phase I of DSTF | Existing | M | M | M | M | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q |
| KV-107 | Proposed DSTF expansion area | To be developed | M/Q | M/Q | M/Q | M/Q | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q |
| KV-108 | Upgradient of proposed DSTF expansion area | Existing | M/Q | M/Q | M/Q | M/Q | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q |
| KV-109 | Flame and Moth Lightning Creek Discharge area near KV-81 | Existing | M/Q | M/Q | M/Q | M/Q | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q |
| BH-MW-1 | Well d/g of the Bermingham 200 Adit | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q |
| RB-MW-1 | Well d/g of the Ruby 400 Adit and WRSA | Existing | Q | Q | Q | Q | - | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q | Q |
| NC-MW-1 | Well  near NC 500 Adit | Existing | M/Q | M/Q | M/Q | M/Q | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| KV-116 | Bermingham Waste Rock Disposal Area | Existing | M/Q | M/Q | M/Q | M/Q | - | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| KV-122 | Bermingham - downgradient of BH SW pit well #1 | Existing | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| KV-123 | Bermingham - downgradient of BH SW pit well #2 | Existing | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| KV-124 | Bermingham - upgradient of BH SW pit | Existing | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| KV-125 | Bermingham - downgradient of BH P-AML well #2 | Existing | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| KV-126 | Bermingham - downgradient of BH P-AML well #2 | Existing | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |
| KV-127 | Bermingham - upgradient of BH P-AML | Existing | M/Q | M/Q | M/Q | M/Q | | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q | M/Q |

Legend:
Q = Quarterly, M = Monthly, M/Q  = Monitoring to occur monthly for first 12 months, reverting to quarterly thereafter

**Table 8-2: Hydrogeological Monitoring Schedule**

| Site | Alternate Well IDs | Description | Proposed & Existing Monitoring | Hydrogeology | | |
|---|---|---|---|---|---|---|
| | | | | Discrete WLs | Synoptic WL | Download Logger |
| KV-84Nd | - | Bedrock well on Keno Firehall lot to replace KV-84 | Existing | Q | SA | Q |
| KV-85D | PH2 | DSTF and Mill Site Groundwater Well #1 (PH2) Deep | Existing | Q | SA | |
| KV-86 | PH5 | DSTF and Mill Site Groundwater Well #2 (PH5) | Existing | Q | SA | |
| KV-87 | PH6 | DSTF and Mill Site Groundwater Well #3 (PH6) | Existing | Q | SA | |
| KV-88D | - | DSTF and Site Groundwater Well #4 (Deep) | Existing | Q | SA | Q |
| KV-89D | - | Flame and Moth Site Groundwater Well #5 (Deep) | Existing | Q | SA | Q |
| KV-103 | Mill Well | District Mill Supply Well | Existing | Q | SA | |
| KV-109 | - | Well near KV-81 on Lightning Creek | Existing | Q | SA | |
| KV-108 | - | Upgradient of proposed DSTF expansion area | Existing | Q | SA | |
| KV-84 | MW-5 | Overburden Monitoring Well | Existing | Q | SA | |
| KC-MW-1B | MW-1 | Bedrock Groundwater Monitoring Well | Existing | Q | SA | |
| KC-MW-2 | MW-2 | Overburden Groundwater Monitoring Well | Existing | Q | SA | |
| KC-MW-3 | MW-3 | Bedrock Groundwater Monitoring Well | Existing | Q | SA | |
| KC-MW-4 | | Well south of Onek 400 adit | Existing | Q | BA | |
| FM-MW-01 | KAR13-02 | Mill / Flame and Moth - Christal Zone | Existing | Q | SA | Q |
| FM-MW-02 | KAR13-01 | Mill / Flame and Moth - Lightning Zone | Existing | Q | SA | Q |
| FM-MW-03 | KAR13-16 | Mill / Flame and Moth - Mill Zone | Existing | Q | SA | Q |
| KV-116 | | Bermingham Waste Rock Disposal Area Well | Existing | M/Q | SA | Q |
| KV-122 | | Bermingham - downgradient of BH SW pit well #1 | Existing | M/Q | SA | Q |
| KV-123 | | Bermingham - downgradient of BH SW pit well #2 | Existing | M/Q | SA | Q |
| KV-124 | | Bermingham - upgradient of BH SW pit | Existing | M/Q | SA | Q |
| KV-125 | | Bermingham - downgradient of BH P-AML well #2 | Existing | M/Q | SA | Q |
| KV-126 | | Bermingham - downgradient of BH P-AML well #2 | Existing | M/Q | SA | Q |
| KV-127 | | Bermingham - upgradient of BH P-AML | Existing | M/Q | SA | Q |

**Quarterly once the monitoring well is installed, SA = semi-annual, in May and November*

# 9. REPORTING

As per Clauses 121 and 122 of Water Licence QZ18-044:

> 121. The Licensee shall provide to the Board, one unbound, single-sided, paper copy of all deliverables required by this Licence. All deliverables, with the exception of design drawings, must be reproducible by standard photocopier.
>
> 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.

# 10. REFERENCES

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# APPENDIX A

## KENO HILL DISTRICT MILL SITE – BLASTING PLAN ANALYSIS

TETRA TECH EBA

# TECHNICAL MEMO

ISSUED FOR USE

| | | | |
|---|---|---|---|
| **To:** | Brad Thrall, Kai Woloshyn | **Date:** | July 23, 2015 |
| **c:** | Anders Frappell, P.Eng.; Aaron Nickoli; Justin Pigage | **Memo No.:** | 1 |
| **From:** | James Kidd | **File:** | W14103353-01 |
| **Subject:** | Keno Hill District Mill Site – Blast Plan Analysis | | |

## 1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) has been commissioned by Alexco Resource Corp. (Alexco) to provide guidance with regards to blast vibrations and specifically to estimate and assess the potential effects blasting may have on instrumentation installed at the Flame and Moth site. The site is being developed as a new underground mine operation from a portal located in the vicinity of existing mine infrastructure such as the processing plant and dry stack tailings facility. In the development of the decline from the portal blasting will occur which will induce vibrations on existing infrastructure. Elements of the instrumentational infrastructure is considered sensitive to blast induce vibrations. It is understood that the instrumentation consists of 12 ground monitoring wells, 3 proposed ground monitoring wells, 5 ground temperature cells (GTC), and 2 slope inclinometers (SI) installed in the area of the proposed portal.

It is further understood that the blast analysis detailed within this memo will be used as the basis for development of a Peak Particle Velocity threshold limit, for which blasting can move ahead without producing permanent harmful effects on various geotechnical instruments.

### 1.1 Scope of Work

1. Review of proposed blast report data – Tetra Tech EBA reviewed the following data:

    (i) AutoCAD site plan; containing 22 locations of known geotechnical instrumentation and existing structure.

    (ii) Typical Blast Round Summary Sheet: Amex/Packaged Powder.

    (iii) Grout-Well® – Product Information Sheet: Which contained information pertaining to the ground wells.

2. Engineering Analysis and Evaluation - The information obtained from Alexco was analyzed and evaluated in order to establish recommendations for the proposed blast operations.

3. Report – This report provides comments on the proposed blast plan and makes recommendations for attenuation. Figures 2a and 2b shows the location of the well sites and instrumentation.

## 2.0 BLAST VIBRATIONS

This section of the memo details how blast vibrations can be predicted and controlled if the charge weight per delay is known.

Tetra Tech EBA Inc.
61 Wasson Place
Whitehorse, YT Y1A 0H7 CANADA
Tel 867.668.3068 Fax 867.668.4349

## 2.1 Simultaneous charge

The primary means of controlling vibrations is by controlling the explosive charge weight per delay during firing. A simultaneous charge is defined as anything less than 8 milliseconds per delay. The control of the explosive charge per delay can be obtained by reducing the drilled length per hole or providing more than one delay in each hole, known as decking. Decking is a method of creating unloaded zones within the borehole to enhance explosive performance or limit the charge weight initiated at any given time.

## 2.2 Scaled distance

Scaled distance is an equation that reduces two controllable variables in the blast to a single variable. The scaled distance is defined as:

$$SD = \left(\frac{D}{\sqrt{W}}\right)$$

Where;

D = Distance from the blast
W = Mass of the explosive per simultaneous charge

## 2.3 Peak Particle Velocity Predictions

To determine the Peak Particle Velocity (PPV but often referred to as the mean Peak Vector Sum or PVS) the following equation is used;

$$\mathrm{PPV}=\mathrm{k}\left(\frac{\mathrm{D}}{\sqrt{\mathrm{W}}}\right)^{\beta}$$

$k$ and $\beta$ are site specific constants developed through a scaled distance plot.

We are not aware of any site specific constants determined from previous blasts, therefore Tetra Tech EBA suggests using the following 'Upper Bound – High Confinement' site constants based on the findings of Blasters handbook 18th Edition for measurements of the proposed blasts. We note that these constants are conservative and are mainly dependent on the lithology, number, and nature of fractures plus other site specific conditions.

$k$ = 4320

$\beta$ = - 1.6

By recording actual blast vibrations on site at known locations and distances from a planned blast, the site specific constants $k$ and $\beta$ can be determined for the Flame and Moth site and used to better predict future blast vibrations. To carry this out will require a blast monitoring program.

# 3.0 PROPOSED BLASTS

It is understood that Alexco proposes to develop the portal at the Flame and Moth site by conducting blasting with the utilization of two separately weighted blast plans. These are detailed in Figure 1.

### 3.1 Typical round loaded with Amex

297.4 kg of Amex explosive (63 % Anfo, 8 % Geldyne, 28 % Xactex) will be distributed over 60 holes. Assuming that the explosives are distributed evenly throughout the holes this gives 4.96 kg / hole.

### 3.2 Typical round loaded with packaged explosive

348.1 kg of packaged explosive (72 % Geldyne, 28 % Xactex) will distributed over 60 holes. Assuming that the explosives are distributed evenly throughout the holes this gives 5.8 kg / hole.

## 4.0 DISCUSSION

Due to the proximity of certain sensitive structures (including instrumentation) blast vibration levels should be controlled. Blasting at the specified site should follow either of the two proposed options detailed below. The first option is essentially a prescriptive basis for blast design and considered to have a low risk, the second option is a risk based approach using an observational methodology.

### 4.1 Option 1

We recommend a peak particle vibration threshold of 50 mm / second be adopted at each sensitive structure (geotechnical instrumentation). Sensitive instrumentation structures are listed in Appendix B.

The vibration threshold for this option is taken as a conservative approach to sensitive structures, and was determined using the following conservative constants.

$k$ = 4320

$\beta$ = - 1.6

The 50 mm / s PPV level has been estimated from case studies in which Tetra Tech monitored the effects of ground vibrations in close proximity to sensitive structures. Furthermore, case studies by Matheson (2000) on the blast vibration damage to water supply wells in the United States concluded similar PPV threshold limits at 50 mm / s. For this reason we recommend the blasts be designed to produce vibrations with a velocity less than 50 mm / s.

Figures 2a and 2b present locations of sensitive structures that might be affected by a blast that will produce vibrations greater than 50 mm / sec. Analysis was conducted on Option 1 PPV threshold, relative minimum distances were able to be determined based on the proposed charge weight per delay discussed in Section 3.0.

The minimum required distance for each blast / hole delay are detailed further in Table 1.

### Table 1: Typical Blast Round Analysis

| Holes per delay | Proposed minimum distance required from blast for estimate PPV ≤ 50 mm / sec (m) | |
|---|---|---|
| | Amex | Packaged Explosives |
| 0.333 (2 decks per hole) | 24 | 24 |
| 0.5 (1 deck hole) | 28 | 28 |
| 1 | 36 | 40 |
| 2 | 52 | 56 |
| 3 | 64 | 68 |
| 4 | 72 | 80 |
| 5 | 83 | |

## 4.2 Blast Plan Option Two – Risk Based Approach

As an alternative to Option 1, Alexco may elect to take a risk based approach towards the blasting. In this case we recommend that a PPV of 75 mm / second for fully bentonite grouted Ground Monitoring Wells is used, and 100 mm / second for grouted inclinometers. It is understood the ground water monitoring wells are installed with Grout-Well bentonite grouting materials. The bentonite grouting material creates an effective measure for sealing the annular space between a well casing and the borehole wall.

The threshold for Option 2 should be adopted as a risk based approach to blasting and was determined using the following constants.

$k\,(1)$ = 1730 (Blast rounds 1 and 2; during initial open area blast conditions are present).

$k\,(2)$ = 4320 (Blast rounds 3 onwards; Should be adopted after confinement has increased into tunneling conditions unless a monitoring program has developed a site specific constant).

$\beta$ = - 1.6.

Specific PPV data constants should be developed for the site in the first few blasts and refined accordingly as blasting progresses into full confinement conditions, where an appropriate $k$ constant can be estimated from measured vibrations.

Aside from the initial blast of the portal, tunneling excavations for the proposed project will mostly have one free vertical face, which is also the drilling face, and for this reason relief of the blast is expected to be poor. This results in a high degree of confinement of the blast and therefore higher vibrations can be expected. This is reflected in the selection of 4320 for the $k$ site constant in Options 1 and 2 in lieu of a site specific constant.

The $k\,(1)$ value was adopted as an upper bound blasting constant from the High Confinement site constants based on the findings of Blasters handbook 18th Edition for measurements of the proposed blasts.

## 4.3 Vibration Analysis:

Respective to Option Plan 1 (Section 4.1), provided five or less holes are not simultaneously detonated, damage to the monitoring wells and inclinometers outside of the minimum distance is unlikely to be caused from the proposed blasts. Blast vibrations inside the minimum distance (Figure 2a, 2b) may have an effect on the surrounding rock by opening and closing of discontinuities, which may affect the rate of discharge/recharge of monitoring wells.

Option 2 (Section 4.2) is designed with a greater risk approach to development of the heading with respect to the integrity of the instrumentation. Blasting using Option 2 should be undertaken accepting that unknown site constants in the blast analysis may result in alteration or damage to instrumentation which may require repair or replacement after blasting.

When an explosive charge is confined in the ground and detonated, the volume that is permanently deformed is ideally a conical solid with the open end of the cone along the ground surface, or free face. The radius of the open end of the cone is approximately equal to the depth of the borehole. According to Matheson (1997), outside of this conical volume, little permanent deformation takes place. Therefore, in theory instrumentation located outside the 'crater zone' should not sustain damage. Provided blast vibrations surrounding inclinometers do not affect the movement of the probe up and down the PVC piping, there should be no major issues blasting with PPV below the specified threshold limit.

# 5.0 RECOMMENDATIONS

## 5.1 Pre Blast evaluation of Instrumentation and Blast Review

- All blast monitoring should be undertaken as described by the International Society of Explosive Engineers Field Practice Guidelines for Blasting Seismographs (2009). This document can be found in Appendix A.
- Site specific constants ($k$ and $\beta$) should be developed as blasting progresses.
- If Option 1 is adopted it is recommended that blasts not exceed the PPV threshold limit of 50 mm / second at each sensitive structure (Appendix B).
- An initial blast condition survey should be undertaken on all ground water monitoring wells, slope inclinometers; and ground temperature monitoring wells. This would entail taking a pre and post reading for each of the 22 instruments under analysis, subject instrumentation is presented in Appendix B. Instrumentation within zones of interest (Figure 2a, 2b) should be monitored before and after each scheduled blast until no further change is noted. Zones of interest include boreholes; BH23, BH36, BH39, BH40, KV87, KV103, FM-MW-01, FM-MW-03.
- Instrumentation showing movement in measured data should continue to be monitored until the change in movement is not noted.

# 6.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Alexco Resource Company and their agents. Tetra Tech EBA Inc. does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Alexco Resource Company, or for any Project other than the blast monitoring program at the Keno Hill site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech EBA's Services Agreement. Tetra Tech EBA's General Conditions (Appendix C) are attached to this memo.

# 7.0 CLOSURE

We trust that this meets your current requirements. Should you have any further questions, please don't hesitate to contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

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# FIGURES

Typical Round loaded with Amex

| Holes | Round length Meters | Total Meters | Load Density per meter of hole | Kg/meter | Totals | | |
|---|---|---|---|---|---|---|---|
| 38 | 4 | 152 | 1.14 | 42.5 | 169.8 | 63% | Anfo |
| 5 | 4 | 20 | 1.48 | 7.3 | 29.0 | 8% | Geldyne |
| 17 | 4 | 68 | 1.48 | 24.7 | 98.6 | 28% | Xactex |
| 60 | | | | 74.4 | 297.4 | | |

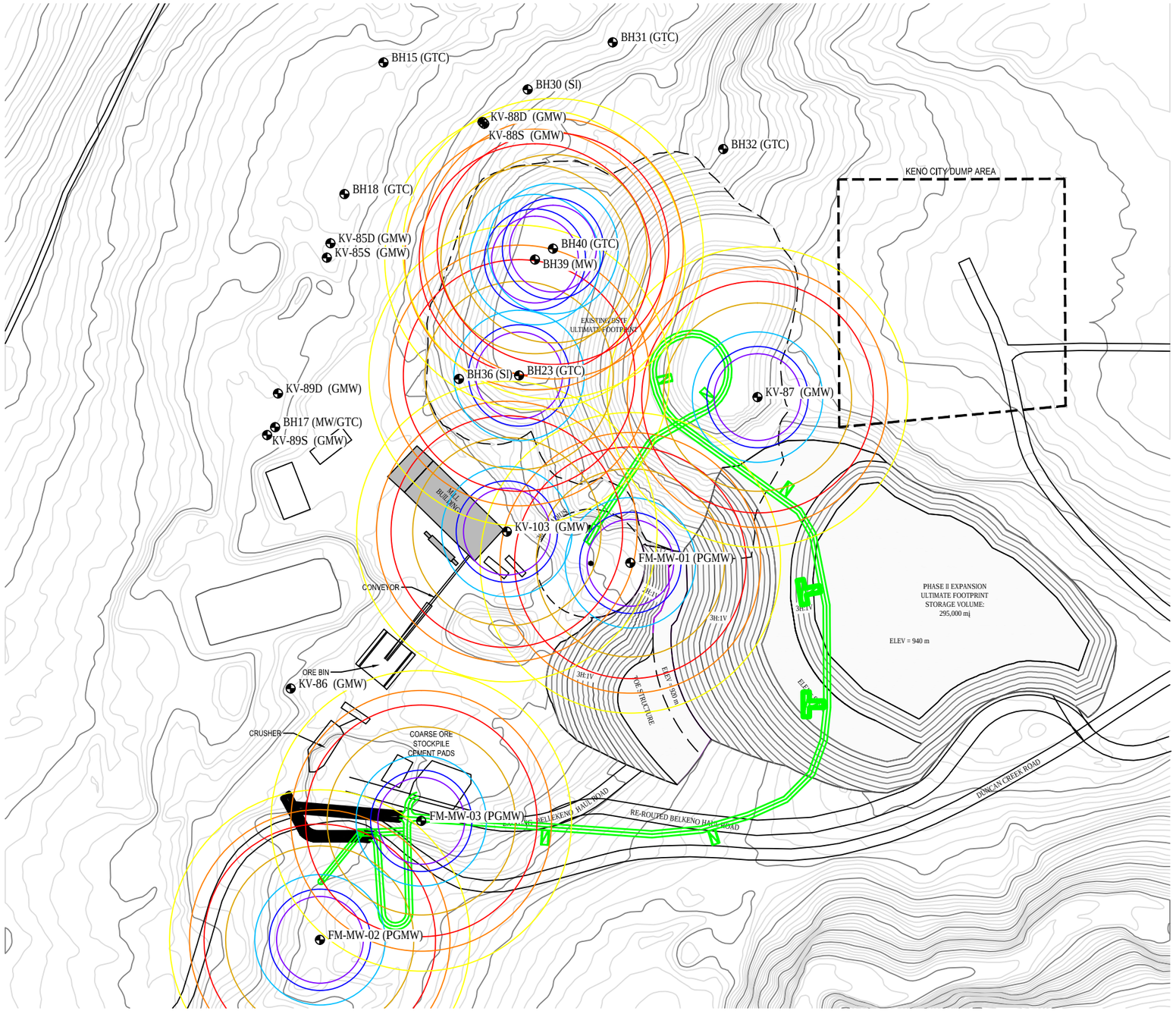
Typical Round loaded with Stick powder

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 43 | 4 | 172 | 1.48 | 62.4 | 249.5 | 72% | Geldyne |
| 17 | 4 | 68 | 1.48 | 24.7 | 98.6 | 28% | Xactex |
| 60 | | | | 87.0 | 348.1 | | |

**Summary**

**A  4 x 4 x4 meter round with a combination of Anfo, Sitick powder will use 298 Kg of explosive per**

**A  4 x 4 x4 meter round with Sitick powder will use 298 Kg of explosive per round.**




ISSUED FOR USE

LEGEND

- Instrumentation Location

AMEX

- 24 m minimum distance (2 decks per hole)
- 28 m minimum distance (1 deck hole)
- 36 m minimum distance
- 52 m minimum distance
- 64 m minimum distance
- 72 m minimum distance
- 83 m minimum distance

SCALE 1:2500

20 0 20 60 100m

NOTES

1. Based on Figure 3-29, Flame and Moth Monitoring Locations

CLIENT

ALEXCO

KENO HILL SILVER DISTRICT MINING OPERATIONS

"PPV THRESHOLD CONTOUR HOLES 1-5"
AMEX EXPLOSIVE

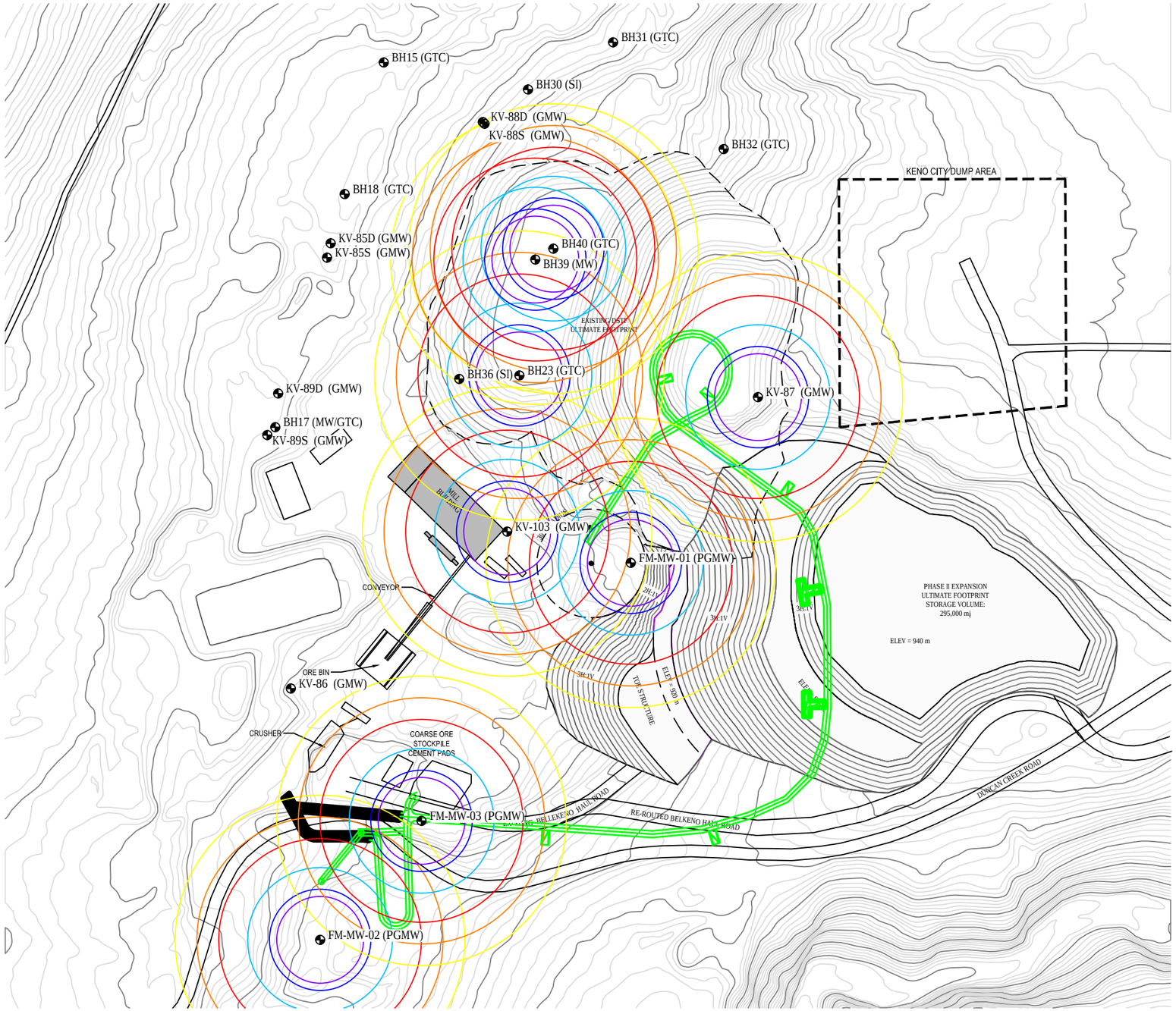
TETRA TECH EBA

| PROJECT NO. | DWN | CKD | REV |
|---|---|---|---|
| W14103303-01 | RH | JK | 0 |

OFFICE: EBA-VANC

DATE: June 16, 2015

Figure 2a




ISSUED FOR USE

LEGEND

Instrumentation Location

PACKAGED EXPLOSIVE

- 24 m minimum distance (2 decks per hole)
- 28 m minimum distance (1 deck hole)
- 40 m minimum distance
- 56 m minimum distance
- 68 m minimum distance
- 80 m minimum distance

SCALE 1:2500

20 0 20 60 100m

NOTES

1. Based on Figure 3-29, Flame and Moth Monitoring Locations

CLIENT

ALEXCO

KENO HILL SILVER DISTRICT MINING OPERATIONS

"PPV THRESHOLD CONTOUR HOLES 1-4"
PACKAGED EXPLOSIVE

TETRA TECH EBA

| PROJECT NO. | DWN | CKD | REV |
|---|---|---|---|
| W14103303-01 | RH | JK | 0 |

OFFICE: EBA-VANC

DATE: June 16, 2015

Figure 2b

Q:\Vancouver\Drafting\Engineering\W14103303-01\Site Plan - June 2015\W14103303-01 amex and stick powder R0a.dwg [FIGURE 2B] June 16, 2015 - 4:51:15 pm (BY: HALL, ROBERT J)

# APPENDIX A

## INTERNATIONAL SOCIETY OF EXPLOSIVES ENGINEERS BLAST VIBRATIONS AND SEISMOGRAPH SECTION

# INTERNATIONAL SOCIETY OF EXPLOSIVES ENGINEERS
# BLAST VIBRATIONS AND SEISMOGRAPH SECTION

## ISEE Field Practice Guidelines for Blasting Seismographs

**Disclaimer:** These field practice recommendations are intended to serve as general guidelines, and cannot describe all types of field conditions. It is incumbent on the operator to evaluate these conditions and to obtain good coupling between monitoring instrument and the surface to be monitored. In all cases, the operator should describe the field conditions and setup procedures in the permanent record of each blast.

**Preface:** Seismographs are used to establish compliance with regulations and evaluate explosive performance. Laws and regulations have been established to prevent damage to property and injury to people. The disposition of the rules is strongly dependant on the reliability and accuracy of ground vibration and airblast data. In terms of explosive performance the same holds true. One goal of the ISEE Blast Vibrations and Seismograph Section is to ensure reliable and consistent recording of ground vibrations and air blasts between all blasting seismographs.

**Part I. General Guidelines**

Seismographs are deployed in the field to record the levels of blast-induced ground vibration and airblast. Accuracy of the recordings is essential. These guidelines define the user's responsibilities when deploying seismographs in the field.

1. Read the instruction manual. Every seismograph comes with an instruction manual. Users are responsible for reading the appropriate sections before monitoring a blast.

2. Seismograph calibration. Annual calibration of the seismograph is recommended.

3. Keep proper records. A seismograph user's log should note: the user's name, date, time, place and other pertinent data.

4. Record the blast. When seismographs are deployed in the field, the time spent deploying the unit justifies recording an event. As practical, set the trigger levels low enough to record each blast.

5. Record the full waveform. It is not recommended that the continuous recording option available on many seismographs be used for monitoring blast-generated vibrations.

6. Document the location of the seismograph. This includes the name of the structure and where the seismograph was placed on the property relative to the structure. Any person should be able to locate and identify the exact monitoring location at a future date.

7. Know and record the distance to the blast. The horizontal distance from the seismograph to the blast should be known to at least two significant digits. For example, a blast within 1000 feet would be measured to the nearest tens of feet and a blast within 10,000 feet would be measured to the nearest hundreds of feet. Where elevation changes exceed 2.5h:1v, slant distances or true distance should be used.

8. Know the data processing time of the seismograph. Some units take up to 5 minutes to process and print data. If another blast occurs within this time the second blast may be missed.

9. Know the memory or record capacity of the seismograph. Enough memory must be available to store the event. The full waveform should be saved for future reference in either digital or analog form.

10. Know the nature of the report that is required. For example, provide a hard copy in the field, keep digital data as a permanent record or both. If an event is to be printed in the field, a printer with paper is needed.

11. Allow ample time for proper setup of the seismograph. Many errors occur when seismographs are hurriedly set-up. Generally, more than 15 minutes for set-up should be allowed from the time the user arrives at the monitoring location until the blast.

12. Know the temperature. Seismographs have varying manufacturer specified operating temperatures.

13. Secure cable. Suspended or freely moving cables can produce false triggers from the wind or other extraneous sources.

### *Part II. Ground Vibration Monitoring*

Placement and coupling of the vibration sensor are the two most important factors to ensure accurate ground vibration recordings.

**A. Sensor Placement**

The sensor should be placed on or in the ground on the side of the structure towards the blast. A structure can be a house, pipeline, telephone pole, etc. Measurements on driveways, walkways, and slabs are to be avoided where possible.

1. Location relative to the structure. Sensor placement should ensure that the data obtained adequately represents the vibration levels received at the structure being protected. The sensor should be placed within 10 feet of the structure or less than 10% of the distance from the blast, whichever is less.

2. Soil density evaluation. The soil density should be greater than or equal to the sensor density. Fill material, sand, unconsolidated soils, flower-bed mulch or other unusual mediums may have an influence on the recording accuracy if not properly dealt with during geophone installation.

3. The sensor must be nearly level.

4. The longitudinal channel should be pointing directly at the blast and the bearing should be recorded.

5. Where access to the structure and/or property is not available, the sensor should be placed closer to the blast in undisturbed soil.

**B. Sensor coupling**

If the acceleration exceeds 0.2 g, slippage of the sensor may be a problem. Depending on the anticipated acceleration levels spiking, burial, or sandbagging of the geophone to the ground may be appropriate.

1. If the acceleration is expected to be:
   a. less than 0.2 g, no burial or attachment is necessary
   b. between 0.2 and 1.0 g, burial or attachment is preferred. Spiking may be acceptable.
   c. greater than 1.0 g, burial or firm attachment is required (USBM RI 8506).

The following table exemplifies the particle velocities and frequencies where accelerations are 0.2 g and 1.0 g.

| Frequency, Hz | 4 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 100 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|
| Particle Velocity - in/s at 0.2 g | 3.07 | 1.23 | 0.82 | 0.61 | 0.49 | 0.41 | 0.31 | 0.25 | 0.12 | 0.06 |
| Particle Velocity - in/s at 1.0 g | 15.4 | 6.15 | 4.10 | 3.05 | 2.45 | 2.05 | 1.55 | 1.25 | 0.60 | 0.30 |

2. Burial or attachment methods.

   a. The preferred burial method is excavating a hole that is no less than three times the height of the sensor (ANSI S2.47-1990, R1997), spiking the sensor to the bottom of the hole, and firmly compacting soil around and over the sensor.

   b. Attachment to bedrock is achieved by bolting, clamping or gluing the sensor to the rock surface.

   c. The sensor may be attached to the foundation of the structure if it is located within $\pm$1.0 foot of ground level (USBM RI 8969). This should only be used if burial, spiking or sandbagging is not practical.

3. Other sensor placement methods.

   a. Shallow burial is anything less than described at 2a above.

   b. Spiking entails removing the sod, with minimal disturbance of the soil and firmly pressing the sensor with the attached spike(s) into the ground.

   c. Sand bagging requires removing the sod with minimal disturbance to the soil and placing the sensor on the bare spot with a sand bag over top. Sand bags should be large and loosely filled with about 10 pounds

of sand. When placed over the sensor the sandbag profile should be as low and wide as possible with a maximum amount of firm contact with the ground.

d. A combination of both spiking and sandbagging gives even greater assurance that good coupling is obtained.

**C. Programming considerations**

Site conditions dictate certain actions when programming the seismograph.

1. Ground vibration trigger level. The trigger level should be programmed low enough to trigger the unit from blast vibrations and high enough to minimize the occurrence of false events. The level should be slightly above the expected background vibrations for the area. A good starting level is 0.05 in/s.

2. Dynamic range and resolution. If the seismograph is not equipped with an auto-range function, the user should estimate the expected vibration level and set the appropriate range. The resolution of the printed waveform should allow verification of whether or not the event was a blast.

3. Recording duration - Set the record time for 2 seconds longer than the blast duration plus 1 second for each 1100 feet from the blast.

**Part III Airblast Monitoring**

Placement of the microphone relative to the structure is the most important factor.

**A. Microphone placement**

The microphone should be placed along the side of the structure nearest the blast.

1. The microphone should be mounted near the geophone with the manufacturer's windscreen attached.

2. The preferred microphone height is 3 feet above the ground or within 1.2 inches of the ground. Other heights may be acceptable for practical reasons. (ANSI S12.18-1994, ANSI S12.9-1992/Part2) (USBM RI 8508 )

3. If practical, the microphone should not be shielded from the blast by nearby buildings, vehicles or other large barriers. If such shielding cannot be avoided, the horizontal distance between the microphone and shielding object should be greater than the height of the shielding object above the microphone.

4. If placed too close to a structure, the airblast may reflect from the house surface and record higher amplitudes. Structure response noise may also be recorded. Reflections can be minimized by placing the microphone near a corner of the structure. (RI 8508)

**B. Programming considerations**

Site conditions dictate certain actions when programming the seismograph to record airblast.

1. Trigger level. When only an airblast measurement is desired, the trigger level should be low enough to trigger the unit from the airblast and high enough to minimize the occurrence of false events. The level should be slightly above the expected background noise for the area. A good starting level is 120 dB.

2. Recording duration. When only recording airblast, set the recording time for at least 2 seconds more than the blast duration. When ground vibrations and airblast measurements are desired on the same record, follow the guidelines for ground vibration programming (Part II C.3).

*Approved December 1999*

# APPENDIX B
## INSTRUMENTATION LOCATION

| Borehole ID | Easting | Northing | Elev (masl) | Depth (m) |
|---|---|---|---|---|
| FM-MW-01 (PGMW) | 484025.71 | 7086770.45 | 911.72 | 183.5 |
| FM-MW-02 (PGMW) | 483854.14 | 7086562.16 | 911.41 | 244.4 |
| FM-MW-03 (PGMW) | 483910.16 | 7086627.86 | 904.96 | 195.7 |
| BH15 (GTC) | 483889.3 | 7087046.9 | 896.9 | 21.3 |
| BH17 (MW/GTC) | 483829.4 | 7086845.4 | 899.9 | 15.25 |
| BH18 (GTC) | 483867.7 | 7086974.2 | 898.9 | 8.5 |
| BH23 (GTC) | 483964.2 | 7086874 | 908.2 | 10.2 |
| BH30 (SI) | 483969 | 7087032 | 907.25 | 26 |
| BH31 (GTC) | 484016 | 7087058 | 907.79 | 24.4 |
| BH32 (GTC) | 484077 | 7086999 | 923.75 | 9 |
| BH36 (SI) | 483931 | 7086872 | 906.5 | 14 |
| BH39 (MW) | 483973 | 7086938 | 920 | 12.6 |
| BH40 (GTC) | 483983 | 7086944 | 920 | 13.7 |
| KV-85D (GMW) | 483860 | 7086947 | 898.5 | 41 |
| KV-85S (GMW) | 483858 | 7086939 | 897.5 | 4.6 |
| KV-86 (GMW) | 483838 | 7086701 | 900 | 36 |
| KV-87 (GMW) | 484096 | 7086862 | 937 | 56.4 |
| KV-88D (GMW) | 483944 | 7087014 | 906 | 50.1 |
| KV-88S (GMW) | 483945 | 7087013 | 906 | 4.1 |
| KV-89D (GMW) | 483831 | 7086864 | 898 | 38.3 |
| KV-89S (GMW) | 483825 | 7086841 | 899.9 | 15.25 |
| KV-103 (GMW) | 483957.4415 | 7086787.666 | 904 | 85.3 |

# APPENDIX C
## TETRA TECH EBA'S GENERAL CONDITIONS

# GENERAL CONDITIONS

## GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

### 1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of Tetra Tech EBA’s Client. Tetra Tech EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than Tetra Tech EBA’s Client unless otherwise authorized in writing by Tetra Tech EBA. Any unauthorized use of the report is at the sole risk of the user.



### 2.0 ALTERNATE REPORT FORMAT

Where Tetra Tech EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed Tetra Tech EBA’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Tetra Tech EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of Tetra Tech EBA’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Tetra Tech EBA. Tetra Tech EBA’s instruments of professional service will be used only and exactly as submitted by Tetra Tech EBA.

Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

### 3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

### 4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

### 5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

### 6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

### 7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

### 8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

### 9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

### 10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

### 11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

### 12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

### 13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

### 14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

# APPENDIX B

## PHYSICAL INSPECTION AND REPORTING PLAN (OCTOBER 2020)

# KENO HILL SILVER DISTRICT MINING OPERATIONS

# PHYSICAL INSPECTION AND REPORTING PLAN

October 2020

Prepared for:

**ALEXCO KENO HILL MINING CORP.**

Prepared by:

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# LIST OF FIGURES



# LIST OF TABLES



# APPENDICES

# 1. INTRODUCTION

## 1.1 PURPOSE OF PLAN

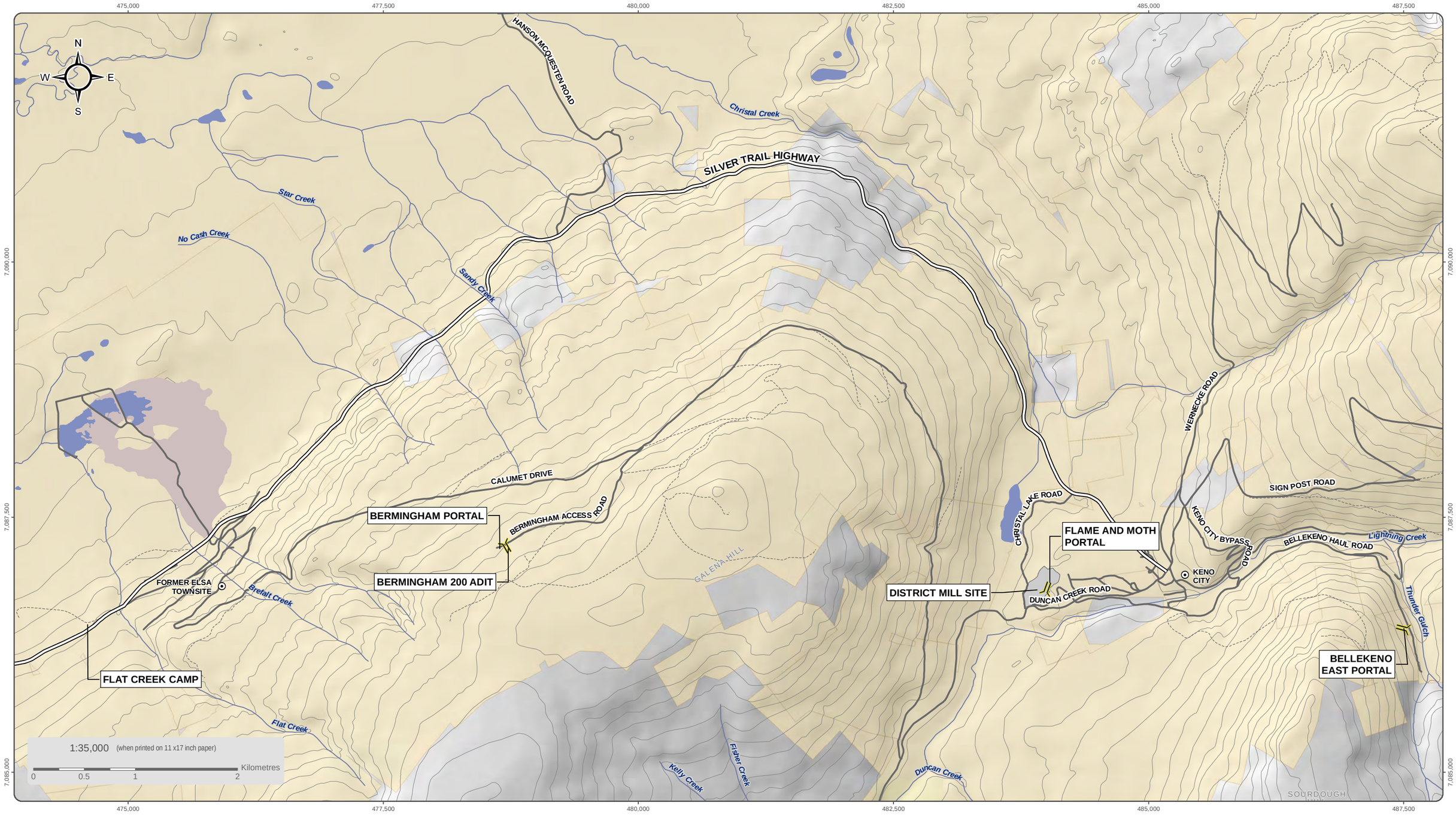
This plan is submitted to fulfill the conditions set out in Part H, Clauses 60 to 62 of Water Licence QZ18-044 issued to Alexco Keno Hill Mining Corp. on July 23rd, 2020:

> 60. Within 90 days of the effective date of this Licence, the Licensee must submit to the Board an update to *Alexco Keno Hill Mining Corp., Keno Hill Silver District Mining Operations: Physical Inspection and Reporting Plan* (PIRP), dated January 2018.
>
> 61. The Licensee must implement the PIRP for all Engineered Structures associated with the Bellekeno 625 settling ponds, the Flame and Moth water treatment pond, New Bermingham settling ponds, the Historic Bermingham SW Open Pit, the Valley Tailings Bellekeno Sludge Storage Area (VTBSSA), all N-AML Waste Rock disposal areas and all P-AML Waste Rock storage facilities, the access roads, the Flame and Moth Christal Creek and Lightning Creek discharge areas, DSTF, and Mill Pond.
>
> 62. The Licensee must inspect weekly, all structures identified in Clause 61 and submit inspection reports quarterly as part of the associated monthly report.

This plan outlines the Physical Inspection and Reporting methodology that will be used during mining and milling operations at Alexco's Keno Hill Silver District mining operations.

# 2. MINE LOCATION AND DESCRIPTION

The Keno Hill Silver District is located in central Yukon Territory, 354 km (by air) due north of Whitehorse. The Bellekeno mine area is located approximately 3 km east of Keno City within the Keno Hill Silver District. The Flame and Moth mine, District Mill site and Dry Stack Tailings Facility (hereinafter referred to as the "DSTF") are located approximately 1 km west of Keno City. The Bermingham deposit is located on northwest slope of Galena Hill ~6.8 km east of Keno City in the No Cash Bog catchment. Please refer to see Figure 2-1 for the site map.






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



- Place of Interest
- Adit
- Alexco/ERDC Quartz Claims
- Tailings Area
- Waterbody
- Watercourse
- Silver Trail Highway
- Road
- Limited-Use Road

AKHM

ALEXCO KENO HILL MINING CORP.

# FIGURE 2-1
# KENO HILL SILVER DISTRICT MINING OPERATIONS OVERVIEW

OCTOBER 2020

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# 3. PHYSICAL INSPECTION LOCATIONS

As per Part H, Clause 61 of Water Licence QZ18-044, the areas to be inspected include:

- Bellekeno 625 settling ponds;
- Flame and Moth Water Treatment Pond;
- New Bermingham settling ponds;
- Historic Bermingham SW Open Pit;
- VTBSSA;
- Bermingham N-AML Waste Rock Disposal Area (WRDAs);
- Bellekeno temporary P-AML Waste Rock Storage Facility (WRSFs);
- Flame and Moth P-AML Waste Rock Storage Facility(WRSFs);
- Bermingham P-AML Waste Rock Storage Facilities (WRSFs);
- Access roads;
- Flame and Moth Christal Creek and Lightning Creek discharge areas;
- Dry stack tailings facility (DSTF); and
- Mill pond.

# 4. PHYSICAL INSPECTION SCHEDULE

As per Clauses 91 of Water Licence QZ18-044

> 91. The Licensee must conduct weekly physical inspections of water retaining and conveyance structures, and associated mine waste and earthworks structures in accordance with the Keno Hill Silver District Physical Inspection and Reporting Plan and provide a summary as part of the annual report.

The physical inspection for all water retaining and conveyance structures will be conducted on a weekly basis (once constructed). The water ponds include the Bellekeno 625 settling ponds, the Bermingham settling pond, Flame and Moth Water Treatment Pond and Mill Pond. The P-AML Waste Rock Storage Facilities include: Bellekeno East, Flame and Moth and Bermingham. The Bermingham N-AML waste rock storage areas (once constructed) and access roads will be inspected weekly. Additionally, the discharge areas for Flame and Moth and the water conveyance structures for the sites will be inspected.

The physical inspection schedule is shown in Table 4-1 below.

**Table 4-1: Physical Inspection Schedule**

| Physical Inspection Location | Inspection Schedule |
|---|---|
| | Weekly |
| Bellekeno 625 settling ponds | x |
| Mill pond | x |
| Flame and Moth Water Treatment Pond | x |
| VTBSSA | x |
| New Bermingham settling pond | x |
| Bellekeno temporary P-AML waste rock storage facility | x |
| Historic Bermingham SW Open Pit | x |
| Flame and Moth P-AML waste rock storage facility | x |
| Bellekeno N-AML waste rock disposal area | x |
| Access roads | x |
| DSTF | x |
| Bermingham Settling Pond | x* |
| Bermingham P-AML waste rock storage facilities | x |
| Bermingham N-AML waste rock disposal area | x |

*See Appendix B for DSTF inspection schedule

# 5. PHYSICAL INSPECTION METHOD

The purpose of the physical inspection is to observe and record sufficient information to permit development of a course of action; repair or rehabilitation if it is required.

The physical inspection will comprise of completing visual inspection methods by competent and trained field operators. Maintaining clear and accurate records is as important as the physical inspection process itself, so documentation is carried out by the use of an inspection checklist. This will ensure that the inspections, even if carried out by different field personnel on different days, will record information of a similar nature.

## 5.1 PHOTO DOCUMENTATION

Photo hubs (physical locations where photos are to be repeatedly taken) will be selected to document the features as listed in Section 3 above. Approximate locations of photo hubs are shown in the overview map (Figure 5-1), and a detailed list and description of these photo hubs is included in Table 5-1below.

**Table 5-1: Photo Hub Descriptions**

| Photo Hub # | Photo Hub Description |
|---|---|
| 1 | Bellekeno Temporary P-AML waste rock storage facility |
| 2 | Bellekeno 625 settling pond 1 |
| 3 | Bellekeno 625 settling pond 2 |
| 4 | Mill pond (from S corner, facing Mill) |
| 5 | DSTF runoff collection sump (on road, facing NW) |
| 6 | DSTF (active deposition face) |
| 7 | Flame and Moth Water Treatment Pond |
| 8 | Flame and Moth P-AML waste rock storage facility |
| 9 | Flame and Moth Christal Creek Discharge Area |
| 10 | Flame and Moth Lightning Creek Discharge Area |
| 11 | Bermingham Settling Pond |
| 12 | Bermingham P-AML Waste Rock Storage Facility North |
| 13 | Bermingham P-AML Waste Rock Storage Facility South |
| 14 | Bermingham Discharge Area |
| 15 | Bermingham N-AML Waste Rock Disposal Area |
| 16 | Bermingham SW open pit |
| 17 | Valley Tailings Bellekeno Sludge Storage Area |

475,000 477,500 480,000 482,500 485,000 487,500

7,092,500 7,090,000 7,087,500 7,085,000

BERMINGHAM INSET

N-AML WASTE ROCK DISPOSAL AREA
BERMINGHAM DISCHARGE AREA
BERMINGHAM SETTLING POND
BERMINGHAM ADIT 200
BERMINGHAM PORTAL
BERMINGHAM P-AML WASTE ROCK STORAGE FACILITY
BERMINGHAM P-AML WASTE ROCK STORAGE FACILITY
BERMINGHAM SW OPEN PIT

FLAME AND MOTH INSET

DSTF RUNOFF COLLECTION SUMP
DRY STACK TAILINGS STORAGE FACILITY
MILL POND
FLAME AND MOTH PORTAL
MILL
DSTF (ACTIVE DEPOSITION FACE)
FLAME AND MOTH CHRISTAL CREEK DISCHARGE AREA
WATER TREATMENT POND
CRUSHER
BELLEKENO HAUL ROAD
DUNCAN CREEK ROAD
FLAME AND MOTH WATERTREATMENT POND
FLAME AND MOTH P-AML WASTE ROCK STORAGE FACILITY
FLAME AND MOTH LIGHTNING CREEK DISCHARGE AREA
Hinton Creek
Christal Creek
Lightning Creek

BELLEKENO INSET

BELLEKENO 625 SETTLING POND 1
BELLEKENO HAUL ROAD
BELLEKENO 625 SETTLING POND 1
Thunder Gulch
Gambler Gulch
Faro Gulch

NO CASH BOG CATCHMENT

CHRISTAL CREEK CATCHMENT

KENO SUMMIT

CALUMET DRIVE
BERMINGHAM ACCESS ROAD
BERMINGHAM INSET
FLAT CREEK CAMP
FORMER ELSA TOWNSITE
Brefalt Creek
BERMINGHAM PORTAL
BERMINGHAM 200 ADIT
GALENA HILL
FLAT CREEK CATCHMENT
Flat Creek
Fisher Creek
Duncan Creek
Christal Lake
FLAME AND MOTH INSET
DUNCAN CREEK ROAD
FLAME AND MOTH PORTAL
KENO CITY BYPASS ROAD
WERNECKE ROAD
SIGN POST ROAD
KENO CITY
BELLEKENO HAUL ROAD
Lightning Creek
BELLEKENO INSET
BELLEKENO EAST PORTAL
Thunder Gulch
Charity Gulch

1:40,000 (when printed on 11 x17 inch paper)
Kilometres
0 0.5 1 2



Photo Hub Locations
Adit

Infrastructure Footprint
Pond
DSTF 322k Tonnes Design
Current DSTF
To Be Constructed Features

Tailings Area
Waterbody
Watercourse
Contours (100 ft intervals)
Silver Trail Highway
Other Road

AKHM

ALEXCO KENO HILL MINING CORP.

# FIGURE 5-1
# PHYSICAL INSPECTIONS AND REPORTING PHOTO HUB LOCATIONS

OCTOBER 2020

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(Last edited by: amallais/revsika;2020-10-22(11:51AM))

GPS coordinates of the photo hubs will be uploaded onto the Site Inspection Map, to accompany inspection to ensure the inspections can be conducted by different personnel. The photo hub sites will be visited for photographic documentation on a monthly basis. The photos will be kept with the onsite Environmental Department for review as needed.

## 5.2 INSPECTION CHECKLISTS

Inspection checklists will be filled out on a weekly basis to ensure structural integrity of mine components and that runoff and discharge is being appropriately managed (see Appendix I). The following rating system will be used in the field reporting to evaluate the structural integrity of the areas to be physically inspected:

Excellent: "As New" Condition.

Good: System or element is sound and performing its function; although it shows signs of use and may require some minor repairs, mostly routine.

Fair: System or element is still performing adequately at this time but needs "priority" and/or "routine" repair to prevent future deterioration and to restore it to good condition. A fair rating will be reported to site manager after the inspection.

Poor: System or element cannot be relied upon to continue to perform its original function without "immediate" and/or "priority" repairs. A poor rating will be reported to site manager after the inspection.

If issues are identified during the weekly inspections the site manager will be informed immediately and the appropriate mitigative measures will be implemented. An inspection by a qualified geotechnical engineer would be undertaken for physical stability if necessary. Additional erosion and sediment controls may need to be implemented as required.

If geotechnical inspections are required, they will be carried out during the summer months when the surface and sides of the various rock-fill structures are not obscured by snow.

## 5.3 DSTF SURVEILLANCE, INSPECTION AND MONITORING

As a requirement of QML-0009, a dry stack tailings facility Operation Maintenance and Surveillance (OMS) manual was prepared by Tetra Tech Inc. (formerly EBA Engineering Consultants Ltd.) on behalf of Alexco. The OMS Manual forms part of the Dry Stack Tailings Facility Construction and Operation Plan under QML-0009. In addition to physical inspection and monitoring measures described in this plan, the OMS Manual describes more detailed operational physical inspection and monitoring.

Section 9 of the OMS Manual deals with surveillance and physical inspection of the DSTF, and is provided attached as Appendix B.

# 6. REPORTING

The weekly and monthly physical inspection checklists in addition to monthly photo documentation will be kept on file internally for proof of inspections and for reference as required.

The results of the weekly physical inspection check list will be summarized and incorporated into the annual reports.

In accordance with Clause 92 and 93 of Water Licence QZ18-044, identified seepage form any water retaining structures shall be reported as part of the monthly report. AKHM will submit and implement a plan for collection, testing and managing the seepage.

> 92. If the Licensee identifies seepage from any water retaining structures, the Licensee must:
>
> a) report on the seepage as part of the next monthly report in accordance with the Keno Hill Silver District Physical Inspection and Reporting Plan; and
>
> b) provide a summary of any new seepage or ponding locations identified through inspection and assign a unique identifier consistent with monitoring stations in this Licence as part of the annual report.

> 93. The Licensee must, within 60 days of the discovery of seepage from any water retaining structures, submit to the Board and implement a plan for collecting, testing, containing or managing the seepage. Reporting on the plan and any proposed mitigative actions are to be submitted as part of the annual report.

Additionally, an inspection report will be prepared certified by a Professional Engineer and submitted as part of the annual report. The report will include the information outlined Clause 94 below:

> 94. The Licensee must conduct an annual physical inspection of all Engineered Structures. The inspection must be conducted by a professional engineer licensed to practice in the Yukon. A report prepared by the professional engineer must be submitted as a part of each annual report and include:
>
> a) documentation of the inspection locations and methodologies;
>
> b) the results of the inspection;
>
> c) all problems identified;
>
> d) remedial measures recommended;
>
> e) the status of any remedial measures recommended in the previous year's report with an explanation regarding any recommendation not implemented; and
>
> f) actions taken or planned in response to any identified issues and/or to prevent recurrence.

# APPENDIX A

## PHYSICAL INSPECTIONS CHECKLIST

**Physical Monitoring Program**
**Inspection Checklist**

| | BELLEKENO | | FLAME AND MOTH | | | DISTRICT MILL | | | BERMINGHAM | | | | | | | ROADS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BK P-AML Waste Rock Storage Facility | BK 625 Treatment Ponds | F&M P-AML Waste Rock Storage Facility | F&M WTP Pond | F&M Dischage Areas | Mill Pond | DSTF | Water Diversion Structures | Treatment Pond | P-AML North | P-AML South | N-AML Waste Rock Disposal Area | Bermgingham SW Open Pit | Water Diversion Structures | BH Dischage Area | CLR 0-8 | BKR 0-5 | BKR 5-15 | BKR 15-18 | BH Road | Calumet Road |
| **General** | | | | | | | | | | | | | | | | | | | | | |
| Checked visually? | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Photo(s) taken? | Y | Y | Y | Y | Y | Y | Y | | Y | Y | Y | Y | Y | | Y | | | | | | |
| Checked after storm event? | | | | | | | Y | Y | | | | | | Y | | Y | Y | Y | Y | Y | Y |
| **Soil / Rock Structures** | | | | | | | | | | | | | | | | | | | | | |
| Materials being disposed of properly? | Y | | Y | | | | | Y | | Y | Y | Y | Y | Y | | Y | Y | Y | Y | Y | Y |
| Check for movement? | Y | | Y | | | | | Y | | Y | Y | Y | | Y | | Y | Y | Y | Y | Y | Y |
| Crest checked? | Y | | Y | | | | | Y | | Y | Y | Y | | Y | | | | | | | |
| Toe checked? | Y | | Y | | | | | Y | | Y | Y | Y | | Y | | | | | | | |
| No tension cracks? | Y | | Y | | | | | Y | | Y | Y | Y | | Y | | | | | | | |
| No creep? | Y | | Y | | | | | Y | | Y | Y | Y | | Y | | | | | | | |
| No failure? | Y | | Y | | | | | Y | | Y | Y | Y | | Y | | Y | Y | Y | Y | Y | Y |
| Safe for use next 24 hrs? | Y | | Y | | | | | Y | | Y | Y | Y | | Y | | Y | Y | Y | Y | Y | Y |
| **Water Conveyance Structures** | | | | | | | | | | | | | | | | | | | | | |
| No loose material or exposed liner? | Y | Y | Y | Y | Y | Y | | Y | Y | Y | Y | Y | | Y | Y | | | | | | |
| Spillway clear? | | Y | | Y | Y | Y | | Y | Y | | | | | Y | Y | | | | | | |
| Good runoff management? | | Y | | Y | Y | Y | | Y | Y | | | | | Y | Y | | | | | | |
| Diversion clear? | | Y | | Y | Y | Y | | Y | Y | | | | | Y | Y | | | | | | |
| No seepage? | | Y | | Y | Y | Y | | Y | Y | | | | | Y | Y | | | | | | |
| No failure? | | Y | | Y | Y | Y | | Y | Y | | | | | Y | Y | | | | | | |
| Safe for use next 24 hrs? | | Y | | Y | Y | Y | | Y | Y | | | | | Y | Y | | | | | | |
| Limits adhered to? | | Y | | Y | Y | Y | | Y | Y | | | | | Y | Y | | | | | | |
| **Piping** | | | | | | | | | | | | | | | | | | | | | |
| No leaks? | | Y | | Y | Y | Y | | | Y | | | | | | Y | | | | | | |
| No sags or deformation? | | Y | | Y | Y | Y | | | Y | | | | | | Y | | | | | | |

Comments (recommendations / corrective actions required):

**Inspected By:** **Date:**

N/A MONTHLY WEEKLY

# APPENDIX B

## DRY STACK TAILINGS FACILITY SURVEILLANCE AND PHYSICAL INSPECTION


Alexco Keno Hill Mining Corp.

REVISION 2010-1

# OPERATION, MAINTENANCE, AND SURVEILLANCE MANUAL
# DRY STACK TAILINGS FACILITY
# KENO HILL DISTRICT MILL, YT

EBA FILE: W14101178.008

September 2010

PREPARED BY EBA ENGINEERING CONSULTANTS LTD

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# 9.0 SURVEILLANCE

## 9.1 OBJECTIVE

Surveillance involves inspection and monitoring of the operation, structural integrity, and safety of the DSTF, and must be consistent with the life cycle and regulatory requirements of the facility. Surveillance of the DSTF consists of both routine and event-driven activities.

Key surveillance parameters and procedures must be identified for:

- Monitoring the operation, safety, and environmental performance of the DSTF;
- Promptly identifying and evaluating deviations from expected behaviour that affect operation safety, structural integrity, and environmental performance of the facility; and
- Reporting significant observations for response.

The DSTF surveillance program will continue to evolve as the facility changes in design or performance criteria, site conditions and/or the operation it is accommodating.

All personnel working at the DSTF will be involved in surveillance as a routine part of daily activities, maintaining visual awareness of the facility in the course of their regular and/or routine duties, in addition to surveillance-specific site engineering, instrument monitoring, analysis, inspection, periodic review and oversight.

It is the combination of all the regular inspections assisted by the eyes of all site personnel that ensures continued integrity and performance of the facility.

Outside consultants will also be on site periodically inspecting the facility as part of a regular program of expert review.

## 9.2 RESPONSIBILITY

A number of personnel conduct routine inspections of the DSTF. The Construction Monitor, or his designated replacement is assigned the responsibility of obtaining the monitoring information and preparing a monthly report for the facility designer and geotechnical consultant to review.

## 9.3 SURVEILLANCE PARAMETERS

Key parameters of surveillance are identified through identifying and describing potential failure modes of the DSTF.

Visual observations of the DSTF can indicate potential failure modes such as:

- Surface – cracking, bulging, depressions, sink holes;
- Seepage – new seepage areas, changes in seepage areas;
- Turbid water in the natural drainages around or downstream of the facility;
- Water or tailings flowing down the stack indicating improper grading; and

- A failure or breach of a component of the facility.

Routine monitoring for ensuring facility performance include:

- Checking for settlement or holes in embankment crest or benches;
- Checking for holes on the surface of the tailings indicating possible piping of material to outside;
- Checking for dust;
- Measuring water levels in monitoring wells located in the foundation soils during operation;
- Measuring ground temperatures using cables in the foundation soils during operation;
- Surveying DSTF components - displacements of survey monuments;
- Measuring slope inclinometers located in the foundation soils;
- Water sampling of Christal Creek; and
- Recording weather conditions.

These parameters are further described in the following sections.

## 9.4 SURVEILLANCE PROCEDURES

Table 13 summarizes surveillance requirements for the components of the DSTF. These surveillance requirements are the licensed monitoring requirements and conditions regarding the tailings presented in Alexco's Quartz Mining and Water Use licenses.

TABLE 13: OPERATIONAL MONITORING SCHEDULE FOR DSTF

| Frequency | Provision | Source/Location | Personnel | Scope | Deliverable |
|---|---|---|---|---|---|
| Periodically During Construction | EBA Design Report and Quality Assurance Program | Entire Facility | Engineering Supervision | Follow monitoring and inspection procedures in Quality Assurance Program | Interim Reporting to Site Management with recommendations for construction process |
| Weekly | EBA Design Report and Quality Assurance Program | Structure of the tailings (toe, dam, tailings, etc.) | Operational personnel | Visual assessment of tailings, diversion berms, collection ditches, conveyance channel and water collection pond. | Daily Log, included in annual report. |
| Weekly | EBA Design Report and Quality Assurance Program | Tailings final runoff | Operational personnel | Visual inspection for suspended solids and erosion evidence. | Daily Log, included in annual report. |

| TABLE 13: OPERATIONAL MONITORING SCHEDULE FOR DSTF – CONT'D | | | | | |
|---|---|---|---|---|---|
| Weekly | EBA Design Report and Quality Assurance Program | Toe runoff collection ditches and conveyance channel | Operational personnel | Visual inspection for failures (possible or occurring) with more frequent checks during spring breakup period | Daily Log, included in annual report. |
| Weekly | EBA Design Report and Quality Assurance Program | Tailings Material | Operational personnel | Record tailings moisture content | Daily Log, included in annual report. |
| Weekly | Type A Water Licence Q209-092 | Tailings Solids ABA Testing | Operational Personnel | Split a 200-500g sample from the daily 24-dried, metallurgical composite sample and retain in a plastic bag | Send a composite sample once per month to an accredited laboratory, as per Appendix C – evaluate results |
| Monthly | EBA Design Report | Groundwater Piezometer | Operational Personnel | Record readings and submit to VP Engineering for review | Results included in annual report. |
| Monthly | EBA Design Report | Ground Temperature Cable | Operational Personnel | Record readings and submit to VP Engineering for review | Results included in annual report. |
| Monthly | EBA Design Report | Settlement Monument Survey | Qualified Surveyor | Record elevations and submit to VP Engineering for review | Results included in annual report. |
| Monthly | Type A Water Licence Q209-092 | Tailings Seepage | Operational Personnel | Sample and lab analysis of tailings supernatant, inspect for seepage, estimate flow | Representative samples shall be collected for laboratory analyses according to Set A[1] requirements outlined in the WUL.[2] |
| Monthly | EBA Design Report | Tailings Deposit | Operational Personnel | Confirm design moisture content density is being achieved | Results included in annual report. |

| TABLE 13: OPERATIONAL MONITORING SCHEDULE FOR DSTF – CONT'D | | | | | |
|---|---|---|---|---|---|
| Monthly | EBA Design Report | Tailings Disposal Basin | Qualified surveyor | A surface profile of the tailings along the centre line of the tailings disposal basin | Map and written description of profile.[2] |
| Annually | QML – Section 9.3.2 | Tailings Disposal Basin | Professional engineer licensed to practice in the Yukon | Thorough visual assessment and physical inspection of the tailings, review of monitoring data to confirm design assumptions, preparation of inspection report | Representative samples shall be collected for laboratory analyses of grain size distribution, densities and moisture content.[2]<br><br>Submission of inspection report. |
| Annually | Type A Water Licence Q209-092 | Center Line of Tailings | Operational personnel | Full depth of tailings will be sampled at four stations along the center line. | Samples will be checked in the field for the presence of frozen tailings. Screen analyses will be done in the laboratory as a check on the homogeneity of the tailings and densities and moisture contents will be determined.[2] |
| | | | | | |

Notes:

1 Set A - water quality analysis includes physical parameters, anions, nutrients, dissolved metals, total metals, and total suspended solids (Table 10.2 - WUL Application)

2 All results from the operation monitoring schedule will be included in the annual report to the Water Board

## 9.5 ADAPTIVE MANAGEMENT

Fundamental to successful adaptive management of the tailings production, handling and placement are triggers for management action. If the tailings handling and deposition is not meeting critical performance objectives according to specific conditions within either the WUL or the QML, the General Manager will be expected to follow Table 14 for appropriate corrective action. Close monitoring of the performance of the DSTF will be critical in determining if and when action will be required. It is expected that improvements will be made to the system on an ongoing basis once initial operating experience has been gained.

| TABLE 14: TRIGGERS AND ACTIONS UNDER ADAPTIVE MANAGEMENT FOR TAILINGS MANAGEMENT | | | |
|---|---|---|---|
| Provision | Monitored Item | Triggers/Thresholds | Action |
| EBA Design Report | Groundwater Monitoring Wells | Tip @ 1.0 m or 1.7 m depth - Porewater pressure parameter (Ru) exceeds 0.15 | Facility designer will review well data.<br><br>Monitoring and review will be increased to semi-weekly until determined unnecessary. |
| | | Tip @ 1.0 or 1.7 m depth - Porewater pressure parameter (Ru) exceeds 0.25 | Facility designer will review existing well data<br><br>Facility designer will conduct a site visit and determine if tailings placement and/or construction plan requires modification<br><br>Monitoring and review will be increased to daily until determined unnecessary.<br><br>Facility designer will determine if additional instrumentation is required.<br><br>Facility designer will complete analysis of mitigative measures should exceedance continue. |
| EBA Design Report | Ground Temperature Cables | Temperature > 0°C at 1.5 m depth | Facility designer will review temperature data. |
| EBA Design Report | Ground Temperature Cables | Temperature > 0°C at 2.0 m depth and greater | Facility designer will review existing temperature data<br><br>Facility designer will conduct a site visit and determine if tailings placement and/or construction plan requires modification<br><br>Facility designer will determine if additional instrumentation or analysis is required.<br><br>Facility designer will complete analysis of mitigative measures should exceedance continue.<br><br>Alexco to complete survey of area of interest to monitor any future displacement, if any. |

TABLE 13: TRIGGERS AND ACTIONS UNDER ADAPTIVE MANAGEMENT FOR TAILINGS MANAGEMENT – CONT.

| Provision | Monitored Item | Triggers/Thresholds | Action |
|---|---|---|---|
| EBA Design Report | Survey Monuments and Slope Inclinometers | Displacements greater than 25 mm in any direction | Facility designer will review existing piezometer, temperature, and survey data.<br><br>Facility designer will conduct a site visit and determine if tailings placement and/or construction plan requires modification.<br><br>Monitoring and review will be increased to semi-weekly until determined unnecessary.<br><br>Alexco to complete survey of area of interest to monitor any future displacement, if any.<br><br>Facility designer will determine if additional instrumentation is required.<br><br>Facility designer will complete analysis of mitigative measures should exceedance continue. |
| Water Licence Q209-092 | Toe runoff collection ditches, conveyance channel and water collection pond | Presence of abnormal cracking or failure | Report to general manager, take corrective action as required |
| Water Licence Q209-092 | Tailings Runoff | Visible turbidity in runoff and/or excessive erosion evidence | Address runoff at source; report to Water Board within 60 days<br><br>Apply appropriate runoff, erosion or sediment control measures |
| Water Licence Q209-092 | Tailings Solids | AML potential is indicated | Expand monitoring program<br><br>Conduct study of options to minimize acid generation |

## 9.6 DOCUMENTATION

Routine reporting of surveillance results is essential to provide time to make adjustments to existing systems or to initiate Emergency Response Plans. It is imperative that any unusual information (outliers) gathered from these undertakings be communicated to the facility designer, the General Manager and Chief Operating Officer.

Document control is vital to ensuring the ongoing performance of the facility. The topic was presented in Section 3.0.

Table 15 identifies the overall responsibilities for surveillance record keeping:

| TABLE 15: DSTF SURVEILLANCE DOCUMENTATION | | |
|---|---|---|
| Task | Responsible Party | Information Recipients |
| Daily Check Sheet | Completed by Construction Monitor | General Manager – copy;<br>Mill Manager – copy;<br>Bellekeno Mine Engineering Server |
| Monthly Placement As built | Completed by Construction Monitor | General Manager – copy;<br>Mill Manager – copy;<br>Bellekeno Mine Engineering Server<br>EBA - copy |
| Instrumentation Data | Completed by Construction Monitor | General Manager – copy;<br>Mill Manager – copy;<br>Bellekeno Mine Engineering Server<br>EBA – copy |
| Construction Photographs | Completed by Construction Monitor | General Manager – copy;<br>Mill Manager – copy;<br>Bellekeno Mine Engineering Server |
| ABA Testing | Completed by Geology Dept | General Manager – copy;<br>Mill Manager – copy;<br>Bellekeno Mine Engineering Server |
| Water Quality Monitoring | Completed by VP Corporate Affairs | General Manager, Mill Manager and Yukon Water Board<br>Original reports located with General Manager |

## 9.7 REPORTING

Observation of any unusual occurrence should be reported immediately to the General Manager, facility designer, and/or the Chief Operating Officer. Unusual occurrences include but are not limited to the following;

- Triggers/Thresholds outlined in Table 13;
- Any seismic event;
- Settlement, cracks or slumping of the tailings stack;
- Slope failure of any of the slopes;
- Abnormal seepage from any of the slopes;
- Increased or high turbidity flow from the drainage blanket; and
- Damage to any component of the DSTF.

All reports are to be maintained by the General Manager and filed in a suitable format and location for easy access by authorized mine personnel, and for review by government agencies. Annual performance reviews will be copied to the regulatory agencies.

The requirements of the consulting geotechnical engineer, other departments, or governmental agencies may dictate certain items that require inspection, monitoring, or reporting.

# 10.0 EMERGENCY PLANNING AND RESPONSE

## 10.1 BELLEKENO EMERGENCY PROCEDURES

The mine site has established procedures and response plans detailing in the following reports:

- A report by Access Consulting Group entitled "Alexco Keno Hill Mining Corp. Bellekeno Project, Monitoring and Surveillance Plan, QML-0009", dated November 2009 and submitted for the Type A Water Use License 2009.
- A report by Access Consulting Group entitled "Emergency Response Plan, QML-0009, Bellekeno Project", dated November 2009 and submitted for the Type A Water Use License 2009.
- MSDS documentation for any material used within the DSTF.

These documents provide the detailed plans on actions to be taken in case of an emergency. They also provide notification procedures.

## 10.2 DSTF EMERGENCY PROCEDURES

Daily visual and routine instrumentation monitoring programs outlined in Tables 12 and 13 are expected to forewarn of potential adverse conditions to the DSTF. Triggers/Thresholds presented in Table 13 must be adhered to and reported on as outlined.

The DSTF has been designed to maintain its structural integrity throughout its operational life; however, a number of conditions can affect the performance of the DSTF. Once the DSTF operations are being completed and instrumentation data is available, the requirement for additional emergency procedures will be reviewed as a part of the annual DSTF performance and OMS manual review.

## 10.3 ENVIRONMENTAL EMERGENCIES

Environmental emergencies of various natures and their specific response procedures are outlined in the project's Spill Contingency Plan. This document includes immediate response procedures and follow up and notification measures appropriate to the particular nature of the emergency.

## 10.4 KEY CONTACTS

Key contact information is detailed in Table A2, found in Appendix A.